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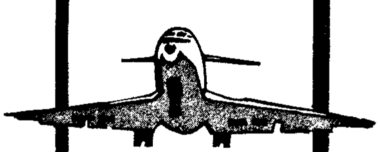

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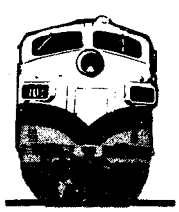

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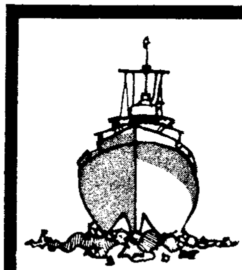
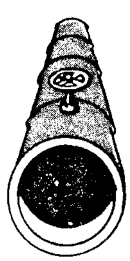
AIRCRAFT ACCIDENT REPORT



HORIZON AIR, INC.
DEHAVILLAND DHC-8
SEATTLE-TACOMA INTERNATIONAL AIRPORT
SEATTLE, WASHINGTON
APRIL 15, 1988



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16. Abstract On April 15, 1988, a deHavilland DHC-8, took off from the Seattle-Tacoma International Airport. Shortly after takeoff, the aircrew noted a power loss on the right engine and decided to return to Seattle for a precautionary landing. After lowering the landing gear on final approach, a massive fire broke out in the right engine nacelle. Because almost all directional control and braking capability was lost, the airplane crossed a grass median area, entered the paved ramp area, and struck a runway designator sign, several baggage carts, and two jetways. The airplane came to rest against another jetway. Four of the 37 passengers sustained serious injuries. The airplane was destroyed by the fire and impact. The safety issues discussed in this report include: the nacelle cowl design of the DHC-8; design and maintenance practice concerning the loose fuel filter cover; design and maintenance practice concerning the generator brush access cover and electrical lead-in port on P&W PW120A engines; shoulder harness/jump seat hold-up strap wear on the DHC-8; and design and use of the closet/wardrobe on the DHC-8. Recommendations concerning these issues were addressed to the Federal Aviation Administration.

17. Key Words

filter cover; shoulder harness; jump seat hold-up strap; closet/wardrobe; DHC-8; nacelle

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CONTENTS

EXECUTIVE SUMMARY

On April 15, 1988, Horizon Air, Inc., flight 2658, a 37-passenger deHavilland DHC-8 registered in the United States as N819PH, was a regularly scheduled passenger-carrying flight between Seattle, Washington, and Spokane, Washington. Shortly after takeoff, with the captain at the controls, the aircrew noted a power loss on the right engine. The captain made the decision to return to Seattle for a precautionary landing. After lowering the landing gear on final approach, a massive fire broke out in the right engine nacelle. After the first officer shut down the engine, the captain proceeded to land the airplane; however, shortly after touchdown, the crew realized that almost all directional control and braking capability was lost. The airplane departed the paved surface of the runway, crossed a grass median area, entered the paved ramp area, and struck a runway designator sign, several baggage carts, and two jetways. The airplane came to rest against another jetway. Four of the 37 passengers sustained serious injuries. The airplane was destroyed by the fire and impact.

The National Transportation Safety Board determines that the probable cause of this accident was the improper installation of the high-pressure fuel filter cover that allowed a massive fuel leak and subsequent fire to occur in the right engine nacelle. The improper installation probably occurred at the engine manufacturer; however, the failure of airline maintenance personnel to detect and correct the improper installation contributed to the accident. Also contributing to the accident was the loss of the right engine center access panels from a fuel explosion that negated the fire suppression system and allowed hydraulic line burn-through that in turn caused a total loss of airplane control on the ground.

The safety issues discussed in this report include:

- the nacelle cowl design of the DHC-8;
- design and maintenance practice concerning the loose fuel filter cover;
- design and maintenance practice concerning the generator brush access cover and electrical lead-in port on P&W PW120A engines;
- shoulder harness/jumpseat hold-up strap wear on the DHC-8; and
- design and use of the closet/wardrobe on the DHC8.

Recommendations concerning these issues were addressed to the Federal Aviation Administration.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

HORIZON AIR, INC.
DEHAVILLAND DHC-8
SEATTLE-TACOMA INTERNATIONAL AIRPORT
SEATTLE, WASHINGTON
APRIL 15, 1988

1. FACTUAL INFORMATION

1.1 History of the Fligh't

On April 15, 1988, Horizon Air, Inc., flight 2658, a 37-passenger deHavilland DHC8 registered in the United States as N819PH, was a regularly scheduled passenger-carrying flight between Seattle-Tacoma International Airport, Washington, and Spokane, Washington. Both pilots and the flight attendant assigned to originate flight 2658 reported to the Horizon Air operations facility at Portland, Oregon, at 1215. They then dead-headed to Seattle on Horizon Air flight 612, arriving at 1420, on N819PH. On arrival, they learned that their trip sequence would also be on N819PH, as flight 2658. After lunch, the captain picked up the dispatch papers, and assisted the first officer in performing a preflight inspection of the airplane. According to company procedures, the first officer performs the preflight inspection when the airplane experiences a crew change or when directed by the captain. The flightcrew had about 1 1/2 hours before the scheduled takeoff, and therefore, they were not rushed during preflight preparations. The crew stated that a typical crew-acceptance preflight takes about 20 minutes. The crew stated that they noted no problems during the preflight. They then flew an uneventful round trip to Pasco, Washington, and arrived back in Seattle at 1755.

In Seattle, the first officer performed a postflight walk-around inspection. No discrepancies were noted. Flight 2658 left the gate at 1810, and following a normal engine start, the flight was cleared to taxi to runway 16L at 1813. At 1823:52, flight 2658 was cleared by the Seattle local controller to ". . . taxi into position and hold runway 16L. Be prepared to go right out as soon as traffic clears the runway." They acknowledged and were cleared for takeoff at about 1825 with instructions to fly a heading of 130" after passing 1,000 feet mean sea level (msl).

The captain made the takeoff at 1825:51 and described everything as routine with no abnormal indications noted during takeoff. The airplane lifted off at 101 knots. At the captain's command, the first officer raised the landing gear, retracted the flaps from 5" to 0", and reduced engine power to the climb power setting of 1,050 propeller rpm and 88 percent engine torque. The climb through 1,000 feet appeared normal to the pilots. They then began the initial left turn. The passenger in seat 9E later stated that during this first turn, he observed liquid leaking from the right engine nacelle. According to the passenger, the rate at which the liquid leaked lessened as the captain leveled the wings at the end of the turn. He did not relay this information to the flight attendant at any time during the flight. About the time the captain completed the turn to 130" at 1826:30, both crewmembers noticed a loss of power on the right (No. 2) engine. The captain observed a slow drop in torque on the right engine to approximately 40 to 60 percent. The loss in torque was accompanied by right yaw. He then advanced the power levers on both engines to the maximum power setting. The flight data recorder (FDR) showed that No. 2 engine torque had dropped to about 36 percent when power on the No. 1 engine was increased. Based on his evaluation, the captain concluded that the right engine was still producing thrust, so he elected to

Figure 1. a photograph of N819PH on its final approach

keep it running. He then told the first officer to advise the tower that they were returning to the airport, to request emergency equipment, to have the emergency checklists readily available, and to inform the flight attendant of their intention to return and land. These actions were completed by 1828:16. After the captain stabilized the power, he flew a somewhat wider than normal downwind leg about 1 to 1.5 miles away from the runway and remained in visual flight rules conditions. The aircrew completed the descent and approach checklists about midfield on the downwind leg by 1829:09. The captain initially intended to lower the landing gear just after turning on to base leg, but he did not because the airplane was above the maximum gear lowering speed at that point. At 1830:56, as the airplane slowed down to below the maximum gear lowering speed, the flightcrew lowered the landing gear and turned onto final approach leg about 1 mile from the intended touchdown point.

The first officer stated that as he was scanning for traffic out the right side window during the turn to final approach, he observed a "flash" from the right engine. The first officer then observed that the center access panel on the left side of the right nacelle was missing and that an orange/yellow flame was in that area. The passenger in seat 9E also observed the fire and saw sections of engine cowl fall from the right nacelle. At 1831:03 the first officer stated, "We got a fire." Three seconds later the captain stated, "Max power. . .," and at 1831:09 he called for 15" of flaps. According to the FDR, the flaps began to move down shortly thereafter. After informing the captain of the fire, the first officer returned his attention to the engine instruments. The captain then retarded the right condition lever to the Start and Feather position and told the first officer to pull the fuel cutoff T-handle and fire the extinguisher bottles. After the first officer fired the extinguisher bottles and pulled the fuel cutoff T-handle, he observed that the fire was still burning and also that the green landing gear lights were no longer illuminated. (See figure 1.)

At 1831:26, the flight attendant delivered her emergency landing briefing that included two different brace positions because of the seating arrangement of the airplane.

About 1/4 mile from the runway (according to the captain) and about 100 feet above the ground (according to the first officer), the crew began to notice a ". . . significant change in controllability" of the airplane. The first officer stated ". . . the airplane felt like it was in slow flight, sort of wallowing around." The airplane landed on runway 16L and then veered off the east side of the runway on a heading of 154". The captain stated that after touchdown at 1831:53 on the paved surface and after reducing the left power lever to flight idle:

> It was immediately obvious that the direction of movement was to the left of [the] runway direction. I attempted to use nosewheel steering, normal differential braking, and rudder to correct the direction. I had no directional control of the airplane. I first eased on the emergency brakes with no result and then finally locked the lever into the parking position.

The first officer also tried his right rudder pedal, but it was already full right. He then noticed that the right brake pedal was already depressed and that the emergency brake was locked. He then advised the tower that the airplane was out of control and manually locked his and the captain's shoulder harnesses. As the airplane rolled onto the ramp pavement after crossing grass areas and taxiways on the airport, it struck and destroyed a frangible lighted runway designator sign. By this juncture, the airplane heading had changed another 2" to the left. Neither crewmember felt any deceleration. As the airplane entered the ramp area south of the tower, it struck jetway B7 damaging the outboard left wing. After striking the first jetway, the airplane struck jetway B9 causing the outboard left wing to separate from the airplane. The airplane struck and destroyed several baggage carts and pieces of ground equipment as it traversed the area between jetways B7 and B9 and came to rest against jetway B11 at 1832:31. (See figure 2.)

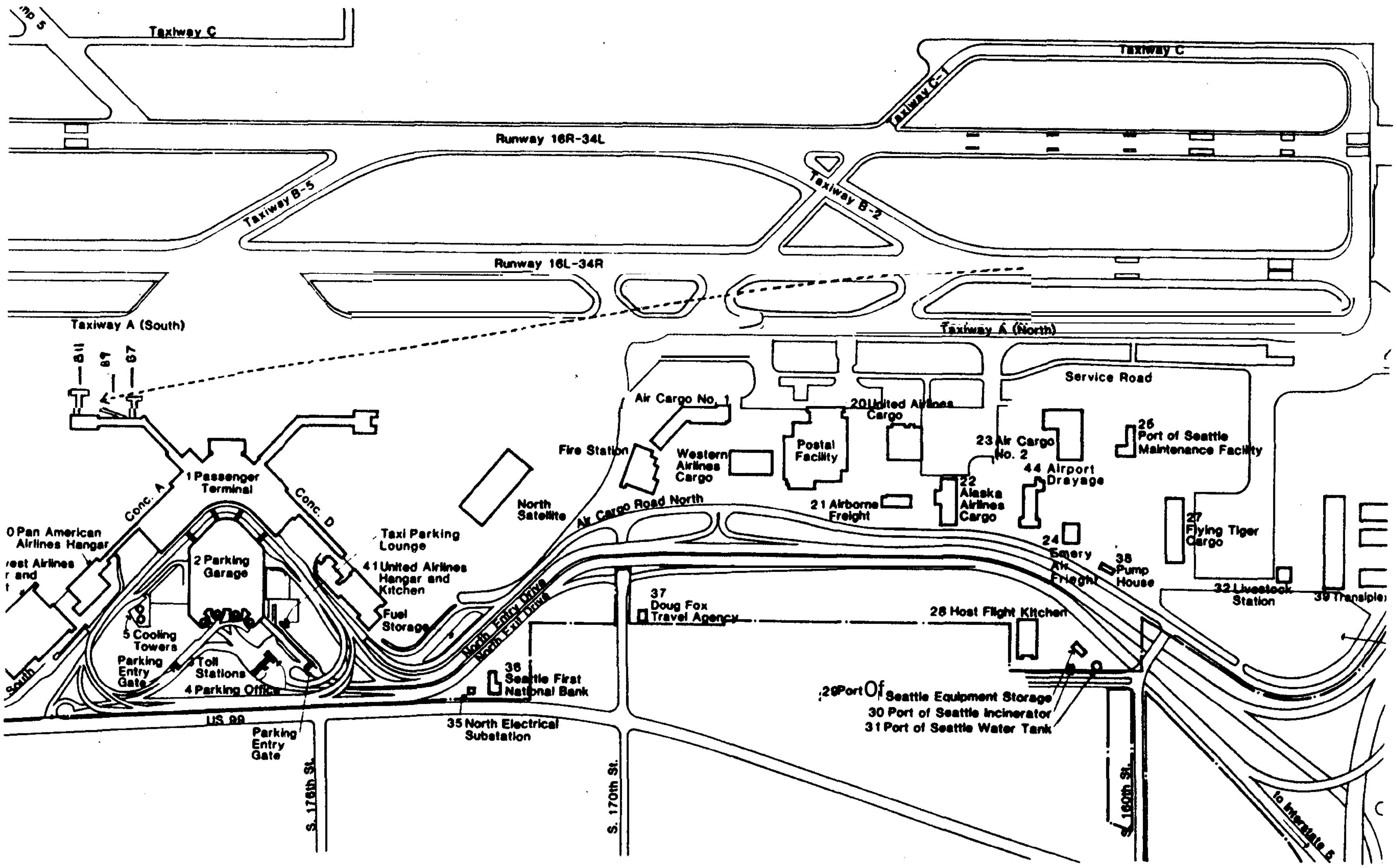

Figure 2. Diagram of the ground path of the airplane

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Within 15 seconds after the airplane came to a stop, the flightcrew saw fire suppressant foam being applied to the airplane. The captain attempted to open the cockpit door and the overhead emergency exits, both of which were jammed. The first officer then attempted to break the captain's side window with the fire axe, but he was not successful. They then heard the firefighters assisting the passengers and were told to wait until the injured passengers had been evacuated. Subsequently, the firefighters opened the jammed cockpit door and assisted the pilots off the airplane.

During the accident sequence, 4 passengers received serious injuries; 24 passengers, the flight attendant, and both pilots received minor injuries; and 9 passengers received no injuries. The airplane and various pieces of ground equipment were destroyed. The accident occurred during daylight hours.

1.2 Injuries to Persons

Iniuries	Crew	Passenaers	Others	Total
Fatal	0	0	0	0
Serious	0	4	0	4
Minor/None	3	33	0	36
Total	3	37	0	40

1.3 Damage to Airplane

The airplane received substantial damage because of the engine fire and was subsequently destroyed during impact with objects and structures on the ramp. The airplane was valued at $5.64 million.

1.4 Other Damage

Numerous pieces of aviation ground support equipment, including one runway designator sign, several baggage carts, a pickup truck, a ground auxiliary power unit, and three terminal jetways were damaged or destroyed by the airplane. The estimated value of these structures and pieces of equipment was $280,000.

1.5 Personnel Information

The captain was hired by Air Oregon in June 1979. Air Oregon was subsequently absorbed by Horizon Air, and the captain was hired by that company on September 1, 1981. He held airline transport pilot certificate No. 1767092 with ratings for the SA-227, the DHC8, airplane multiengine land, and commercial privileges for airplane single-engine land. At the time of the accident, he had accumulated approximately 9,328 total flying hours, 981 hours of which were in the DHC-8. He received his initial type rating in the DHC-8 on November 5, 1986. The captain's last line check was completed on September 5, 1987, and his last proficiency check was completed on October 5, 1987. The captain's last recurrent training was accomplished on October 30, 1987. His most recent first-class Federal Aviation Administration (FAA) medical certificate was issued on January 19, 1988, with the limitation, "Holder shall wear correcting lenses while exercising the privileges of his airman certificate."

The first officer was hired by Horizon Air on March 30, 1987. He held airline transport pilot certificate No. 548882459 with ratings for airplane multiengine land and commercial privileges for airplane single-engine land. He also held a flight instructor certificate for airplane single-engine and multiengine land which was valid until March 31, 1989, and an air traffic control specialist certificate. At the time of the accident, he had accumulated approximately 3,849 total flying hours, 642 hours of which were in the DHC-8. The first officer completed his initial proficiency check on May 7, 1987, and his last line check on May 22, 1987. His last recurrent training was accomplished on March 11, 1988. His most recent second-class FAA medical certificate was issued on January 12, 1988, with no limitations.

The flight attendant was hired by Horizon Air on March 9, 1987, after completing 56 hours of basic indoctrination, emergency training, and security training. She completed her initial operating experience of 5.2 hours on the DHC-8 on March 12, 1987. She received her last recurrent ground school and emergency training on March 20, 1988.

1.6 Airplane Information

The deHavilland DHC-8-102, N819PH, serial number 061, was manufactured on December 21, 1985, and acquired by Horizon Air on February 6, 1987.

The airplane weight and balance for the flight was as follows:

Basic weight (lbs.)	22,425
Passengers and cargo (lbs.)	7,372
Zero fuel weight (ZFW)(lbs.)	29,797
Correction factor (lbs.)	94
Corrected ZFW (lbs.)	29,891
Fuel load (lbs.)	3,000
Takeoff weight (lbs.)	32,891

The planned fuel burn of 1,100 pounds would have resulted in a landing weight of 31,791 pounds at Spokane. The maximum allowable takeoff weight was 34,500 pounds and the maximum landing weight was 33,900 pounds. The forward center of gravity limit range varied linearly from 20 to 21 percent mean aerodynamic chord (MAC) for weights between 32,000 and 34,500 pounds. The aft limit was 38 percent MAC. At the time of the accident, the center of gravity was about 28.75 percent MAC.

1.6.1 Hydromechanical Fuel Metering Unit Replacement

Both engines on the airplane were equipped with a hydromechanical metering unit (HMU). An HMU assembly consists of the hydromechanical fuel control, a high-pressure fuel pump with an integral fuel filter housing that contains the high-pressure fuel filter. The HMU assembly was replaced on the right engine of N819PH on April 8 and 9, 1988. The replacement HMU assembly was removed as a complete unit from a spare serviceable engine in Horizon stores that had been received from the Pratt and Whitney Canada factory. The fuel nozzles on the right engine also were replaced at that time. Horizon Air maintenance personnel stated that they performed the following activity concerning the HMU:

1. An engine shop mechanic removed the replacement HMU assembly from spare engine S/N 120141 in the Horizon maintenance facility.

2. A Horizon engine maintenance inspector examined the HMU assembly and signed the "serviceable tag."

3. Another engine mechanic installed the HMU on the right engine (S/N 120078) of N819PH. Part of the installation procedure was to attach the filter impending bypass switch electrical lead onto the fuel filter cover.

4. An inspector signed off the replacement action for the HMU in the maintenance logbook for N819PH.

5. Two different maintenance inspectors supervised a quality control engine run on N819PH which included a fluid leak check and signed off the quality control inspection in the maintenance logbook.

6. A Horizon Air lead mechanic signed off the maintenance release on airplane N819PH.

These maintenance actions were in response to an earlier series of crew maintenance log entries concerning fuel/oil fumes in the cockpit during flight. A teardown of the replaced HMU by its manufacturer later disclosed that the fuel fumes had been caused by a cracked bellows in the unit. According to a maintenance log entry, the removal and replacement of the HMU and the fuel nozzles was in accordance with Horizon maintenance manual 71-00-00, page 523. There were no other maintenance log entries in the log for the airplane after the HMU and fuel nozzle were replaced on April 8 and 9.

1.7 Meteorological Information

A Seattle-Tacoma International Airport National Weather Service observation taken at 1832 indicated a 2,300-foot scattered cloud layer with a measured 2,800-foot overcast ceiling. Visibility was 7 miles with a temperature of 60 °F and a dew point of 48 “F. Winds were from 250” at 4 knots and the altimeter setting was 29.94 inches of mercury. At 1829:39, the tower controller cleared flight 2658 to land on runway 16L and gave flight 2658 winds of 240” at 8 knots during the same transmission.

1.8 Aids to Navigation

The crew of N819PH did not use any navigational aids during the flight.

1.9 Communications

No communications difficulties were reported by the flightcrew or the air traffic controllers.

1 .10 Aerodrome Information

Seattle-Tacoma International Airport is operated by the Port of Seattle, Washington. It has two parallel runways designated 16L-34R and 16R-34L. Runway 16L is 11,900 feet long and 150 feet wide with a displaced threshold of 490 feet. It has an asphalt surface. The field elevation is 429 feet msl. Runway 16L has high intensity runway tights, a medium intensity approach lighting system with sequenced flashing lights, and a visual approach slope indicator system. The airport’s last disaster exercise was an unannounced drill in January 1988.

1 .11 Flight Recorders

The airplane was equipped with a Sundstrand FDR that recorded 32 separate flight and equipment parameters during the flight. It was removed from the wreckage intact. An examination of the recovered data indicated that the recorder operated normally throughout the accident flight. However, the parameters transmitted to the FDR for the right and left inboard and outboard spoiler position, rudder position, left and right elevator position, and aileron position were not recorded when the airplane was on the ground during the landing roll. The reason for

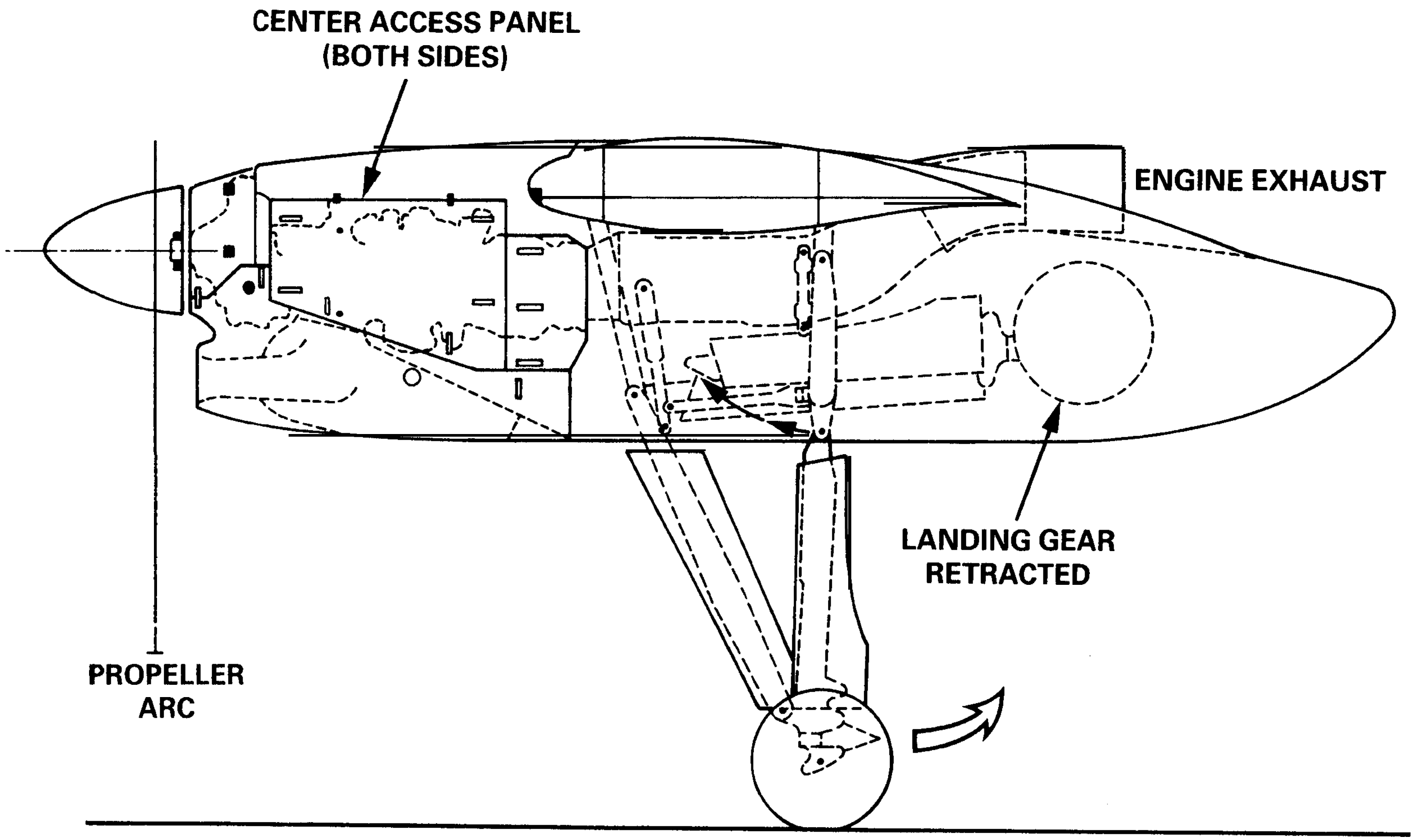

CENTER ACCESS PANEL
(BOTH SIDES)
ENGINE EXHAUST
LANDING GEAR
RETRACTED
PROPELLER
ARC

Figure 3.

this data loss was attributed to the fire that compromised a number of electrical components on the airplane.

The airplane was also equipped with a Sunstrand Model AV557-C cockpit voice recorder (CVR). It, too, was recovered from the wreckage undamaged. The tape was of excellent quality, and a transcript of the last 10 minutes on the tape is included as appendix E. At 1827:42, the recorder stopped and reversed direction; this is a normal function on this type of CVR.

1.12 Wreckage and impact Information

The right engine inboard center access panel was located 10,300 feet to the north of the threshold for runway 16L in a school yard. This panel was almost completely free of sooting and displayed no fire damage. No other components were recovered outside the airport boundary.

The first evidence of airplane ground contact was a set of wheel tracks associated with the left wheel assembly when the airplane rolled off the east side of the runway. These tracks were 3,275 feet south of the end of the runway threshold and began 128 feet east of the runway centerline. The direction of these tracks was 6" to the left of the runway heading. The right wheel tracks began 3,535 feet south of the threshold, and the nosewheel tracks began 3,672 feet south of the threshold.

The path of the airplane was traced farther by more tire tracks, a trail of burned debris from the right nacelle area, and the use of an airport surveillance video tape that showed the landing sequence, landing rollout, and portions of the final impact with the jetways.

A large hole was ripped in the right side of the fuselage during impact with the ground equipment. It extended from the floor level of the cabin to above the window line and from the right underwing emergency escape hatch forward to the right emergency door. The airplane came to rest against jetway B11 with its fuselage pointing east and the right wing penetrating the jetway boarding tunnel. (See figure 3). The position of the flaps was about 6" down when the airplane was later examined. This was also the last flap position recorded on the FDR about 74 seconds before the end of the recording.

1.12.1 Right Engine Fire Damage

The right wing and right engine/engine nacelle sustained heavy fire damage. The aft portion of the nacelle was consumed by fire. The propeller was attached to the engine; however, one blade had separated and was recovered about 15 feet behind the left engine nacelle. (See figure 4.)

The engine nacelle was covered with soot and severely damaged from excessive heat. There was extensive heat damage and buckling of the zone 1 access doors and the nacelle skins behind the firewall. The outer wing panel leading edge de-ice boot and landing light lens were damaged only slightly from heat.

The right nacelle outboard center access panel was not attached to the nacelle, but it was found propped against a tire on the right landing gear. It is most probable that the panel was recovered elsewhere and carried to this location by unidentified airport personnel. This panel was bowed in the middle and exhibited some buckling along the lower edge, upper edge, and at the bottom left corner. The upper left corner of the panel exhibited signs of severe overheating. The inside of the door was clean except for the normally dirty areas around the starter generator cooling air inlet and outlet seals, and there was slight heat discoloration at the upper left corner.

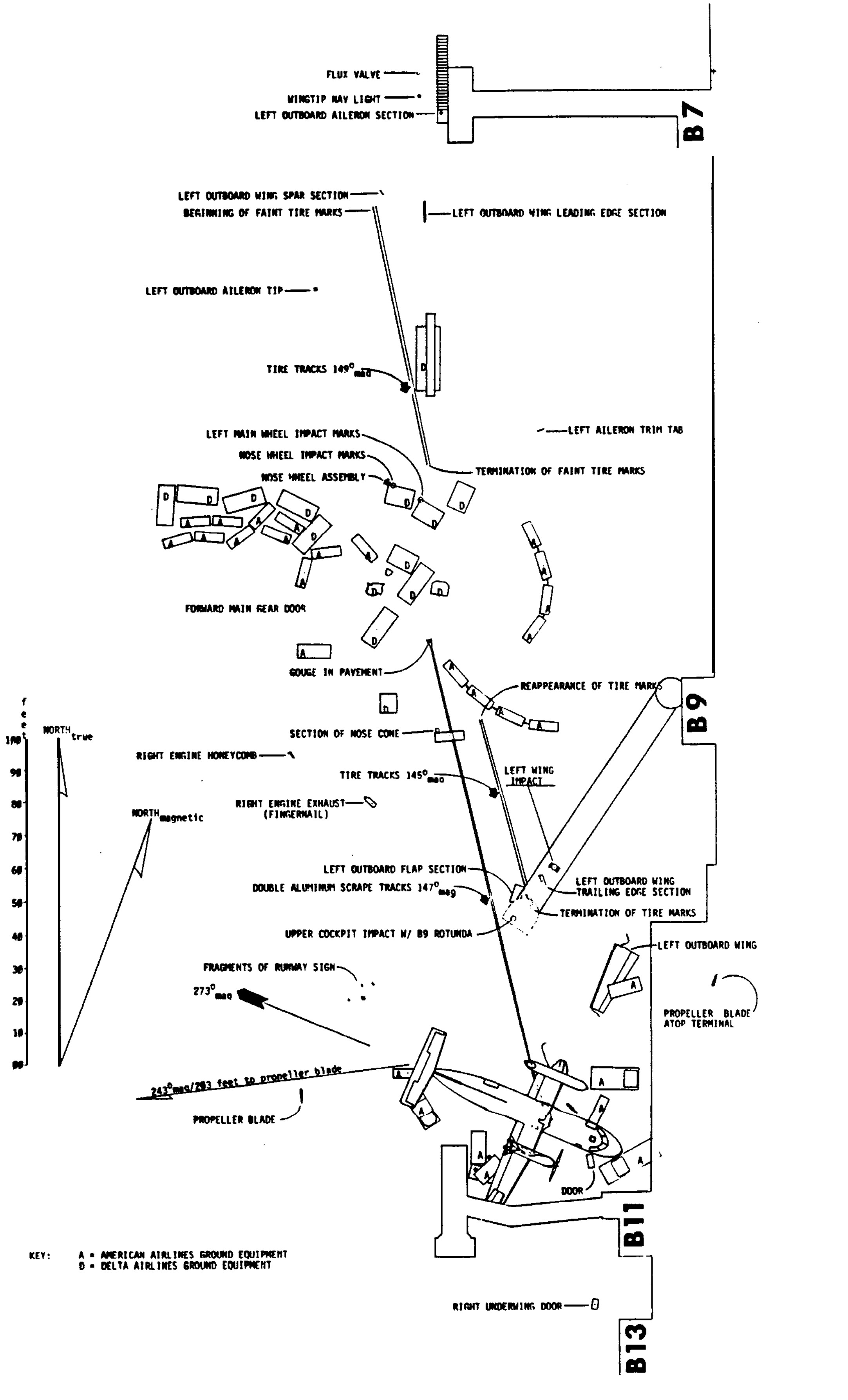


Figure 4. Diagram of N819PH against the jetway

Both panel hinges located along the upper edge of the door had fractured. The six cowl door spring closed latches were all closed and latched.

The right nacelle inboard center access panel was bowed and moderately buckled along the lower edge and right rear corner. All six of the cowl door spring closed latches were closed and latched. There was no heat damage to the outer or inner surface of the door panel. The oil servicing door was deformed outward. The upper push-to-release latch was closed and latched; however, the latch pin was outside the pocket. The lower push-to-release latch was in place and latched.

The underside of the cowling was lightly sooted to about the center of the intake cowl. Aft of this area, the intensity of the sooting and fire damage increased toward the wheel well area. Just below the outboard zone 1 access panel, the metal was burned extensively and exhibited heat damage. The top of the cowl exhibited only very light sooting. The inside and the outside surfaces of the upper rear access panel were damaged severely by heat. Although the louver was missing, the louver screen was in place, but it was punctured and covered with soot. The cowl right rear edge where the side door rear hinge attaches to the upper cowl structure was burned severely as well as the rear left corner of the cowl rear access panel. Both sides of the right engine cowls were lightly sooted from the propeller spinner to the front edge of the side access panels and along the lower edges of side access panel frames to a point midway along the lower frame members. Aft of this area, there was increased heavy heat and fire damage that extended aft to the wing trailing edge.

The engine was sooted heavily over its entire surface; there was no physical damage and no external punctures noted on the compressor and, turbine cases. Continuity was established between the HMU and the cockpit controls; however, the cable drum was damaged. All hoses exhibited extensive heat damage; insulation was burned from most of the electrical wiring, and tube and wire clamp insulators were reduced to ash,

There was a 0.116-inch gap between the HMU high pressure fuel filter cover and the face of the housing. Fuel was observed leaking from the bottom of the gap 22 hours after the accident. The fuel filter cover on the left engine was examined, and the cover was noted to be bottomed against the filter housing; there was no gap. Specified torque on the fuel filter cover is 100 to 150 inch pounds.

The right starter generator was heavily sooted and the brush cover band plating was blistered over a 140” arc. The ignition exciter box was undamaged, but the outer surface was covered lightly with soot.

1.13 Medical and Pathological Information

The captain was not requested to provide specimens for toxicological analysis following the accident because investigators were unaware that he was sent to a different hospital than that of the other crewmembers. The hospital where the captain was treated was not requested to collect blood or urine as part of his treatment. The Center for Human Toxicology, University of Utah, Salt Lake City, Utah, examined toxicological specimens from the first officer and the flight attendant. Using gas chromatography-mass spectrometry testing procedures, the Center did not detect drugs or alcohol in the specimens taken from either individual.

The captain, the first officer, and the flight attendant reported that they had experienced no significant adverse events in their lives recently. The investigation disclosed no unusual life habits or events that could have affected the performance of either pilot or the flight attendant on the day of the accident.

1.14 Fire

Statements from the first officer and several passengers revealed that the first time they noticed flames was shortly after the landing gear was lowered. The first officer stated, "We got a fire," at 1831:03, 50 seconds before touchdown. The fire continued to burn throughout the flight, the landing rollout, and after the airplane came to a stop against the jetway at 1832:31. Port of Seattle Fire Department (POSFD) truck 4 radioed to the fire station dispatcher, "We've got the fire tapped," at 1839, meaning that the fire was completely extinguished at that time.

1.15 Survival Aspects

The cockpit seating arrangement consisted of seats for the captain and first officer and a stowable jumpseat (stowed during the accident sequence) on the front face of the cockpit door. Neither the captain's nor the first officer's seats were displaced during the accident sequence. The shoulder harnesses on both seats were intact and operational; however, they were frayed and abraded at the "Y" junction to about 12 inches above that junction. The plastic covers over the shoulder harness guide rollers on the backs of both seats were missing. In addition, the cockpit jumpseat hold-up strap in the cockpit was frayed and split. The jumpseat was held in the stowed position by placing this split strap over the jumpseat hold-down stud on the hinged seat. The crash ax was found on the floor behind the left seat, and the aft left cockpit window was cracked.

The cabin seating arrangement consisted of 37 coach seats. Seat rows l-8 were double occupancy seats (four passengers per row with an aisle down the middle), and row 9 was a continuous row that seated five passengers. (See figure 5.) An aft facing single-occupancy flight attendant jumpseat was attached to the left rear side of the closet/wardrobe adjacent to the forward main cabin door.

The airplane had five emergency exits: the main cabin door; the forward cabin emergency exit; two mid-cabin emergency window exits at row 4; and the cockpit emergency hatch. All passengers escaped or were evacuated through the left mid-cabin window emergency exit or the hole in the right side of the fuselage. The hole extended from fuselage station 270 to fuselage station 348 and from waterline 100 to waterline 160 (from seat rows 1 through 3).

Seats 1DE, 2DE, and 3DE, in the area most heavily damaged during impact with ground equipment, were torn loose during the accident sequence. The passengers in seats 3D and 3E were ejected from the airplane while still buckled in their seats. The forward and aft outboard leg attachments of seat 9E separated from the floor track. All other passenger seats as well as the flight attendant's seat remained attached to the airplane floor, although some passenger seats sustained some degree of impact deformation. The overhead compartments over seats 2DE and 3DE were open, while all other overhead compartments were closed.

The beverage cart was found on its side in the aisle between seat rows 3 and 4. The secondary securing latch for the cart was unlatched. Structural continuity of the floor area in the cart storage area was lost around the "mushroom" floor lock doubler. The floor covering was torn on the forward side of the doubler, and the floor underneath the covering had dropped away from the doubler. The secondary securing latch for the lower compartment door was also unlatched.

A closet/wardrobe was installed on the left side of the cabin, forward of the main cabin door. A placard on the wardrobe read, in part, "100 Ibs. floor load limit." Objects removed from this wardrobe following the accident included catering boxes, beer, wine and liquor containers, a suitcase and a small, portable mechanical carpet sweeper. The objects (not including the carpet

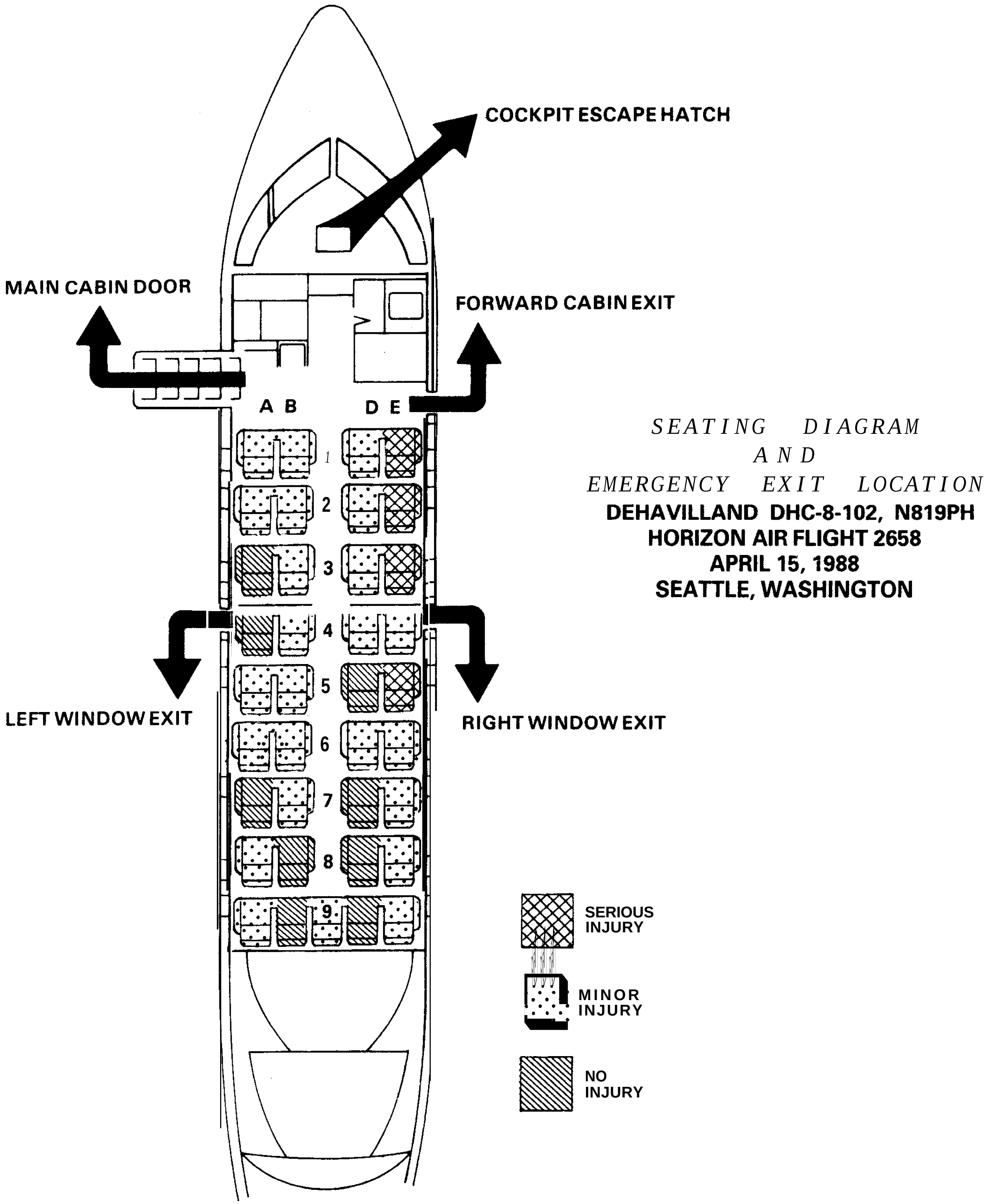


Figure 5. Injury distribution chart and seating arrangement

sweeper) weighed 146 pounds. DeHavilland Service Bulletin 8-25-35, dated February 19, 1988, called for a 1/4-turn latch that, at the operator's option, can be installed on the door of the wardrobe to prevent it from opening unexpectedly. This service bulletin also stated that until the latch had been installed, the wardrobe should be restricted to hanging items only. The 1/4-turn latch had not been installed on N819PH, and the closet/wardrobe door separated completely during the accident. Following the accident, on November 28, 1988, Transport Canada issued Airworthiness Directive (AD) CF-88-24. This document made the provision of Service Bulletin 8-25-35 mandatory for Canadian operators of DHC-8s. The FAA has not acted on this Canadian AD to make the service bulletin mandatory for U.S. operators.

Aircraft rescue and firefighting activities began at 1827 when the ground controller notified the POSFD that flight 2658 was returning to land. The fire department initiated a full response which included two heavy crash trucks, one quick response vehicle, one engine, one fire department ambulance, and one command vehicle. After assuming their standby positions on the airfield, these vehicles followed the airplane as it crossed the ramp to the jetway area. According to the POSFD and the video tape, firefighters began extinguishing the fire immediately after the airplane stopped at about 1832.31. The firefighters extinguished the fire in the right engine area by 1839, about 7 minutes after the airplane first touched down. A firefighter entered the cabin as soon as passengers stopped using the exit and began extricating two passengers (seated in 1 E and 2E) who were trapped by wreckage. Other firefighters assisted with the extrication after the fire was extinguished and both passengers were removed from the wreckage on backboards. All occupants were removed from the airplane by 1853. The first officer and the captain were the last two individuals to be assisted off the airplane.

1 .1 6 Tests and Research

1.16.1 The Cockpit Shoulder Harnesses

The captain's and first officer's shoulder harness restraint systems were removed from the airplane and tested at the FAA's Civil Aeromedical Institute's Protection and Survival Laboratory in Oklahoma City, Oklahoma. Pull tests were conducted on the abraded area of the upper torso webbing of both restraint systems on an Instron Model 1123 Universal Testing Machine. The captain's shoulder harness failed at 1,160 pounds just below the stitching at the "Y" junction in the webbing. The first officer's shoulder harness webbing failed at 1,600 pounds in the same area on the harness. According to Am-Safe, Inc., the company that manufactured the harnesses, the webbing used on the harnesses was originally rated at 4,000 pounds.

1.16.2 Postaccident Fuel System Pressure Test

Because of the amount of maintenance accomplished on the right engine before the accident to eliminate a fuel/oil odor in the cabin, an undisturbed pressure test on the fuel system of the right engine was performed. The postaccident test protocol consisted of introducing a test fuel under pressure from an auxiliary tank into the engine fuel system to expose leaks. If no static leakage occurred, the fuel pump would then be rotated to increase pressure by driving the accessory gearbox with an auxiliary motor.

The engine accessory gear box breather adaptor and drive coupling shaft were removed first in order to decouple the accessory drives from the main engine rotor and to allow rotation of only the accessory gears and fuel pump drive. A flexible pipe was used to connect the auxiliary fuel tank to the fuel heater inlet port. Test fuel then was applied at 10 psig to the fuel system; leaks were observed immediately at the fuel pump filter housing vent (top) and drain (bottom) holes.

Inlet fuel pressure was then increased to 20 psi and a clear flow of fuel came from the vent and drain holes. Inlet fuel pressure was subsequently increased to 30 and 50 psi, respectively. At that time, a considerable flow of test fuel sprayed from both the vent and drain holes in the fuel filter housing. Further, additional test fuel leaked from the housing-cover gap. All of the leaking occurred statically without the planned rotation of the fuel pump gears by motoring the gear box.

1.16.3 High-Pressure Fuel Pump Examination and Test

The HMU/fuel pump assembly was removed from the engine for operational testing. Before the disassembly, radiographs were made of the filter housing area of the assembly. (See figure 6.) Several of the radiographs clearly showed that a portion of the preformed o-ring packing had come out of its groove in the filter cover and was looped toward the cover face. This gap provided a direct path for fuel to flow beyond the o-ring groove and annulus machined into the cover, to pass the looped and pinched o-ring packing, then to flow overboard, and into the engine compartment through the vent and drain holes drilled in the fuel filter housing.

Before testing the HMU/fuel pump assembly that was removed from the accident airplane, an identical serviceable HMU/fuel pump assembly was tested to determine the validity of the proposed test plan. Using the substitute pump, the test would determine the following:

- the effect on outlet fuel flow leakage from the HMU ejector;
- loss of pump inlet boost pressure;
- torque requirement for backing out the filter cover under normal operating conditions; and
- at what point (gap) a backed out fuel pump filter cover would start to leak fuel from the vent and drain parts on the filter housing.

After the test was completed, the following conclusions were reached:

- fuel ejector flow leakage did not effect fuel flow to the engine; and
- a decrease in pump inlet fuel pressure had no effect on HMU output flow.

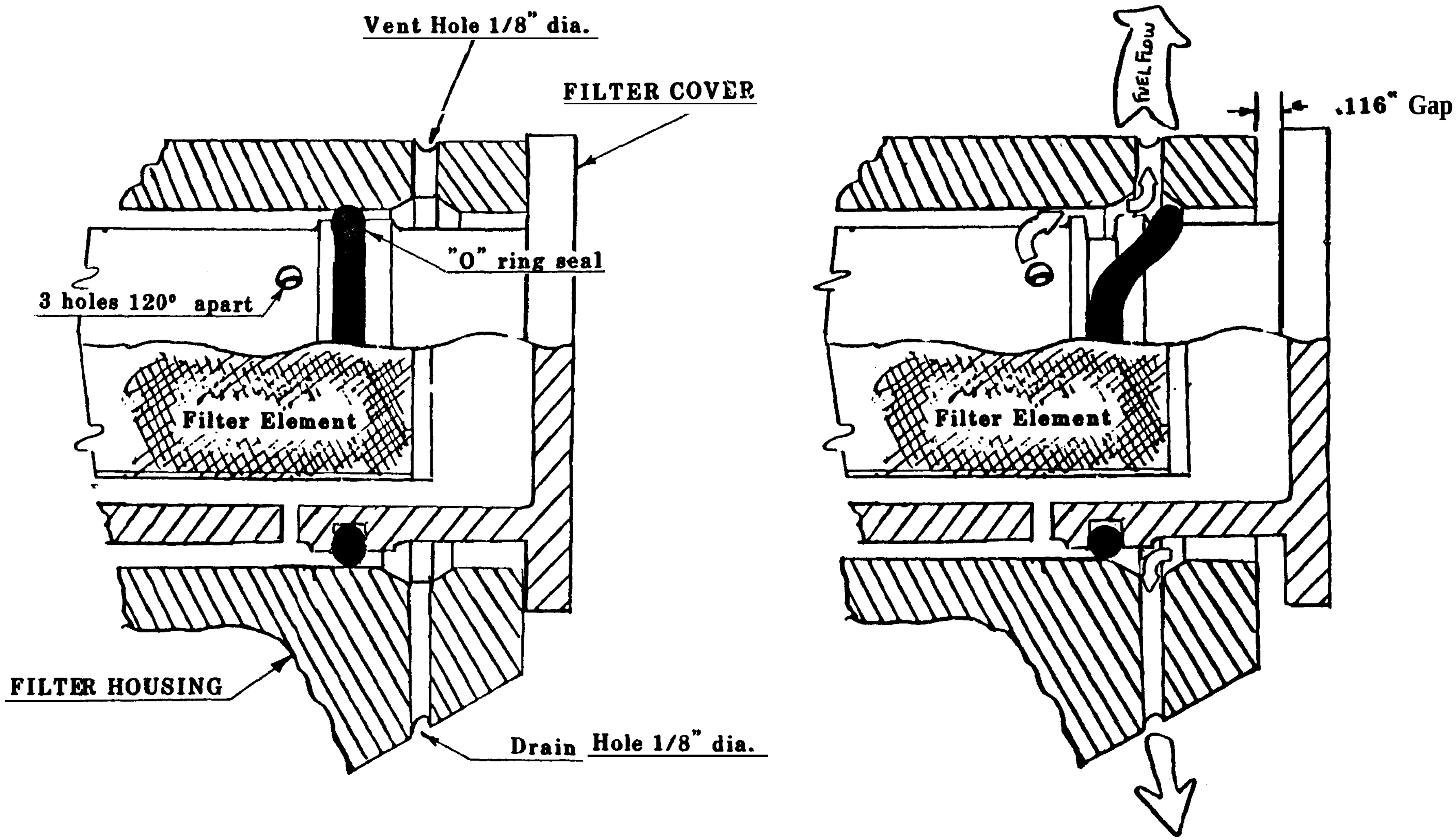
At this point, the test was terminated, and a gap of. 100 inch was established between the fuel filter cover and the pump housing. A gap of less than the .116 inch found on the actual pump from the engine was selected so that any production machining tolerances would not affect the subsequent pump testing. Pump testing was started again, and it was noted that no fuel leakage was evident from the vent or drain holes or from the .100 inch gap between the housing and the cover.

An attempt was then made to increase the gap by unthreading the fuel filter cover out of the housing. In order to move the cover, the friction of the o-ring packing as well as the affect of fuel pressure had to be overcome. To back out the cover with a fuel pressure of 150 psi, 260 in/lbs. of torque were required. Normal free running torque, without fuel pressure, was 10 in/lbs.

The filter cover then was backed out continually in small increments to determine at what point leaking would occur from the drain and vent holes. A constant flow of fuel occurred when the filter cover was backed out .194 inch and with fuel pressure of 150 psi from a fully seated position.

Stylized Side View

HP Fuel Pump Filter Assembly



Filter Assembly and O-Ring In Normal Position

Filter Assembly (with gapped cover) and O-Ring in Extruded Position

Figure 6. Cut-away diagram of a fuel filter housing

At this point, the test was terminated again. The filter cover was reseated and the filter was altered by installing a controllable bleed in the filter cover to simulate a fuel leak from the vent and drain holes. Then, by increasing the rate of the leak, it could be determined at what point a fuel leak from the vent and drain ports would affect fuel flow.

By motoring the HMU/pump assembly to obtain fuel flow and pressure and then by gradually increasing the leak rate from the fuel cover, the tests indicated a significant loss of HMU metered fuel flow when the filter leakage exceeded approximately 2,000 pounds per hour (pph). Fuel flow to the engine decreased from 602 pph to approximately 444 pph with a simulated leak of 2,450 pph from the controllable bleed.

1.16.3.1 Right Engine HMU/Fuel Pump Bench Test

The right engine HMU assembly was installed on the test bench in the "as-received" condition. A short flushing cycle purged the control and it was pumped of trapped air. Since an extensive leak from the filter area of the pump was anticipated, a clear plastic cover was fabricated to protect the observers. As boost pump pressure was applied, leaks were observed coming from the vent and drain holes. At 300 rpm pump speed (100 percent pump speed is approximate 4,100 rpm), a massive fuel leak was observed at the filter housing vent and bleed holes as well as the housing cover thread area. Fuel was also dripping from the HMU power lever shaft. Because of the magnitude of the leak from the filter area at 300 rpm pump speed, it was considered unsafe and unnecessary to proceed, and the pump test was terminated.

1.16.3.2 Fuel Pump Disassembly

In order to confirm the findings available from the radiographs and to examine the o-ring packing and determine the cause of the leaks from the power lever shaft, the pump was disassembled partially.

To remove the fuel filter cover required 80 in/lbs. breakaway and 40 in/lbs. running torque, which gradually decreased to a point where the cover could be removed by hand. A visual examination of the cover showed that the threads were in good condition. The o-ring was in one piece and in the proper position, but it exhibited some abrasion in the area where it had been forced out of its groove. It also exhibited a small cut in this area. When the pump was disassembled, it revealed that the power lever shaft seals exhibited considerable heat damage. The power lever portion of the HMU as installed in the airplane was in an area of moderate to heavy fire damage.

1.16.4 Starter Generator Brush Access Cover Examination

The starter generator brush access covers on the starter generators of both engines were not installed in accordance with the Lucas Corporation overhaul manual. This manual is the only place where the correct installation procedure is outlined. Horizon Air maintenance personnel did not have the procedure on their work cards, nor was the procedure included in deHavilland maintenance information concerning the generator (the source of the work card data). These access covers are metal bands that surround the generators with a gap or open area where the ends of the band connect. When properly installed, this gap is positioned over the top of a rib on the generator case. On the starter generators of both engines of the accident airplane, both brush access covers were rotated on the generator cases so that their gaps were over openings in the generator cases. The position of the brush access covers allowed an open path between the outside of the starter generators and the starter generator brush areas. In addition, the design of the covers allowed another open path to ambient air where the generator leads enter the starter generator cases.

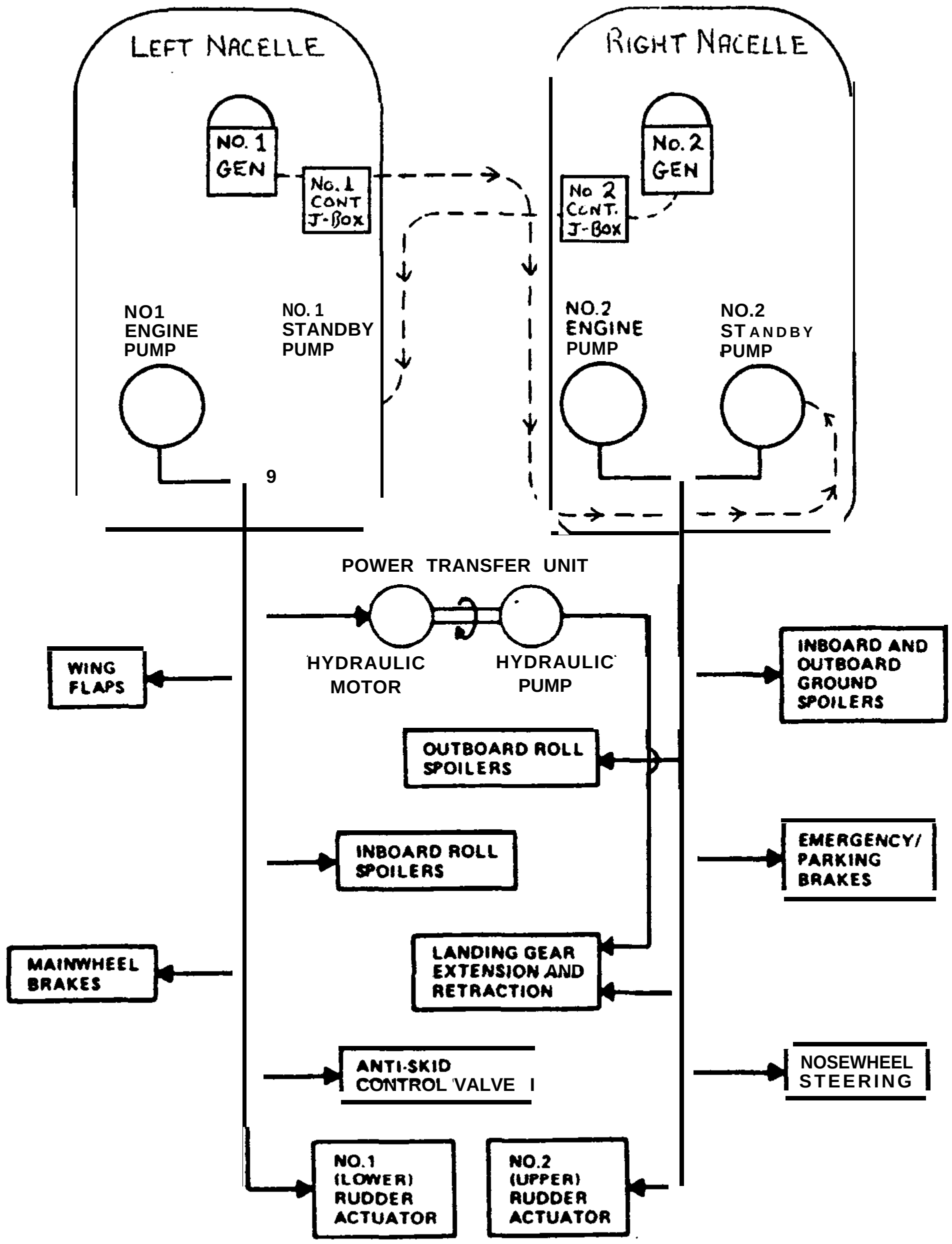


Figure 7. Schematic of the DHC-8 hydraulic system primary component

1.16.5 Airplane Hydraulic Systems Description

The N819PH was equipped with two independent constant pressure, variable flow hydraulic systems called the No. 1 (left) and the No. 2 (right) systems. By design, it was not possible to transfer control of hydraulic devices from one system to the other. The airplane was equipped with an emergency hydraulic system hand pump for use during emergency extension of the landing gear. Also, a power transfer unit (PTU) was installed to aid in the retraction of the landing gear in the event of a right engine failure on takeoff. The PTU consisted of a No. 1 (left) system hydraulic motor mechanically linked to a hydraulic pump that provided emergency pressure to the landing gear retract cylinders, a No. 2 (right) system component. No fluid transfer between hydraulic systems could occur normally in the PTU. The output pressure of the engine driven hydraulic pumps was rated at about 3,000 psi. Their flow rate was rated as 9.2 gallons per minute. The output pressure of the electric standby hydraulic pumps was rated as 2,750 psi under load. Their flow rate was rated as 1.56 gallons per minute. The No. 1 (left system) electric standby hydraulic pump received electrical power from the No. 2 (right) electrical supply contactor junction box, and vice versa. (See figure 7.)

The following devices operated from the No. 1 (left) hydraulic system that received hydraulic pressure from the No. 1 engine-driven hydraulic pump and/or the No. 1 electrically driven hydraulic standbypump:

1. the wing flaps;
2. the mainwheel brakes;
3. the inboard roll spoilers;
4. the anti-skid control valve;
5. the No. 1 (lower) rudder actuator; and
6. the hydraulic motor section of the PTU.

The following devices operated from the No. 2 (right) hydraulic system that received hydraulic pressure from the No. 2 engine-driven hydraulic pump and/or the No. 2 electrically driven hydraulic standbypump:

1. the landing gear extension and retraction system;
2. the nosewheel steering system;
3. the emergency/parking brake;
4. the inboard and outboard ground spoilers;
5. the outboard roll spoilers; and
6. the No. 2 (upper) rudder actuator.

1.16.5.1 Damage to the Hydraulic Systems

The fire had burned through electrical wiring insulation in the right wheel well that was associated with the No. 2 electrical-standby hydraulic pump. Circuit breakers associated with this pump were found open. Also, the fire destroyed the wiring to the No. 1 electrical-standby hydraulic pump from its normal power supply in the right wheel well.

Three No. 1 (left) hydraulic pressure and fluid return lines in the right wing rear spar area of the right wheel well had been burned through by the fire. These fluid return lines included: one 1/4-inch diameter hydraulic pressure supply line to the right wing inboard roll spoilers; one 1/4-inch diameter lift dump pressure line; and one 3/8-inch diameter No. 1 hydraulic system return line. Also, the emergency/parking brake accumulator unit was found intact but both hydraulic lines to it were burned through. (See figure 8.) The destruction of these five hydraulic lines disabled both hydraulic systems.

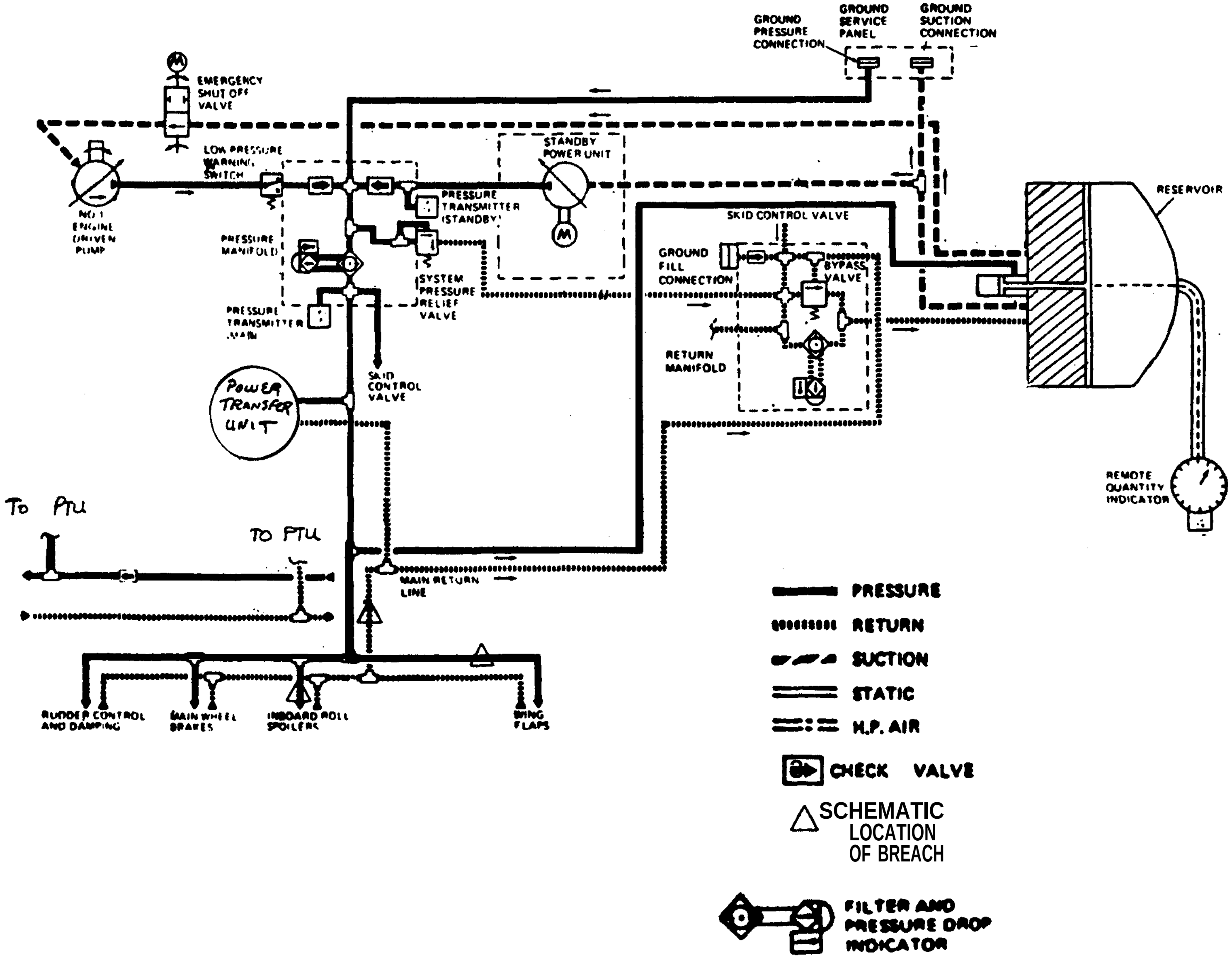


Figure 8. Simplified schematic of the No. 1 hydraulic system

Following the accident, the No. 2 hydraulic quantity gauge indicated about 1.5 quarts, and its mechanical float linkage was seized. Less than 1 quart of fluid was drained from the reservoir after it was detached from the wreckage. The normal No. 2 reservoir quantity is up to 5.19 U.S. quarts with at least 3 quarts needed to dispatch the airplane. The No. 1 hydraulic reservoir was found to contain about 2 quarts of fluid. The normal No. 1 reservoir quantity is up to 2.68 U.S. quarts with at least 1.5 quarts needed to dispatch the airplane.

1.16.5.2 Emergency/Parking Brake System Description

The DHC-8 emergency/parking brake system provides an independent source of braking to the main wheel brakes. During normal operations, the system receives hydraulic pressure from the No. 2 system engine-driven hydraulic pump. A check valve isolates the system from the No. 2 system pump in the event of an upstream line failure. An accumulator provides power for the system when engine-driven pump pressure is unavailable. The system is operated by a handle on the center console and serves as a parking brake system under normal operations. The crew may activate the lever and use a spring loaded button on the control lever to lock the lever in the on position. This provides hydraulic pressure to the main wheel brakes through the system powered by the accumulator. In an emergency, the lever is activated to provide braking to the main wheel brakes independent of No. 2 system hydraulic pressure. (See figure 9.)

1.16.5.3 Left Hydraulic Pump Examination

Before the engine was shipped to the teardown facility, the Safety Board noted that the drive shaft of the left engine-driven hydraulic pump was sheared. Using a scanning electron microscope, the Safety Board examined the shaft fracture surface. The examination revealed several small areas of undamaged dimple rupture overstress failures. The structure and orientation of the dimples were consistent with shearing overstress forces and also consistent with sudden stopping of the propeller gear-train rather than sudden stopping or overloading of the pump.

The pump was tested and then disassembled at the Vickers, Inc. facility, where it was manufactured. The operational test of the pump on a test bench revealed that it functioned within established specifications. The teardown of the pump revealed a broken control spring guide and no other anomalies.

1.16.6 Postcrash Hydraulic System Research

Pertinent No. 1 (left) hydraulic system components from N819PH were removed from the wreckage for subsequent testing on a deHavilland hydraulic system test stand. This test stand replicates the hydraulic system of a DHC-8. Tests can be run by using test stand hydraulic components alone or by using hydraulic components that are returned by customers to the deHavilland facility for diagnostic testing. Also, the effects of breached hydraulic lines and air introduced into the hydraulic systems can be duplicated on this test stand.

A test program was designed first to establish a baseline for normal system operation using serviceable test stand components, and second to simulate hydraulic failures consistent with the damage found on N819PH. The objective was to determine why hydraulic fluid remained in the left system reservoir following apparent left system line breaching because of the fire.

Serviceable left system hydraulic components were operated separately and later in combinations to determine if the failure of any one component would cause pump cavitation and subsequent loss of hydraulic pressure with fluid remaining in the system. This experiment determined that the failure of any separate hydraulic component did not cause pump cavitation.

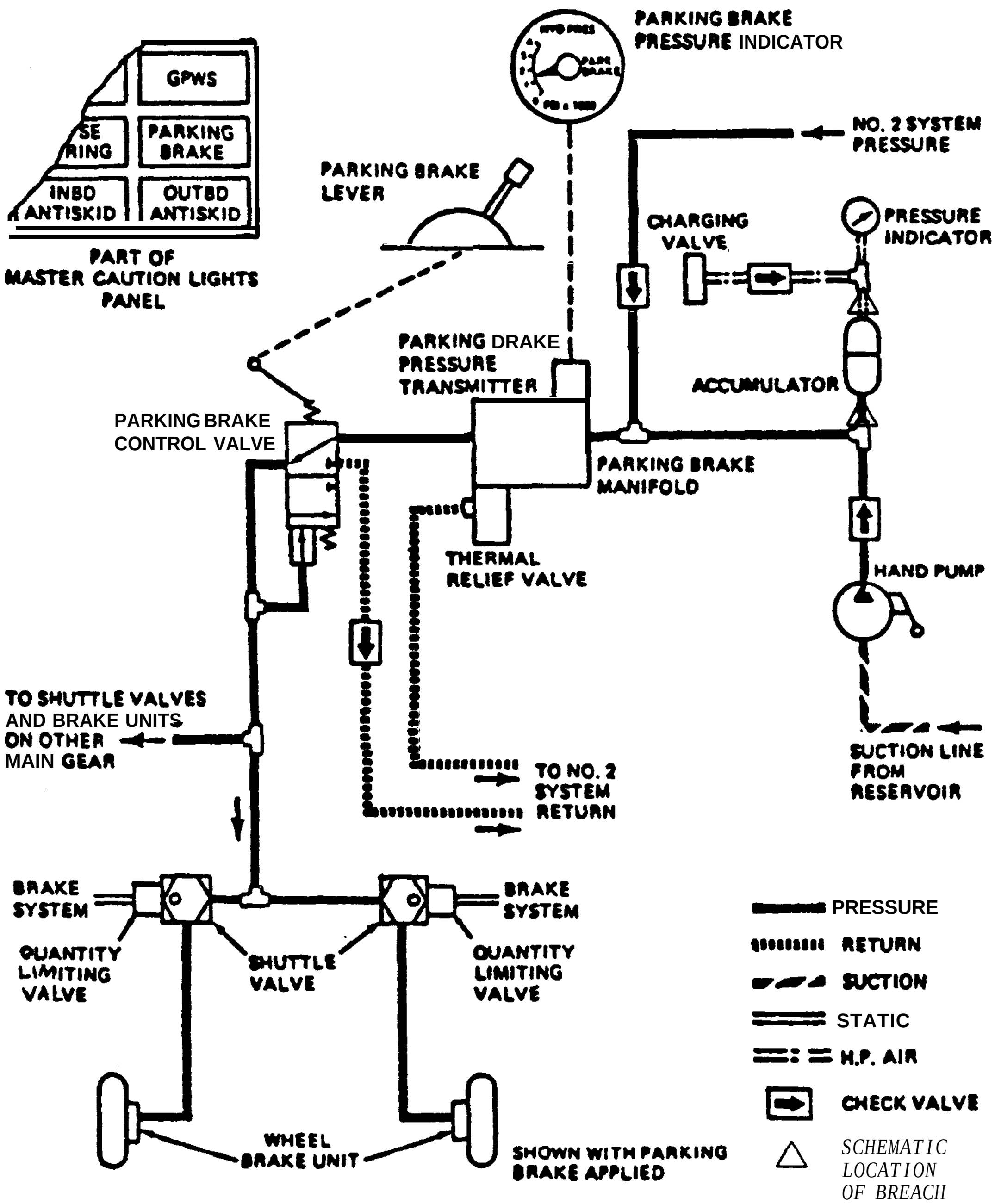


Figure 9. Schematic of the emergency/parking brake system

Next, the hydraulic components from N819PH were installed on the test stand and numerous test runs were performed. For the rest of the testing, the No. 1 (left) hydraulic system was configured with three rapid activation valves located in the system at the approximate sites of the line breaches found on N819PH. These valves were fast-acting, electrically powered valves that could simulate sudden line rupture.

During the first test run in this configuration, the system did not contain extraneous air, and all three valves were opened. This resulted in the cavitation of the engine-driven hydraulic pump, in the system pressure falling to 0 psi, and in a small amount of hydraulic fluid remaining in the hydraulic lines and reservoir. This amount of fluid was less than the amount of fluid found in the left hydraulic system in the wreckage of N819PH. In the numerous additional test runs that followed, when the hydraulic lines were breached, the pump cavitated, the hydraulic pressure dropped, and a small amount of fluid remained in the system.

The next test run was accomplished after the No. 1 hydraulic system filter was removed, drained, and replaced on the No. 1 hydraulic system. The air intentionally introduced into the system by the drained filter was not bled out before the beginning of the test run. By introducing a known quantity of air into the lines, there was a further attempt to determine why a great amount of fluid remained in the left hydraulic reservoir following the accident. During this run, the 1/4-inch hydraulic pressure supply line for the left roll spoilers was breached via one of the fast-acting valves. This line was the smallest in diameter of the three that were burned through in the fire and it contained system operating pressure of 3,000 psi. It was determined that because it was the smallest line with the highest operating pressure of the three lines, it would have failed first during the fire. Following the simulated breach of this line, the pump cavitated as before, hydraulic system pressure fell to 0 psi as before, but this time a considerable amount of hydraulic fluid remained in the reservoir. This test was repeated with identical results.

1.17 Additional Information

1.17.1 Discovery of Another Loose Fuel Filter Cover

During the investigation, when a loose fuel filter housing on N819PH first became suspect, another newly overhauled engine from Horizon Air stores was examined by Horizon Air personnel to determine what the filter housing should look like in a secured condition. The engine that was examined also had a loose fuel filter cover. This loose filter cover was later examined by Horizon Air's FAA principal maintenance inspector. This engine, according to Horizon Air maintenance personnel, was recently shipped from Pratt and Whitney of Canada and had not been disturbed by anyone since its arrival at Horizon Air.

1.18 New Investigation Techniques

1.18.1 Radiographic Examination of the Fuel Filter

The high-pressure fuel filter assembly was examined via radiograph (x ray) before removing the filter cover from the HMU. (The resulting radiographs did not contain sufficient photographic contrast to be reproduced in this report.) Although the use of radiograph technology in accident investigation is not a new technique, the ability of radiographs to reveal the position of nonmetallic o-rings was particularly important to this investigation. At the time, some investigators and the technician operating the x-ray machine believed that the o-ring probably would be masked fully by the denser metallic filter housing. In point of fact, the extruded o-ring was visible on several of the radiographs. This knowledge was especially valuable because the o-ring snapped back into its correct position when the filter housing was removed. Because of its damaged condition, the o-ring still would have been identified as the fuel leak source, but without the radiographic proof, the fact that the o-ring had extruded over the filter weep hole would not have been discovered. Given the relatively small amount of damage to the o-ring, it would have been very difficult to explain the high volume of the fuel leak.

1.18.2 Computer Enhancement of the Video Tape

The video tape of the accident sequence was of poor quality, but after key frames of the tape were computer-enhanced, it was useful in proving that ground spoiler actuation did not occur during the landing rollout.

The images on the video tape were enhanced electronically to highlight any horizontal and vertical edges on the wing upper surface. A mathematical "Roberts" edge filter was applied to the digitized video pictures. This Roberts filter compared the brightness values of the neighboring pixel elements and enhanced the occurrences of line segments in the pictures. This enhancement was used to see if edges of the spoilers could be detected over the edge of the wing. Using this technique, no evidence of ground spoiler activation was found on either wing in any of the key video frames examined on the accident video tape.

2. ANALYSIS

2.1 General

The captain, first officer, and flight attendant aboard Horizon Air flight 2658 were trained and qualified for the flight in accordance with company policy and FAA regulations. The Safety Board also notes that Horizon Air has an established cockpit resource management (CRM) training program. The flightcrew's actions during this accident illustrated familiarity with the concepts of this training.

In addition, the flight attendant's instructions to passengers to take one of two brace positions (due to the seating arrangement of the airplane) were delivered correctly before touchdown. Further, her repeated insistence that the passengers remain in the braced position while the airplane rolled across the ramp and into the jetways was important in preventing more serious injuries.

FAA air traffic control personnel in the Seattle tower and approach control facilities performed their duties in a timely and appropriate manner during the accident sequence. During the first phase of the incident, after the flightcrew notified the tower that they were returning to land (with no amplifying comments), the controller sequenced the airplane into landing traffic according to established procedures. Shortly thereafter, the local controller ordered emergency personnel into position, even though he knew only that the airplane was returning for unknown reasons. Although the flightcrew had not declared an emergency at that point, the controller initiated an emergency equipment response solely as a safety precaution. Because the incident evolved from a simple precautionary landing into a catastrophic in-flight fire less than a minute before touchdown, the controller's actions in alerting the emergency crews resulted in a timely response and effective evacuation of the passengers and crew.

The effectiveness of the aircraft rescue and firefighting activities of the POSFD was also noteworthy. The fire that engulfed the right engine nacelle area was extinguished by 1839, within 7 minutes after touchdown. In the video tape of the accident sequence, several firetrucks reversed their direction after the plane touched down, and in order to be in good position to put out the fire and begin passenger rescue as soon as possible, the firetrucks followed flight 2658 across the ramp when the crew lost control of the airplane. The rapid response of the emergency personnel was instrumental in saving the life of the passenger in seat 1E who sustained a lacerated aorta. The rescue of this passenger began before the fire was extinguished.

2.2 The Right Engine Fuel Leak and Fire

The Safety Board determined that the cause of the fuel leak on the accident flight was the improperly installed fuel filter cover on the right engine high-pressure fuel pump. The Board believes that repeated high-pressure fuel pressurizations of the unsecured fuel filter cover allowed the neoprene o-ring to distort and extrude into a position so that it allowed high-pressure fuel to be channeled to a vent and drain hole on the filter housing and thereafter overboard into the nacelle. The distorted o-ring and its position in relation to the vent and drain hole appeared on radiographs before the filter cover was removed. The manufacturer stated that the purpose of the vent and drain holes in the filter housing was to prevent the possible spill of less than 1 pint of fuel during periodic filter changes and that it was mainly a minor environmental safeguard.

The Board further believes that the filter cover was not seated before the installation of the HMU/fuel pump/filter assembly on the right engine of N819PH on April 8 and 9, 1988, but it was unable to determine positively if Horizon Air received this unit in its unsafe condition. According to Horizon Air personnel, they would have had no need to adjust or inspect the filter housing or the filter element before April 8 and 9. In addition, at the time of the accident, Pratt and Whitney of Canada had no established procedure for documenting proper filter cover installation after the postoverhaul engine run and before engine shipment to customers. Such documentation is now a standard practice at Pratt and Whitney. However, Horizon Air did install the filter impending bypass switch electrical lead on the filter cover as part of the HMU assembly change. This would have allowed maintenance personnel an opportunity to question the gap between the filter cover and the filter housing as being abnormal. Maintenance personnel at Horizon Air should have been familiar with what a properly seated cover looks like and should have been able to detect the gap because the filter cover on the HMU has to be removed every 300 operating hours to check the filter for contamination.

The fact that another unseated filter cover was found on a spare engine that had been shipped recently from Pratt and Whitney to Horizon Air stores would tend to suggest that the loose filter originated at the factory. Further, according to Pratt and Whitney personnel, it is their practice to inspect filters and chip detectors after overhaul testing to determine the health of the engine. It is possible that following this procedure, the filter cover was not tightened properly. The fact that Pratt and Whitney did not have a specific step on the post overhaul checklist that required torqueing of the filter cover (a step was added after the accident) would also suggest that an untorqued filter cover could have been missed at the factory. Based on these facts, it could be concluded that the origin of the loose filter occurred at the factory. However, the circumstantial nature of the evidence precludes the Safety Board from drawing a positive conclusion about the origin of the loose filter.

On April 19, 1988, Pratt and Whitney of Canada issued an Alert Wire asking all customers to check installed and spare engines for loose fuel filter covers. Any instances of loose covers were to be reported back to Pratt and Whitney. Three weeks later, the survey was completed and it revealed no other loose covers other than the two discovered at Horizon Air. On April 2 1, 1988, the FAA New England Engine Certification Office (ANE-140) recommended compliance with the Alert Wire. On May 13, 1988, Transport Canada issued AD CF-88-11 which mandated compliance with the Pratt and Whitney of Canada Alert Wire.

The Safety Board is also concerned that from the time the filter cover was last installed on the HMU assembly at Pratt and Whitney to the time the HMU was installed on the airplane by Horizon Air, no one who handled or examined the HMU assembly noticed that the filter cover was not seated properly. This oversight occurred in spite of the fact that the words "TORQUE TO 100-150 INCH POUNDS" are cast into the top of the filter cover. None of the mechanics, inspectors, or quality assurance personnel at Horizon Air inspected this unit closely to see if the filter cover was seated properly. All of these individuals, in addition to the Pratt and Whitney of Canada individual who first put the cover on the HMU, either overlooked the gap or assumed that the job was performed correctly. Their actions negated the entire concept of maintenance quality assurance and inspection.

The Safety Board believes that the fuel leak that was the source of the in-flight fire began shortly after takeoff as the torque readings in the cockpit first began to drop. At that time, fuel began to collect in the engine nacelle, and shortly thereafter, the fuel also flowed rearward to collect in the right wheel well. Fuel also leaked overboard from that wheel well and was observed by a passenger seated on the right side of the airplane. This passenger, following the observation of the fuel leak, could not have been expected to raise an alarm because he was unfamiliar with airplanes.

Before the outbreak of the fire, the Safety Board believes that the fuel/air mixture within the nacelle and wheel well was too rich to ignite. As the landing gear doors opened on final approach, this fuel/air mixture was leaned by ambient air, became combustible, and ignited rapidly. The exact source of ignition could not be determined positively. The misplaced starter generator brush access cover on the right generator conceivably could have been a factor in the ignition because it may have allowed a combustible fuel/air mixture to accumulate in the area of the generator brushes.

There is also another clear, unshielded path to the brush/armature area. Near the top of the starter, generator electrical leads progress into the generator armature and brush area. There is an open gap at this location which is about 1 foot closer to the fuel leak than the brush access cover. Therefore, in spite of the mispositioning of the access cover, there was another open path to an ignition source.

Following the accident, on June 20, 1988, Lucas Aerospace Power Equipment Corporation issued a Service Information Letter 23088-00X-03 that outlined the correct installation of the starter-generator brush access covers on 23088 series generators. The Service Information Letter also recommended that any new or overhauled starter-generators be checked for correct brush cover installation before being placed on engines. On July 22, 1988, Lucas Corporation issued Service Information Letter 23088-00X-04 that recommended a procedure for sealing the open gap associated with the electrical leads on 23088 series generators. This procedure was recommended to be accomplished at the earliest opportunity. On July 26, 1988, Transport Canada issued AD CF-88-15 that mandated compliance with these two Lucas Service Information Letters. On September 2, 1988, FAA AD 88-18-12 became effective. This AD also called for mandatory compliance with the two Lucas Service Information Letters.

Another possible ignition source could have been the engine exhaust pipe. Atomized, fuel could have been drawn into the cooling air shroud surrounding the exhaust pipe. The area where this cooling air originated contained a large amount of accumulated fuel.

2.3 The Loss of Control on the Ground

The Safety Board noted that in accordance with accepted airplane design practices, a fire and subsequent shutdown of one engine on a twin-engine airplane should not have caused the deterioration and subsequent loss of airplane control. The Board concluded that all systems that would have aided in stopping N819PH on the ground after touchdown were disabled by the fire.

2.3.1 The No. 2 (Right) Hydraulic System

Following the outbreak of the fire, the pilots immediately shut the right engine down in accordance with their emergency training. During a simple right engine shutdown (with no other associated problems), the following components, which could only receive hydraulic pressure from the right engine-driven hydraulic pump or the No. 2 electrical-standby hydraulic pump, would be disabled:

1. The inboard and outboard ground spoilers. These wing-mounted automatically activated panels normally activate on touchdown and aid in airplane control by destroying lift on the wings and by acting as air brakes.

2. The outboard roll spoilers. Also mounted on the wings, these spoilers enhance the roll rate while airborne and automatically activate and act as the ground spoilers above when the airplane is on the ground.

3. The emergency/parking brakes. This wheel brake system, hydraulically separate from the pilot's mainwheel brakes, mechanically slows the airplane down via a hand lever in the cockpit. The captain attempted to use this system to no avail.

4. Nosewheel steering. This system casters the nosewheel via the captain's hand control or by either captain or first officer rudder input. Both the captain and the first officer attempted to use the nosewheel steering system to no avail.

5. The upper rudder actuator. This hydraulic actuator along with the lower rudder actuator powers the rudder, which yaws the airplane and provides directional control at moderate to high speeds during landing rollout. The system consists of two actuators, one on each hydraulic system. Both crewmembers attempted to steer the plane with the rudder, but to no avail.

6. Landing gear extension and retraction system. The nomenclature is self-explanatory.

The No. 2 electrical-standby hydraulic pump (located in the right engine nacelle) automatically should have provided hydraulic pressure to these systems when the right engine-driven hydraulic pump was deactivated. This did not occur, however, because the electrical wiring and control unit that furnishes power to the pump was destroyed by the fire. The No. 2 electrical-standby hydraulic pump circuit breaker, in fact, was tripped because of short circuiting in the control unit due to the fire.

2.3.2 The No. 1 (Left) Hydraulic System

The Safety Board believes the following components of the left hydraulic system were disabled because the in-flight fire breached a No. 1 (left) lift dump hydraulic pressure line, a No. 1 hydraulic system pressure return line, and a No. 1 system hydraulic line servicing the right wing in-board roll spoiler system, all located in the right wheel well:

1. The wing flaps. Trailing edge flaps that would have shortened the landing roll to some degree in their fully extended position. The pilots attempted to position the flaps to the 15" landing position, but the flaps stopped at about 6" down as the left system hydraulic pressure was lost.

2. The mainwheel brakes. These brakes are the primary ground braking devices on the airplane. Both pilots depressed their brake pedals to no avail. In fact, the first officer's pedals are linked mechanically to the pilot's pedals, so the failure of the left hydraulic system disabled both sets of brake pedals.

3. The in-board roll spoilers. These spoilers function like the outboard roll spoilers. (See item number 2 under the right hydraulic system discussion.)

4. The hydraulic motor half of the PTU. This device is a hydraulically powered motor designed to power automatically an auxiliary right system hydraulic pump to assist only in landing gear retraction in the event of a right engine failure. There was no indication that this device was operating at any time during the flight, nor would it have aided the crew under the circumstances of this accident.

5. The lower rudder actuator. This unit is the identical counterpart to the upper rudder actuator, but powered from the left hydraulic system.

6. The anti-skid control valves. There are two hydraulic valves that regulate hydraulic fluid flow to the wheel brakes. These valves operate through an anti-skid control unit. Since the mainwheel brakes were inoperative during the accident sequence, the failure of these valves did not affect the outcome of events.

The tests accomplished on the deHavilland hydraulic test stand indicate that as the fire breached the left system hydraulic lines, the hydraulic pressure from the No. 1 engine-driven hydraulic pump to the No. 1 hydraulic reservoir dropped rapidly. The differential piston within the pump and the diaphragm in the reservoir then relaxed to the point where normal hydraulic pump inlet pressure in the reservoir rapidly dropped to near 0 psi. The No. 1 hydraulic pump then cavitated because of the loss of pump inlet pressure.

Had the pump not cavitated, the hydraulic test stand experiments indicate that most of the fluid in the reservoir would have been expelled from the system through the breached lines. This also would have caused the loss of all left system hydraulic components.

Last, the No. 1 electric-standby hydraulic pump was rendered inoperative because wiring from its power source (the No. 2 contactor junction box in the right nacelle) was burned severely. The crosstie circuitry (also located in the right nacelle) that would have allowed the pump to operate from the No. 1 generator was destroyed also. If this pump had been operating, the outcome of the accident would have been the same due to the breached left system hydraulic lines and resulting loss of hydraulic fluid and system pressure.

Following the successful operational test of the left engine-driven hydraulic pump at the Vickers facility, this unit was disassembled. During the disassembly, a broken control spring guide was discovered. An analysis of this anomaly revealed that the broken guide would have tended to bias the pump toward maximum output, if the guide had interfered with the spring compression. Therefore, it was concluded that the engine-driven pump was functioning normally until it cavitated while the airplane was on short final approach. The structure and orientation of the dimple overstress failures observed on the pump drive shaft end were consistent with shearing overstress forces. This type of failure is also consistent with the sudden stopping of the propeller gear-train during the impact sequence, rather than sudden stopping or overloading of the pump itself during flight.

2.4 Aircrew Actions

The flightcrew noted nothing out of the ordinary during the preflight inspections of the exterior of the airplane. According to deHavilland and Horizon Air procedures, there is no requirement for aircrew inspection of the interior of the engine compartments during preflight activity.

The entire incident involving flight 2658 spanned 6 minutes--when the initial partial power loss occurred at 1826:30 to impact with jetway B11 at 1832:30. Until the fire broke out in the right engine area, the flightcrew was confronted with an unexplained loss of right engine torque with no other associated problems. The Safety Board concludes that their actions in assessing the loss of power and its effect on the safe recovery of the airplane were appropriate and indicative of good CRM. The Safety Board notes that comments from the captain during the initial power loss such as: "Okay, help me watch the airspeed there"; "Have that [emergency] checklist standing by"; and "Okay, let's analyze [for] anything else . . ." are good examples of a captain enlisting the aid and knowledge of his first officer. Also, the captain's instruction to the first officer to advise the flight attendant that they were returning to the airport and the fact that he later double-checked that this was done insured that all three crewmembers were involved in the attempt to recover the airplane safely. From the onset of the emergency, the captain treated the situation as a team effort.

The first officer's quick and effective use of the various checklists and his frequent verbal confirmation of activity in the cockpit are also commendable. His comments such as: "We still got some power, we don't have an uptrim, we don't have an autofeather"; ". . . everything's lookin' good except for that torque"; and "Gear is down, but we don't have any lights . . ." are all indicative of procedures and events the captain probably realized had occurred during the emergency, but it also indicated that the first officer was an active and involved member of the flightcrew and was not just following the captain's lead or his specific orders.

At 1832:21, about 9 seconds before final impact and as the airplane was rolling unguided toward the terminal, the first officer had the presence of mind to lock the captain's shoulder harness. At 1832:29, about 1 second before final impact, the captain stated, "We're gonna' do okay here, hang on." These actions and comments indicate to the Safety Board that this crew was trying to mitigate the results of the emergency to the maximum extent possible.

The flightcrew did not complete the Engine Fire (In Flight) emergency checklist after the first officer discovered the right engine fire at 1831:03. Of the six steps on this checklist (see appendix D), they did not place the condition lever in the Fuel Off position, and they did not complete the Engine Shutdown procedure (another checklist) as a final step. During the investigation, the Safety Board determined that had the crew placed the condition lever in the Fuel Off position, they would have prevented a small amount of fuel from reaching the engine components feeding fuel to the fire. The Safety Board believes that this small amount of fuel, given .the already large stream of fuel flooding the nacelle, did not contribute significantly to the overall intensity of the fire or to the eventual fire damage., In addition and more important, the fire broke out only 50 seconds before touchdown and (unbeknownst to the crew) almost immediately disabled the rudder and all wing spoilers and' caused the flaps to stop at an intermediate position. It is the opinion of the Safety Board that at that juncture, the difficult task of landing the airplane without full lateral and roll control in an engine-out condition took precedence over completing the remaining steps in the Engine Fire (In Flight) emergency checklist.

The pretouchdown loss of rudder control, automatic ground spoiler activation, nose-wheel steering, pilot braking capability, and thrust from one engine precluded almost all ability to steer the airplane. Conceivably, the airplane heading could have been changed by varying thrust on the operating left engine; however, such an action could have resulted in an increase in ground speed if positive thrust was applied, and the varying thrust possibly could have resulted in an inadvertent collision with other objects, such as taxiing or parked airplanes or the terminal building. During a postaccident interview, the captain stated that at the time, he considered collision with the lightly constructed jetways a better option than a collision with the terminal building.

2.5 Airplane Design

2.5.1 Engine Fire Suppression versus Engine Cowl Design

The Safety Board is very concerned that the effectiveness of the engine fire suppression system was negated by apparent flaws in the design of the cowl and cowl latches on the deHavilland DHC-8. During this accident sequence, the left cowl on the right engine was blown off the nacelle when the fuel pooled in the nacelle ignited. Although it could not be determined positively, the right cowl on that engine probably was blown open during the initial explosion and fell off the nacelle during impact with the jetways. When the first officer activated the fire bottles on the engine shortly after the fire broke out, the fire suppressant was expelled quickly onto and around an essentially uncowled engine to no apparent avail. With no cowls to contain the fire suppressant, the fire suppressant system was rendered ineffective.

Following the accident, the center access panels from the right engine were examined. Both panels were bowed out and except for one corner of the right panel, exhibited no fire damage or sooting. Ail latches on the panels were latched and undamaged. it was apparent that the outward force of the fuel explosion bowed and buckled the panels so that the latches could no longer hold the center access panels to the nacelle.

The Safety Board is aware of another instance of apparent center access panel latch failure on another Horizon Air DHC-8. On June 19, 1987, aircraft N813PH experienced a right engine fire due to a leaking fuel line. However, in this instance, the center access panels remained attached but in a loosened state, and the fire suppression system was effective.

The Safety Board is pleased to note that deHavilland is exploring means to enhance the effectiveness of the engine cowls to preclude their loss during engine fires. Although an evaluation of the DHC-8 engine cowl design and installation revealed that they meet the requirements of the regulations, the Safety Board believes that the regulations should be reviewed to determine whether more stringent requirements are necessary. It is obvious that engine cowls cannot be designed to preclude loss during a significant explosion; however, the Safety Board believes that explosions involving lesser overpressures can be better contained to preclude loss of engine fire extinguishing agent. Among the options that should be considered are stiffener bands on the cowl panels, improvement of existing latches, an increase in the number and strength of the latches, or the incorporation of hinged pressure relief doors, or blow-out doors.

2.6 Shoulder Harness and Jumpseat Hold-up Strap Wear

Although the flightcrew's shoulder harnesses operated effectively during this relatively low-impact accident, the Safety Board is concerned that both cockpit shoulder harnesses on N819PH along with two others on another Horizon Air DHC-8 airplane examined by the Safety board were worn beyond acceptable limits. Tensile tests on the harnesses on the accident airplane revealed that the pilot's and first officer's harnesses failed at 29 percent and 40 percent of their designed rating, respectively. The Board notes that new harnesses were placed on order by Horizon personnel during the investigation after the worn ones were discovered. The wear on the harnesses examined during the investigation was obvious however and should have been noticed by Horizon pilots or maintenance personnel. It is also disturbing that FAA maintenance and operations inspectors failed to notice the harness wear and to order replacements as specified in FAA Action Notice A8300.11, dated November 1986. This notice required FAA inspectors to ensure that air carriers establish procedures to inspect periodically, repair, and replace restraint systems "when there is obvious damage, wear or chafing which could degrade the integrity of the system."

The Safety Board believes that shoulder harness wear similar to that discovered at Horizon Air is endemic to the entire DHC-8 fleet, even though the DHC-8 design is not old. When the Safety Board examined a factory-new DHC-8, it noted hard plastic covers over the shoulder harness guide rollers on the backs of the seats. This plastic cover had been broken away on older DHC-8 airplanes that were examined during the investigation, and its absence did not affect the operation of the harness. The Safety Board believes that the FAA should review the design of the shoulder harness guide cover on DHC-8 cockpit seats with the intent of determining the reason for excessive wear on the shoulder harness webbing.

In addition, the jumpseat hold-up strap on the cockpit bulkhead of N819PH was not in a serviceable condition, although it remained somewhat effective when a split in the bulkhead strap was looped over the jumpseat hold-down stud on the seat to hold the hinged seat in an upright, stowed position. The danger of inadvertent deployment of the unoccupied, stowed jumpseat during an accident and subsequent effect on pilot evacuation is obvious. This too, appears to be a problem that is widespread among older DHC-8 airplanes. Therefore, the Safety Board believes that Transport Canada and -the FAA should direct a one-time inspection of the jumpseat hold-up strap and mandate repair, replacement, or redesign as necessary.

2.7 Closet/Wardrobe Weight Restrictions

The floor of the closet/wardrobe in the forward left portion of the passenger cabin was overloaded by about 50 pounds. The normal floor load limit for the closet was 100 pounds; however, 146 pounds of material was stowed on the floor of the closet, in addition to a small carpet sweeper that was not weighed during the investigation. The Safety Board is concerned that the door to the closet was never designed to contain such weight. Because it is conceivable that items in the closet could be expelled during an accident sequence, block exits from the cockpit or cabin, and impede evacuation, the Safety Board believes that a 1/4-turn latch should be installed on the closet door as recommended in Transport Canada's AD CF-88-24 and that the FAA should ensure that this is accomplished by issuing a similar AD. Also, the Safety Board believes that the FAA should include compliance with placarded closet load limits in its routine in-flight and ground inspections of DHC-8 operations.

3. CONCLUSIONS

3.1 Findings

1. The flightcrew and flight attendant were trained and qualified in accordance with current company and Federal requirements.

2. The fuel filter cover on a replacement high-pressure fuel pump was not seated fully in the filter cover housing.

3. Despite the fact that the HMU/fuel pump assembly was handled or inspected by many maintenance technicians before final installation on the right engine of N819PH, no one noticed that the filter cover was not seated properly.

4. The flights of N819PH between the installation of a replacement HMU assembly and the accident were uneventful.

5. The flightcrew and flight attendant were well rested before the flight, and there were no indications of chronic or stress-related factors that would have affected their performances.

6. After takeoff, a loss of torque occurred on the right engine due to a drop in fuel pressure caused by a massive fuel leak from the high-pressure fuel filter cover.

7. The flight was handled by air traffic control in accordance with applicable air traffic control procedures, and ATC response to the emergency was commendable.

8. The flight attendant's instructions to passengers were concise and accurate, and her actions were commendable and instrumental in preventing more serious injuries.

9. When the landing gear was lowered, a fire broke out in the right engine nacelle/right wheel well that subsequently rendered both the left and right hydraulic systems inoperative.

10. The starter generator, located in the right engine compartment, had an improperly installed brush access cover. It could not be determined if this was the ignition source of the fire.

11. The initial explosive force of the fire blew one of the engine cowl panels off and the other open and rendered the engine fire suppression system ineffective.

12. Airplane control began to deteriorate in the air because of the loss of rudder control and roll spoilers on short final approach due to the burn through of hydraulic lines.

13. Following touchdown, all airplane control was lost due to the loss of normal brakes, emergency brakes, nosewheel steering, and rudder control.

14. During the emergency, the flightcrew performed commendably and exhibited coordinated crew interaction in accordance with good CRM concepts which mitigated the seriousness of the emergency.

15. The rapid response of the aircraft rescue and firefighting personnel was commendable and instrumental in preventing fatalities.

16. The shoulder harness and jumpseat hold-up strap in the cockpit of N819PH were worn beyond safe limits.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the improper installation of the high-pressure fuel filter cover that allowed a massive fuel leak and subsequent fire to occur in the right engine nacelle. The improper installation probably occurred at the engine manufacturer; however, the failure of airline maintenance personnel to detect and correct the improper installation contributed to the accident. Also contributing to the accident was the loss of the right engine center access panels from a fuel explosion that negated the fire suppression system and allowed hydraulic line burn-through that in turn caused a total loss of airplane control on the ground.

4. RECOMMENDATIONS

As a result of its investigation, the National Transportation Safety Board made the following recommendations to the Federal Aviation Administration:

> Reassess the design requirements for the engine cowls on the DHC-8 with the view toward amending the regulations to enhance the fire suppression capabilities of the engine cowling. (Class II, Priority Action) (A-89-8)
>
> Take action to verify the compliance of Federal Aviation Administration (FAA) operations and maintenance inspectors with FAA Action Notice A8300.11, concerning cockpit shoulder harness/seat belt wear. (Class II, Priority Action) (A-89-9)
>
> Review the design of the shoulder harness guide cover on DHC8 cockpit seats with the intent to determine the reason for excessive wear on the shoulder harness webbing. (Class II, Priority Action) (A-89-10)
>
> Direct a one-time inspection and review the design of the cockpit jumpseat hold-up strap on DHC-8 airplanes for excessive wear, and mandate repair, replacement, or redesign as necessary. (Class II, Priority Action) (A-89-l 1)
>
> Issue an airworthiness directive (AD) to require the installation of the 1/4-turn latch on the closet/wardrobe door of DHC-8 airplanes as required by Transport Canada's AD CF-88-24. (Class II, Priority Action) (A-89-12)
>
> Issue an air carrier operations bulletin for operations inspectors to review with operators of DHC-8 airplanes the requirement to comply with the wardrobe's placarded floor loading. (Class II, Priority Action) (A-89-13)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES L. KOLSTAD
Acting Chairman

/s/ JIM BURNETT
Member

/s/ JOHN K. LAUBER
Member

/s/ JOSEPH T. NALL
Member

/s/ LEMOINE V. DICKINSON, JR.
Member

March 6.1989

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The National Transportation Safety Board was notified of the accident at 2200 on April 15, 1988. An investigation team was dispatched from Washington, D.C. the next morning and arrived on scene later that afternoon. Investigative groups were formed for operations, survival factors, human performance, structures, systems, air traffic control, and powerplants. Groups were later formed for readout of the FDR and CVR in Washington, D.C.

Parties to the investigation were the FAA; Horizon Air, Inc.; deHavilland of Canada, Ltd.; the Port of Seattle, Washington; and the Association of Flight Attendants. A Canadian accredited representative from the Canadian Aviation Safety Board assisted in the investigation in accordance with International Civil Aviation Organization Annex 13, and representatives from Transport Canada and the Airline Pilots Association were assigned observer status.

2. Public Hearing

The Safety Board did not hold a public hearing on this accident.

APPENDIX B

PERSONNEL INFORMATION

Captain Carl Eric Carlson

Captain Carlson, 38, was hired by Air Oregon in June 1979. Air Oregon was subsequently absorbed by Horizon Air, and the captain was hired by that company on September 1, 1981. He held airline transport pilot certificate No. 1767092 with ratings for the SA-227, the DHC-8, airplane multiengine land, and commercial privileges for airplane single-engine land. At the time of the accident, he had accumulated approximately 9,328 total flying hours, 981 hours of which were in the DHC-8. He received his initial type rating in the DHC-8 on November 5, 1986. The captain's last line check was completed on September 5, 1987, and his last proficiency check was on October 5, 1987. The captain's last recurrent training was on October 30, 1987. His most recent first-class FAA medical certificate was issued on January 19, 1988, with the limitation, "Holder shall wear correcting lenses while exercising the privileges of his airman certificate."

First Officer Mark Raymond Hilstad

First Officer Hilstad, 35, was hired by Horizon Air on March 30, 1987. He held airline transport pilot certificate No. 548882459 with ratings for airplane multiengine land and commercial privileges for airplane single-engine land. He also held a flight instructor certificate for airplane single-engine and multiengine land which was valid until March 31, 1989, and an air traffic control specialist certificate. At the time of the accident, he had accumulated approximately 3,849 total flying hours, 642 hours of which were in the DHC-8. The first officer completed his initial proficiency check on May 7, 1987. His last recurrent training was accomplished on March 11, 1988. His most recent second-class FAA medical certificate was issued on January 12, 1988, with no limitations.

Flight Attendant Kimberly Walker

Flight Attendant Walker, 24, was hired by Horizon Air on March 9, 1987, after completing 56 hours of basic indoctrination, emergency training, and security training. She completed initial operating experience (5.2 hours) on the DHC8 on March 12, 1987, and was also qualified to serve on Fokker F-27 and Fokker F-28 airplane. Her most recent recurrent training occurred on March20, 1988.

APPENDIX C

AIRPLANE INFORMATION

The deHavilland of Canada DHC-8-102 was issued a U.S. type certificate under the bilateral provisions of Title 14 Code of Federal Regulations Part 21. It is equipped with two Pratt and Whitney PW120A engines and two Hamilton Standard 145F-7 propellers. N819PH, serial number 61, was manufactured on December 21, 1985, and acquired by Horizon Air on February 6, 1987.

The airplane had accumulated a total of about 3,106 flight hours and about 4,097 cycles at the time of the accident. The left engine, serial number 120215 had a total time of 3,106 hours and 4,097 cycles. It was an original installation on the airplane. The right engine, serial number 120078, had a total time of 3,886 hours and 4,948 cycles. It was installed on February 25, 1988.

APPENDIX D

DHC-8 ENGINE FIRE (IN FLIGHT) CHECKLIST

HORIZON AIR

The crew will also notify the tower or company of the nature of the emergency, and if a fire is indicated, request assistance before turning off the aircraft power. The hazards to passengers posed during an emergency evacuation are such that a Captain must carefully consider the given circumstances and indications prior to ordering this course of action.

ENGINE FIRE (IN FLIGHT)

1. POWER lever . . . . FLT IDLE.
2. Condition Lever . . . . FUEL OFF.
3. T-Handle. . . . . PULL.
4. TANK AUX PUMP switch. . . . . .OFF.
5. EXTINGUISHER switch . . . . .FWD BTL.
If fire persists - AFT BTL.

NOTE

If fire le extlnguiehed all engine fire warning lights will go out.

8. Complete ENGINE SHUTDOWN pmcedure.

NOTE

If, following selection of Condition Lever to FUEL OFF the propeller does not feather, ● elect appmprlete ALTERNATE FEATHER/UNFEATHER switch to RATHER.

HORIZON AIR

ENGINE FIRE (IN FLIGHT)
Procedure

PILOT FLYING	NON-FLYING PILOT
1. CALLS: 'NUMBER (1 or 2) POWER LEVER".	Places hand on correct Power Lever.
Verifies visually and calls, “FLT IDLE”.	Retards to FLT IDLE.

	PILOT FLYING	NON-FLYING PILOT
2.	"NUMBER (1 or 2) CONDITION LEVER".	Places hand on correct Conditio Lever.
	Verifies visually and calls, "FUEL OFF".	Retards to FUEL OFF.
3.	"NUMBER (1 or 2) T-HANDLE."	Places hand on correct T-Handle,
	Verifies visually and calls, "PULL".	Pulls T-Handle.
4.	"NUMBER (1 or 2) TANK AUX PUMP - OFF"	Selects correct Tank Aux Pump OFF.
5.	"EXTINGUISHER SWITCH-FND BTL"	Discharges extinguisher by selecting switch to FWD BTL.
	If fire persists - "AFT BTL'.	Discharges extinguisher by selecting switch to AFT BTL.
	Calls for ENGINE FIRE Checklist.	Reads all checklistitems and responses and checks that appropriate items have been accomplished.

APPENDIX E

COCKPIT VOICE RECORDER TRANSCRIPT

TRANSCRIPT OF A **SUNDSTRAND MODEL AV557-C** COCKPIT **VOICE RECORDER** S/N 9993 **REMOVED FROM** A HORIZON AIR **DEHAVILLAND DASH-8 AIRCRAFT WHICH** WAS INVOLVED IN AN ACCIDENT **AT SEATTLE'S SEATAC AIRPORT** ON APRIL 15, 1988.

CAM	**Cockpit • rea microphone voice or • ound source**
RDO	**Radio transmission from •** CCid8nt • ircreft
MIC	**Crewmember's** individual boom **microphone •** □♦□♍♏
PA	Aircraft **public address•** ⍓□♦♏❍
-1	Voice identified **as** Captain
-2	Voice identified **as** First Officer
-3	Voice identified as Flight Attendant
	Voice unidentified
TWR	SEATAC **Local** Control (Tower)
DEP	SEATAC ***Radar*** Departure Control
UNK	Unknovn
*	Unintelligible word
Q	Nonpertinent **vord**
#	Expletive deleted
%	Break in continuity
0	Questionable text
(())	Editorial insertion
-	**Pause**

NOTE : **All times** are **expressed** in Pacific Daylight Savings **time.** Only radio **transmissions** to and **from the accident** aircraft **were transcribed.**

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1823:50	*((start of transcript))*
1823:58 MIC-1	*okay speaker down -*
1824:00 HJC-2	**okay**
1824:01 MIC-1	*below the line*
1824:04 MIC-2	*controls*
1824:10 MIC-2	**ignition's manual** *bleeds off* **min** *chime's given controls* **are** *free transponder is on before takeoff Is complete*
1824:30 *CAM*	*(sound of one cabin chime))*

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT
1823: 52 *TYR*	*Horizon***airsixfifty ● ♦♑♒♦ taxi** *into* **position** *and* **hold runway** *on.* **six left** *be* **prepared** *to* **go right at** *sooa* **as** *traffic* **clears the runway please**
1823:56 RDO-2	*six fifty eight* **position***and bold*
1825:22 TWR	*Horizon six fifty* **eight leavin'** *one thousand* **feet** *tom loft* **heading** *one three zero runway* **one six left cleared** *for takeoff*

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	CONTENT
		1825:26 RDO-2	Horizon six fifty lg)rt out of a thousand left.one three zero cleared for takeoff
1825:30 MIC-1	cleared to go		
1825:32 CM	((sound of increasing propeller noise))		
1825:36 MIC-1	set the power		
1825:43 MIC-2	seventy		
1825:51 JtJC-2	rotate		
1825:56 nrc-2	positive rate		
1825:57 MIC-1	gear up		
1825:58 CM	((sound similar to landing gear being raised))		
1825:58 CAM	((sound of cabin chime))		
1826:06 PA-3	((start of flight attendents standard post departure cabin briefing))		

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	CONTENT
1826:11 MIC-1	*flaps* **upclimb** *power*		
1826:14 MIC-1	*and an after takeoff check*		
		1826:22 TWR	**Horizon six** *fifty* **eight** *contact departure good* **evening**
		1826:24 RDO-2	*six fifty* **eight** *thank you good day*
1826:25 CAM	*((sound of decreasing engine turbine noise))*		
1826:30 MIC-2	*uh oh* **we we just-**		
1826:31 MIC-1	*what* **was** *that*		
1826:33 CM	*((sound similar to* **fluctuating** *engine speed))*		
1826:38 MIC-1	*that's two* **okay** *okay let's take it this ray*		
1826:40 HJC-2	**okay**		
1826:41 MIC-1	**max power** *first*		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1826:42 NJC-2	we got max power
1826:43 MIC-1	okay just- okay help me watch the airspeed there
1826:46 MIC-1	okay go to let's see what we got here we got it still producing power there
1826: 49 MIC-2	we still got some power we don't have an up-trim we do not have an auto-feather
1826: 50 PA-3	((end of flight attendents briefing))
1826:53 MIC-1	okay
1826:54 MIC-1	okay let him know that we have to core back to the airport first bare
1826:58 MIC-2	okay

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT
1827:00 RDO-2	and tower Horizon six fifty eight we are going to have to return to the airport
1827:04 TWR	Horizon six fifty ● tglt roger you witb departure yet sir

APPENDIX m

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1827:11 MIC-1	okay it looks like ah right engine torque
1827:13 MIC-2	right engine torque
1827:14 MIC-1	okay let's just make sure that the sync's off there
1827:24 MIC-1	tell him we need to get back to the airport -tell him

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT
1827:06 RDO-2	ah negative sir
1827:07 TWR	contact departure control they'll bring you right back sir as soon as possible
1827:10 RDO-2	roger
1827:17 RDO-2	and departure Horizon six fifty eight
1827:20 DEP	Horizon six fifty eight radar contact out of two thousand turn left one zero zero climb and maintain one three thousand
1827:26 RDO-2	Horizon six fifty eight we have to return to the airport sir

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1828:23 MIC-1	*ah yeah standing by*
1828:28 MIC-2	*thirty seven thirty eight thirty nine forty*
1828:28 MIC-1	*forty*
1828:37 MIC-1	okay
1828:39 MIC-1	*have that checklist standing by let's da the ah ah appro- ah excuse* me *descent* check *followed by approach check we'll* just stand by cause we *still have an* engine running -- *it is* ah okay

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT
1828:24 RDO-2	*ah* affirmative
1828:25 DEP	alright *sir give* me - *if you get a chance* give me the *souls* on board and the estimated fuel remaining
1828:30 RDO-2	okay we *have forty persons on board an ah twenty eight* hundred *pounds of fuel*
1828:33 DEP	*twenty* eight *hundred* pounds *of* fuel *and forty persons* okay

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	CONTENT
1828:46 MIC-2	okay we still have an engine running okay approach check-		
1828:50 MIC-1	did you talk to her yet		
1828:51 MIC-2	J told her		
		1828:52 DEP	• towers got the info and ah there'll be jet traffic north of Boeing going to the right United seven twenty seven he'll probably beat you Jr contact tower one nineteen nine
1828:56 MIC-2	okay fl- flight instruments are set altimeters are two nine nine four set and cross checked ECU is top • ux pumps are on auto-feather is selected aux pumps are -one and two sync is off no smoke sign is -		
1829:08 CM	((sound of one cabin chime))		
1829:09 MIC-2	- on - approach check is complete and descent check is completed		
1829:13 MIC-1	props normal - okay we just lost torque but that's all		

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	CONTENT
		1827:30 MP	are you visual there sir
		1827:32 RDO-2	ah affirmative
		1827:33 DEP	okay turn- how about a left turn for the downwind left traffic runway one six left
		1827:36 RDO-2	okay left turn for left downwind one six left six fifty ● l*t
1827:39 MIC-1	okay we lost torque but the engine's still running--		
		DEP	• *
1827:42	((CVR recorder stopped and reversed direction))		
1827:44 MIC-1	- let it run		
1827:45 nrc-2	okay		
		1827:46 RDO-2	oh yes sir we have reduced power on the right engine it's still running though

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1827:51 MIC-1	*emergency checklist out*
1827:55 MIC-1	*okay* **did** *you tell him* **we** *want the* **trucks out**
1827:57 MIC-2	*oh 1 will*
1827:59 nrc-1	*okay do that*
1828:06 MIC-1	*okay let her know on the phone real* **quick that we're** *just* **goin'** *back nothing to he concerned about --just let her know*
1828:09 CAM	*((sound of cabin chime))*
1828:16 nrc-2	**yeah** *we* **are** *returning to the airport just* **to** *let you know*
1828: 19 MIC-1	*okay just torque loss looks like an 111 loss -*

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT
1827: 59 RDO-2	*and Horizon* **six fifty eight we'd like the equipment standing by**
1828:22 DEP	*Horizon sir* **fifty eight** *do you rant equipment*

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	CONTENT
PA-3	*((start of flight attendants cabin briefing)) ladies and gentlemen the flight deck has turned on the no smoking signs at this time,* **please** *extinguish all cigarettes thank you.*		
		1829: 16 MP	**six fifty ● ight nineteen nine**
1829: 17 MIC-2	*yeah and* **a** *lot of it*		
MIC-1	**okay**		
1829: 19 PA-3	*((End of flight* **attendents** *briefing))*		
		1829: 19 RDO-2	**six fifty eight switching**
		1829:21 RDO-2	[illegible] ● *b tower* **Horizon** *six fifty eight is on a left downwind for* **one** *six*
1829:28 MIC-1	*okay* **we** *got torque everything's running okay bare fuel flow's* **low** *though*		
		1829: 32 TWR	*Horizon six fifty* **eigh***t Seattle tower traffic* **just** *nortb o***f Boeing** *is* **a Boeing seven twenty seven for the right runway** *do you* **have him in sight**

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	CONTENT
		1829:37 RDO-2	negative
1829:38 MIC-1	just north of Boeing negative		
		1829:39 TWR	Horizon six fifty eight descend at your discretion cleared to land on runway one six left runway's open the wind is two four zero at eight
		1829:44 RDO-2	okay cleared to land one six left Horizon six fifty eight
1829:46 MIC-1	oh - okay let's analyze anything else okay just be standing by with feathers to the right engine's the bad one okay		
1829:51 MIC-2	okay		
1829:53 MIC-1	just in case he goes out on us but I'm gunna keep it runnin' if it's runnin' looks like we're not damaging anything so let it go on		
1829:55 MIC-2	if it's runnin' we -nope everything's lookin' good except for that torque--		

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	CONTENT
1829:59 MIC-1	okay approach approach check		
1830: 01 MIC-2	approach check is complete		
1830:02 MIC-1	okay we're cleared on the left correct		
1830:03 nrc-2	we're cleared to land		
1830:06 MIC-1	okay you've talked to tbe folks we got the trucks standing by		
1830:07 MIC-2	ah I've told ber ●		
		1830:10 TWR	Horizon six fifty eight that seven twenty seven traffic now ton o'clock tuo and a half miles south bound on final for the right
		1830:13 RDO-2	okay six fifty ● i@bt we're still looking for him
		1830:16 TWR	roger
1830:18 MIC-1	tell him we'll get the gear till were on base		

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	CONTENT
		1830:20 RDO-2	and six fifty eight we're gunna hol: the gear till we're about to turn final
1830:21 MIC-1	okay just a torque loss everything else looks normal okay		
1830:24 MIC-2	there he is		
1830:27 MIC-1	okay in sight		
		1830:28 RDO-2	and six fifty eight has the traffic in sight
1830:30 MIC-1	okay gear down -disregard disregard disregard hold on		
		1830:31 TWR	okay minimum separation caution wake turbulence runway one six -- ah left cleared to land
1830:33 MIC-2	we're too fast		
1830:34 MIC-1	yeah I'm just a little fast here		

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	CONTENT
		1830:36 RDO-2	six fifty eight cleared to land
1830:55 MIC-1	gear down lading check		
1830:56 CM	((sound of landing gear being lowered))		
1830:59 MIC-2	okay		
1831:03 MIC-2	we got a fire		
1831:04 MIC-1	okay		
1831:06 MIC-1	max power-okay		
		1831:08 UNK	you got a fire goin' on tbat airplane Horizon
1831:09 MC-1	okay flaps fifteen		
1831: 10 CM	((sound of cockpit chime))		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1831:11 MIC-1	*okay let's feather number okay number two back*
1831:15 MIC-1	okay
1831:17 MIC-1	*okay*
1831:21 MIC-1	*okay let's fire the* bottle
1831:23 MIC-2	*okay forward bottle's fired*
·1831:25 MIC-1	*okay fire* the *other bottle*
1831:26 PA-3	*((start of fligbt* • *ttendents emergency briefing))* ladies *and gentleman please if you are seated in* rows *one or* four *fasten your seat belts* low *and* tight and *grab your ankles if you are seated in* rows two three *five seven eight and nine put your bands* on the back *of your seat and* bend *forward* please thank *you*

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT
1831:15 UNK	• *b right wing right* engine *appears to* be burning
1831: 19 RDO-2	we know

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	CONTENT
1831:26 MIC-2	the other bottle's fired		
1831:30 MIC-1	okay hit the emergency thing		
1831:33 MIC-1	okay get the trucks standin' by there		
1831:38 MIC-1	okay is the other bottle fired		
1831: 39 MIC-2	both bottles are fired		
1831:41 MC-1	okay		
1831:43 MIC-1	gear's down		
1831:44 MC-2	gear is down but we don't have any ligbts ah- it appears to be down		
1831:45 PA-3	((end of flight attendents emergency briefing))		
1831:50 MIC-1	okay prepare to evacuate on the runway		

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	CONTENT
1831:53 CAM	((sound similar to touchdown)		
1831:53 MIC-2	bleeds are off		
1831:56 MIC-1	okay I can't steer this # at a		
		1831:57 RDO-2	we're out of control
1831:59 MIC-1	okay hang on		
1832:00 MIC-2	hang on		
1832:02 CAM	((sound of decreasing engine noise))		
1832:02 CAM	((sound similar to departure from hard runway surface))		
1832:05 MIC-1	**		
1832:06 CAM	((sound of bang))		
1832:10 MIC-1	I can't s3er this # at all		

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME & SOURCE	CONTENT
1832:13 MIC-2	you have no steering		
1832:14 MIC-1	okay		
1832:15 MIC-2	alright		
1832:17 MIC-1	please stand by we are going to hit somethin' here		
1832:19 MIC-2	want your's locked		
1832:20 MIC-1	yeah 1 don't have okay lock me up		
1832:21 MIC-2	you're locked in		
1832:23 MIC-1	#		
1832:25 MIC-1	okay hit the brakes we're gunna' hit this # here		
1832:27 MIC-1	okay		
1832:29 MIC-1	we'regunna' do okay here hang on		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
183[illegible]:31 CAM	((sound of impact))
1832:33	((end of recording))

AIR-GROUND COMMUNICATION

TIME & SOURCE	CONTENT

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