06/02/83 Air Canada

Official Accident Report Index Page

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Abstract

On June 2, 1983, Air Canada Flight 797, a McDonnell Douglas DC-9-32, of Canadian Registry C-FTLU, was a regularly scheduled international passenger flight from Dallas, Texas, to Montreal, Quebec, Canada, with an en route stop at Toronto, Ontario, Canada. The flight left Dallas with 5 crewmembers and 41 passengers on board. About 1903, eastern daylight time, while en route at flight level 330 (about 33,000 feet m.s.l.), the cabin crew discovered a fire in the aft lavatory. After contacting air traffic control (ATC) and declaring an emergency, the crew made an emergency descent, and ATC vectored Flight 797 to the Greater Cincinnati International Airport, Covington, Kentucky.

At 1920:09, eastern daylight time, Flight 797 landed on runway 27L at the Greater Cincinnati International Airport. As the pilot stopped the airplane, the airport fire department, which had been alerted by the tower of the fire on board the incoming plane, was in place and began firefighting operations. Also, as soon as the airplane stopped, the flight attendants and passengers opened the left and right forward doors, the left forward overwing exit, and the forward and aft right overwing exits. About 60 to 90 seconds after the exits were opened, a flash fire

enveloped the airplane interior. While 18 passengers and 3 flight attendants exited through the forward doors and slides and the three overwing exits to to evacuate the airplane, the captain and first officer exited through their respective cockpit sliding windows. However, 23 passengers were not able to get out of the plane and died in the fire. The airplane was destroyed.

On August 8, 1984, the National Transportation Safety Board adopted the report and probable cause of the accident. On December 20, 1984, the Air Line Pilots Association submitted a petition for reconsideration of the contributing factors statement of the probable cause that was adopted in the original report. As a result of the Air Line Pilots Association's petition, the accident report and the probable cause have been revised.

The National Transportation Safety Board determines that the probable causes of the accident were a fire of undetermined origin, an underestimate of fire severity, and misleading fire progress information provided to the captain.

The time taken to evaluate the nature of the fire and to decide to initiate an emergency descent contributed to the severity of the accident.

Facts of the Accident

Accident NTSB ID	86-02
Airline	Air Canada
Model aircraft	DC-9-32, C-FTLU
Year shipped	1968
Aircraft manufacturer	McDonnell Douglas
Engine type	JT8D17B
Engine manuafacturer	Pratt & Whitney
Date	06/02/83
Time	1920
Location	Greater Cincinnati International Airport, Covington, KY
Country	USA
Fatalities	23
Injuries	16
Fire during flight?	Y
Fire on the ground?	Y
Probable cause	A fire of undetermined origin, an underestimate of fire severity, and misleading fire progress information provided to the captain.
Contributing causes	The time taken to evaluate the nature of the fire and to decide to initiate an emergency descent contributed to the severity of the accident.
Weather conditions	Visibility 12 miles, light rain
Total crew size	5
Cockpit crew size	2
Cabin crew size	3
Passengers	41
Report ID	NTSB/AAR-86/02 (supersedes 84-09)
Pages	116
Day or night?	Evening
Flight number	797
Flight origin	Dallas, TX
Flight destination	Montreal, Quebec, Canada
Description	After a fire was discovered in the aft lavatory, the aircraft made an emergency landing at the Cincinnati Airport. Sixty to ninety seconds after the exits were opened, a flash fire enveloped the interior of the aircraft, taking the lives of 23 passengers.

Synopsis

On June 2, 1983, Air Canada Flight 797, a McDonnell Douglas DC-9-32, of Canadian Registry C-FTLU, was a regularly scheduled international passenger flight from Dallas, Texas, to Montreal, Quebec, Canada, with an en route stop at Toronto, Ontario, Canada. The flight left Dallas with 5 crewmembers and 41 passengers on board.

About 1903, eastern daylight time, while en route at flight level 330 (about 33,000 feet m.s.l.), the cabin crew discovered smoke in the left aft lavatory. After attempting to extinguish the hidden fire and then contacting air traffic control (ATC) and declaring an emergency, the crew made an emergency descent and ATC vectored Flight 797 to the Greater Cincinnati International Airport, Covington, Kentucky.

At 1920:09, eastern daylight time, Flight 797 landed on runway 27L at the Greater Cincinnati International Airport. As the pilot stopped the airplane, the airport fire department, which had been alerted by the tower to the fire on board the incoming plane, was in place and began firefighting operations. Also, as soon as the airplane stopped, the flight attendants and passengers opened the left and right forward doors, the left forward overwing exit, and the right forward and aft overwing exits. About 60 to 90 seconds after the exits were opened, a flash fire engulfed the airplane interior. While 18 passengers and 3 flight attendants exited through the forward doors and slides and the three open overwing exits to evacuate the airplane, the captain and first officer exited through their respective cockpit sliding windows. However, 23 passengers were not able to get out of the plane and died in the fire. The airplane was destroyed.

The National Transportation Safety Board determines that the probable causes of the accident were a fire of undetermined origin, an underestimate of fire severity, and misleading fire progress information provided to the captain.

The time taken to evaluate the nature of the fire and to decide to initiate an emergency descent contributed to the severity of the accident.

1. Factual Information

1.1 History of the Flight

The in-flight fire

On June 2, 1983, Air Canada Flight 797, a McDonnell Douglas DC-9-32, of Canadian Registry C-FTLU, was a regularly scheduled international passenger flight from Dallas, Texas, to Montreal, Quebec, Canada, with an en route stop at Toronto, Ontario, Canada.

At 1625 central daylight time, Flight 797 left Dallas with 5 crewmembers and 41 passengers on board and climbed to its assigned en route altitude, flight level (FL) 330 (approximately 33,000 feet m.s.l.).1 According to the captain, about 30 minutes after departure, a 30-inch-long by 9-inch-wide louvered panel at the bottom of the cockpit door was kicked accidentally from its mounts and fell to the floor. The panel was placed to one side and the flight continued. Except for a deviation to the south of their filed flight plan route to avoid weather, the flight progressed without incident until it entered the Indianapolis Air Route Traffic Control Center's (ARTCC) airspace.

At 1851:14 eastern daylight time2, the three circuit breakers associated with the aft lavatory's flush motor and located on a panel on the cockpit wall behind the captain's seat, tripped in rapid succession. (The motor is a three-phase alternating current (a.c.) motor; each phase incorporates a circuit breaker for protective purposes.) After identifying the circuit breakers, the captain immediately made one attempt to reset them; the circuit breakers would not reset. The captain assumed that the flush motor had probably seized and took no further action at this time. About 1859:58, the captain again tried unsuccessfully to reset the three circuit breakers. According to the cockpit voice recorder (CVR), he told the first officer that the circuit breaker(s), "Pops as I push it."

About 1900, a passenger seated in the last row asked the No. 3 flight attendant3 to identify a strange odor. The flight attendant thought the odor was coming from the aft lavatory. She took a CO_2 fire extinguisher from the cabin wall and opened the lavatory door a few inches. She saw that a light gray smoke had filled the lavatory from the floor to the ceiling, but she saw no flames. While she was inspecting the lavatory, she inhaled some smoke and closed the door. The No. 3 flight attendant then saw the No. 2 flight attendant nearby and asked her to tell the flight attendant in charge of the situation. The No. 2 flight attendant testified that she did not remember if she had been told there was smoke or fire in the lavatory; however, when she reached the flight attendant in charge she told him that there was a fire in the lavatory.

Upon being advised there was a fire, the flight attendant in charge instructed the No. 2 flight attendant to inform the captain and then to assist the No. 3 flight attendant in moving the passengers forward and in opening the eyebrow air vents over the passenger seats to direct air to the rear of the cabin. The flight attendant in charge then took the CO_2 extinguisher and opened the lavatory door about three-quarters open. He also saw no flames, but he observed thick curls of black smoke coming out of the seams of the aft lavatory walls at the top of the wash basin behind the vanity and at the ceiling. He then proceeded "to saturate the washroom with CO_2," by spraying the paneling and the seam from which smoke was seeping and spraying the door of the trash bin. He then closed the lavatory door.

At 1902:40, the No. 2 flight attendant reached the cockpit and told the captain, "Excuse me, there's a fire in the washroom in the back, they're just...went back to go to put it out." Upon being notified of the fire, the captain ordered the first officer to inspect the lavatory. The captain then donned his oxygen mask and selected the 100-percent oxygen position on his regulator. The first officer left the cockpit but did not take either smoke goggles or a portable oxygen bottle with him. (The airplane was not equipped with nor was it required to be equipped with self-contained breathing equipment or a full face smoke mask.) The first officer said that he could not get to the aft lavatory because the smoke, which had migrated over the last three to four rows of seats, was too thick. The flight attendant in charge told the first officer what he had seen when he opened the lavatory door, that he had discharged the CO_2 extinguisher into the lavatory, and that he had not been able to see the source of the smoke before closing the door. He told the first officer, however, that he did not believe the fire was in the lavatory's trash container. The first officer told the flight attendant in charge that he was going forward to get smoke goggles.

At 1904:07, the first officer returned to the cockpit and told the captain that the smoke had prevented him from entering the aft lavatory and that he thought "we'd better go down." He did not tell the captain that the flight attendant in charge had told him that the fire was not in the trash bin. However, at 1904:16, before the captain could respond, the flight attendant in charge came to the cockpit and told the captain that the passengers had been moved forward and that the captain didn't "have to worry, I think its gonna be easing up." The first officer looked back into the cabin and said that it was almost clear in the back. At 1904:23, he told the captain, "it's starting to clear now," and that he would go aft again if the captain wanted him to do so. According to the captain, the first officer's smoke goggles were stored in a bin on the right side of the cockpit and were not easily accessible to the first officer while he was not in his seat. Since the first officer needed the goggles and since there was a hurry, the captain gave him his goggles and, at 1904:46, directed him to go aft. The first officer also testified that the captain and he "did not discuss the type of fire at all" during the time he was in the cockpit before he went to the lavatory the second time.

At 1906:52, while the first officer was out of the cockpit, the flight attendant in charge told the captain again that the smoke was clearing. The captain testified that he believed the fire was in the lavatory trash bin and that he did not decide to descend at this time because, "I expected it (the fire) to be put out."

In the meanwhile, the first officer proceeded to the aft lavatory and put on the smoke goggles. He testified that he had intended to open the door to see what the situation was inside, but when he discovered that the lavatory door felt hot to the touch, he decided not to open it and instructed the cabin crew to leave it closed. At that time, he noticed a flight attendant signaling him to hurry back to the cockpit. The first officer returned to the cockpit and got into his seat, and at 1907:11, he told the captain, "I don't like what's happening, I think we better go down, okay?" The captain testified that, from the first officer's voice inflection, he knew that the first officer believed the fire was out of control and that he had to descend immediately.

About 1905:35, while the first officer was aft to inspect the aft lavatory, the airplane had experienced a series of electrical malfunctions. According to the captain, the master caution light illuminated, indicating that the airplane's left a.c. and d.c. electrical systems had lost power. At 1906:12, the captain called Indianapolis Center and requested the Center to standby because the flight had an "electrical problem." About 30 to 45 seconds later, the Louisville high radar sector controller working Flight 797 lost the flight's radar beacon target. The controller then directed the computer to track all primary targets. Flight 797's position was then depicted on the scope by a plus sign and associated data block.

About 1907:41, after the first officer had returned to the cockpit, the master warning light illuminated and the annunciator lights indicated that the emergency a.c. and d.c. electrical buses had lost power. The captain's and first officer's attitude directional indicators tumbled. The captain ordered the first officer to activate the emergency power switch, thereby directing battery power to the emergency a.c. and d.c. buses. The attitude directional indicators' gyros began erecting, however, because of the loss of a.c. power, the stabilizer trim was inoperative and remained so during the rest of the flight.

The descent

At the Air Traffic Control Facilities.—At 1908:12, Flight 797 called the radar high sector controller at Indianapolis Center and said, "Mayday, Mayday, Mayday."4 The Louisville radar high sector controller acknowledged the call, and at 1908:47, the flight told the controller that it had a fire and was going down. The controller told the flight that it was 25 nautical miles (nmi) from Cincinnati and asked "can you possibly make Cincinnati." The flight answered that it could make Cincinnati and then requested clearance; it was then cleared to descend to 5,000 feet. At 1909:05, Flight 797 reported that it was leaving FL 330. The flight then told the controller that it needed to be vectored toward Cincinnati, that it was declaring an emergency, and that it had changed its transponder code to 7700 -- the emergency code. However, the transponder was inoperative due to the power loss, and the emergency code was never portrayed on the Center's radarscopes. At 1909:29, the Louisville radar high sector controller directed the flight to turn to 060° and told it that the Greater Cincinnati Airport (Cincinnati Airport) was at "twelve o'clock at twenty miles." The controller said that it was obvious to him that Flight 797 had to descend "immediately;" therefore, he issued the clearance and stated that he was going to coordinate the descent with the other sectors at the center later. He further stated that the 060° heading was intended to place the flight on course toward Cincinnati Airport. He heard Flight 797 report leaving FL 330; however, because of the inoperative transponder, mode C altitude information was no longer being received and there was no indication on his radarscope that the flight was descending.

At 1909:17, Indianapolis Center's Lexington low altitude D (LEX-D) controller called the approach controller at the Cincinnati Airport's Terminal Radar Control (TRACON) facility to alert him of an impending handoff in his southwest sector. Six seconds later, the LEX-D controller told the approach controller at Cincinnati he had a "code for you," and at 1909:25, the LEX-D controller then told the Cincinnati approach controller that he had "an emergency for you, Air Canada seven nine seven." The approach controller replied, "Zero six six two, thirty-five thousand." Zero six six two was the code assigned to Continental 383, a westbound flight at FL 350. At 1909:33, the LEX-D controller answered, "Yeah, thirty-three right now, he's twenty-five southwest." The approach controller replied, "Radar contact, okay." However, at 1909:38 when the approach controller accepted the handoff of Flight 797, he had mistaken the radar beacon target of Continental Flight 383 as that of Flight 797. Shortly after he had accepted the handoff, the approach controller had notified the Cincinnati Airport tower local controller that he intended to land an Air Canada jet with an on board fire on runway 36. The tower's local controller alerted the airport fire station, and crash-fire-rescue (CFR) vehicles were dispatched and positioned for an emergency landing. The firefighters had also been advised that the airplane had electrical problems, that smoke was coming from the aft lavatory, and that there was smoke or fire in the rear of the airplane. At 1910:01, almost coincident with the end of his message to the local controller, the LEX-D controller informed the approach controller of Flight 797's assigned 060° heading. Although the approach controller repeated the heading, he stated that he could not recall hearing this message.

At 1910:25, Flight 797 contacted the Cincinnati approach controller, declared an emergency, and said that it was descending. The approach controller acknowledged and told the flight to plan for a runway 36 instrument landing system (ILS) approach and requested the flight to turn right to 090°. He then realized the target he was observing was not responding and attempted unsuccessfully to assign a discrete transponder code to it in order to track it better. Thereafter, at 1910:48, Flight 797 reported that it had a fire in its aft lavatory and that the cabin was filling with smoke. The controller asked the flight to "say the type airplane, number of people on board, and amount of fuel (on board)." The first officer answered that he would supply this data later because "I don't have time now."

At 1912:40, the approach controller called the Evansville/Nabb D controller on the landline to request assistance. Almost simultaneous with the call, he also observed an eastbound primary target and began to monitor it. At 1912:44, the flight requested the cloud ceiling at the airport and the controller responded that the ceiling was "two thousand five hundred scattered, measure(d) eight thousand feet overcast, visibility one two (12) miles with light rain." The controller then decided that the eastbound target was Flight 797, and at 1912:54, he requested the flight to "say altitude." The approach controller said that, by 1912:54, he knew that he was observing Flight 797's primary target, but that it was not "fully identified." He also knew, based on the target's position -- about 3 nmi east of runway 36's extended centerline and about 8 nmi south of its threshold -- and its reported altitude of 8,000 feet, that it was too high and too fast to land on runway 36. He decided to use runway 27L for landing, and used the primary target to monitor the flight and vector it toward the airport.

At 1913:38, after Flight 797 was unable to tell him its heading because its heading instruments were inoperative, the approach controller asked the flight to turn left. The controller said that this was an identification turn and that it was also designed to place the airplane closer to the airport. At 1914:03, after observing the target in a left turn, the approach controller said that Flight 797's primary target was now "fully identified." He then told the flight that this was a "no gyro"5 radar approach for runway two seven left..." and cleared it to descend to 3,500 feet. He then told the flight that it was 12 nmi southeast of the Cincinnati Airport, cleared it to land on runway 27L, and informed it that the surface wind was 220° at 4 knots. He informed the tower of the change of landing runways and the tower directed the fire department to position its vehicles along runway 27L.(See figure 1.)

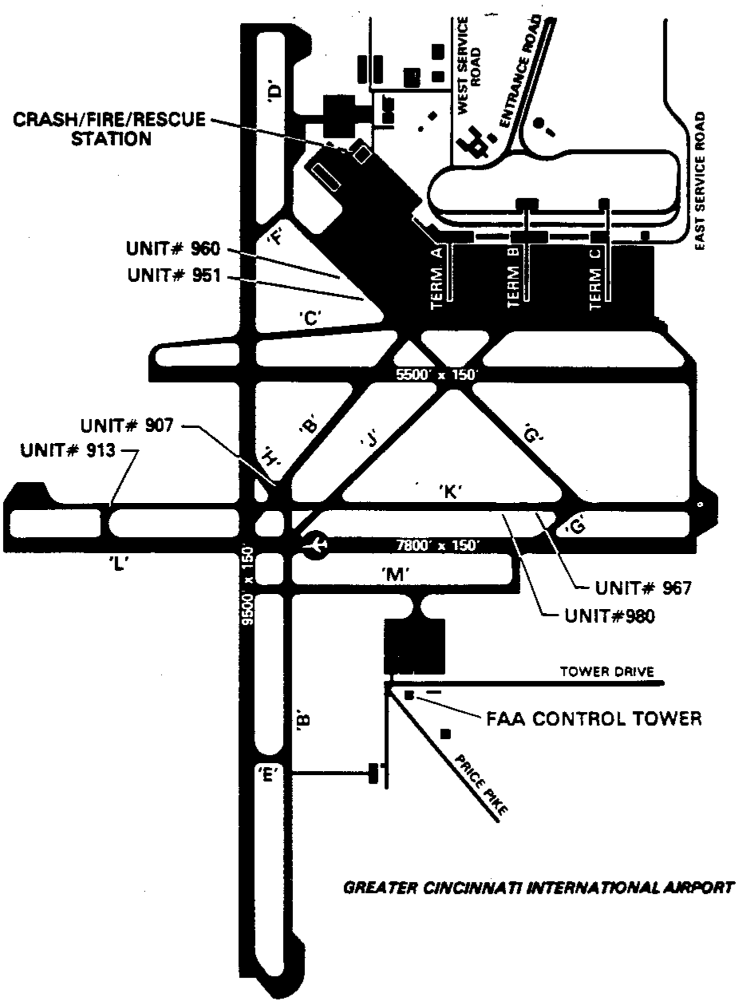

Figure 1.—Standby Positions of Crash/Fire/Rescue Units.

At 1915:11, Flight 797 reported that it was level at 2,500 feet, and at 1915:27, that it was "VFR [visual flight rules] now...." The approach controller vectored the flight to runway 27L, and at 1915:58, told it that it was 12 nmi from the airport. The flight descended to 2,000 feet, and the controller continued to supply range calls.

At 1917:11, the controller told the flight that the crash-fire-rescue vehicles were standing by and again asked the flight to provide the number of persons and the amount of fuel on board. Flight 797 answered, "We don't have time, its getting worse here."

At 1917:24, the runway and approach lights were turned up to full intensity. At 1917:35, Flight 797 reported the airport in sight; the approach controller cleared it to land, and told it that the surface wind was 230° at 4 knots. At 1918:48, the approach controller told the flight that it was 3 nmi from the airport and then asked the tower local controller if she had the airplane in sight. The local controller said that she did. After telling Flight 797 that it was 2 nmi from the airport, the approach controller asked the local controller to tell him when Flight 797 had landed. At 1920:09, the local controller told the approach controller, "He's landed."

On the airplane.—As the airplane descended, the smoke front continuously moved forward filling the passenger cabin and entering the cockpit. The first officer had left the captain's smoke goggles in the aft end of the airplane. Therefore, after he returned to the cockpit, he gave one of the two pairs of smoke goggles stowed on the right cockpit wall to the captain. (See appendix F.) Although there was another pair available, the first officer chose not to use them. The captain donned the smoke goggles and wore them during the descent and landing. The captain said that during the descent, he wore his oxygen mask and the oxygen regulator was set to the 100-percent position; therefore, he had no trouble breathing. However, during the latter stages of the approach and landing, he had difficulty seeing the instruments because of the smoke in the cockpit and had to lean forward to do so. He testified that his perspiration was causing his smoke goggles to steam up and he had to pull them away from his face from time to time to clear them. The first officer also wore his oxygen mask during the descent and set his oxygen system regulator to the 100-percent position and encountered no trouble in breathing.

The captain began the emergency descent almost simultaneously with the "Mayday" call. The throttles were retarded to idle and the speed brakes were extended. However, when the speed brakes were deployed, the spoiler/speed brake handle was moved inadvertently to the full aft position and the spoiler panels were deployed to the full-up or ground position. The captain testified that this had no effect on the airspeed during the descent but it increased the descent rate. The descent was flown at 310 knots indicated airspeed (KIAS), and since the needle on the instantaneous vertical speed indicator (IVSI) was pegged, the rate of descent exceeded 6,000 feet per minute (fpm).

According to the flightcrew, Flight 797 was operating in visual meteorological conditions before the emergency descent. The captain said that the airplane was almost totally in clouds from about FL 250 to about 3,000 feet; however, it did not encounter either turbulence or icing. At leveloff at 3,000 feet, the airplane was in and out of the cloud bases so he descended to 2,000 feet to obtain VFR flight conditions. According to the flightcrew, except for the cloud conditions at 3,000 feet, the emergency descent and landing were not affected by weather.

The cockpit door was left open throughout the descent. The captain testified that he did not remember the door's being open and that he did not order it opened.

During the initial stages of the descent, the cabin crew completed moving the passengers forward of row 13. They briefed them on the emergency evacuation procedures and passed out wet napkins until instructed by the first officer to sit down. They also designated passengers to open the overwing exits and briefed them on opening them; they then prepared them for the landing.

After the initial level off at 3,000 feet, the captain ordered the first officer to depressurize the airplane in preparation for landing. The first officer complied, and although it is not required by the emergency procedure checklist, he turned the air conditioning and pressurization packs off. He testified that although he knew this was not required by procedure, he did so "because the smoke was getting bad at that point and my reasoning was I have to do something...." He said that he thought the packs were feeding the fire. A few moments afterward, he opened his sliding window in an effort to clear the smoke from the cockpit, but closed it almost immediately because of the high noise level. The first officer opened and closed the window several times during the final stage of the flight.

The landing

When the captain sighted the runway, he extended the landing gear. Since the horizontal stabilizer was inoperative, the captain extended the flaps and slats incrementally through the 0°, 5°, 15°, 25°, and 40° positions. He allowed his indicated airspeed to stabilize at each flap position as he slowed to approach speed. He flew the final approach at 140 KIAS and completed the landing. After touchdown, he made a maximum effort stop (using extended spoilers and full brakes). Because of the loss of the left and right a.c. buses, the antiskid system was inoperative and the four main wheel tires blew out. The airplane was stopped just short of the intersection of taxiway J.(See figure 1.) After the captain completed the emergency engine shutdown checklist, both he and the first officer attempted to go back into the cabin and assist in the passenger evacuation, but were driven back by the smoke and heat. Thereafter, they exited the airplane through their respective cockpit sliding windows.

After the airplane stopped, the left (L-1) and right (R-1) forward cabin doors, the left forward (L-2) overwing exit, and the right forward (R-2) and aft (R-3) overwing exits were opened, and the slides at the L-1 and R-1 doors were deployed and inflated. The 3 cabin attendants and 18 passengers used these 5 exits to evacuate the airplane.

After the 18 passengers and 5 crewmembers left the airplane, the cabin interior burst into flames. Twenty-three passengers perished in the fire. Neither the passengers, crew, nor witnesses outside of the airplane saw flames inside the cabin before the survivors left the plane. The fuselage and passenger cabin were gutted before airport fire personnel could extinguish the fire.(See figure 2.)

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others	Total
Fatal	0	23	0	23
Serious	0	3	0	3
Minor	0	13	0	13
None	5	2	0	7
Total	5	41	0	46

Figure 2.—Airplane after fire burned through top of fuselage.

1.3 Damage to Airplane

The airplane was destroyed by fire.

1.4 Other Damage

None.

1.5 Personnel Information

The flightcrew were certificated and the flight attendants were qualified in accordance with current Canadian regulations. (See appendix B.) Air traffic control (ATC) controllers were qualified in accordance with current United States regulations.

1.6 Airplane Information

The airplane, a McDonnell Douglas DC-9-32, Canadian registry C-FTLU, was owned and operated by Air Canada, a Canadian Crown corporation. The airplane was manufactured on April 7, 1968, and had been operated by Air Canada since delivery to the company at that time. (See appendix C.)

On September 17, 1979, the airplane experienced an in-flight failure of its aft pressure bulkhead shortly after takeoff from Logan International Airport, Boston, Massachusetts.6 The separation and ensuing depressurization occurred shortly after the airplane had leveled off at FL 250. At the time of the Logan accident, the airplane had flown about 28,425 hours and had completed 26,816 landings. The damage to the aft part of the airplane was extensive. There was disruption of some engine and flight control components. Except for severed flight data recorder connections, no damage was found on any electrical components, wires, and cables examined during the investigation. However, in effecting repairs, numerous wire bundles were cut in order to examine the airplane and to facilitate the removal of damaged structure and reinstallation of replacement structure. Repairs to the airplane were made by McDonnell Douglas and inspected by Air Canada under its authority as a Canadian Ministry of Transport (MOT) approved company. The aft pressure bulkhead and aft accessory compartment were rebuilt at Logan Airport between September 18, 1979, and November 20, 1979. The installation of the aft lavatories and interior furnishings was made by Air Canada at their Dorval Base in Montreal. Air Canada and McDonnell Douglas each wrote engineering reports on repairs to the airplane. An FAA Form 337, which was part of the Air Canada report7, listed 29 individual repair items. Item 3 of this list stated, "Spliced electrical wires through aft pressure bulkhead per service sketch 2958." The sketch designated where the splices were to be made and the manner in which they were to be made. In addition, the Air Canada report stated that the contractual agreement required "that the repairs be carried out to restore the aircraft to condition substantially conforming to specification for the airplane as originally delivered." The airplane was returned to service December 1, 1979.

During the investigation of the Cincinnati accident, all of the wire splices made during the repairs at Logan which were found and not destroyed were examined. No evidence of arcing or short circuiting was found.

1.6.1 Flight and Cabin Maintenance Logbook Writeups

Between June 1, 1982, and June 2, 1983, 76 writeups were entered in the airplane flight log concerning the two engine-driven generators and the auxiliary power unit (APU) generator. One writeup concerned the right engine-driven generator; 6 writeups concerned the left engine-driven generator; 34 concerned the APU generator; and 35 concerned crosstie relay lockout malfunctions. Of the 35 writeups relating to the crosstie relay lockout, only 1 — on December 30, 1982 — described an accompanying generator malfunction. The last crosstie relay lockout malfunction occurred on March 18, 1983.

The seven writeups on the engine-driven generators concerned the generators' tripping off line. On August 1, 1982, the right generator tripped and was reset by the flightcrew; on August 2, the right generator's voltage regulator was replaced. The six left generator malfunctions occurred between December 28, 1982, and January 4, 1983. On January 4, 1983, the left generator control panel was removed and replaced and thereafter the generator operated without further problems. A shop check of the removed control panel disclosed a bad solder connection between circuits on the under frequency protection printed circuit board.

Between May 7, 1983, and June 2, 1983, the flightcrews logged 38 APU generator malfunctions; during this period there were no engine-driven generator malfunctions logged. Thirty-four writeups indicated that the APU generator would not come on line; four indicated that the generator had tripped from the line. The examination of the flight log showed that corrective action had been taken for these entries. Except in an electrical emergency, the APU generator is not used in flight. Flight 797's flightcrew did not try to start the APU generator during the flight from Dallas to Cincinnati.

Between September 1, 1980, and June 2, 1983, the cabin logbook entries indicated only minor deficiencies in the toilet pump flushing system and routine flush pump and flush motor changes; all were signed off properly with no out-of-the-ordinary repairs having been made. The last flush system component change was made on May 4, 1983; the pump assembly was replaced and the repair signed off by a mechanic and an inspector.

On May 2, 1983, during a scheduled major maintenance check, an unscheduled work card -- No. 150 -- contained the following writeup, "Insulation at bottom of pressure bulkhead in rear cargo (compartment) soaked with toilet detergent liquid, investigate leak." The item was signed off, as follows, "Connectors checked and tightened. Also, insulation replaced where needed."

1.6.2 Passenger Cabin Modification

During June 1982, Air Canada refurbished the airplane's passenger cabin. The right aft lavatory was removed and replaced with a clothing stowage area. Overhead luggage bins were installed and the cabin walls and ceilings were replaced. The modification was performed using an assembly kit manufactured by the Heath Tecna Corporation, Kent, Washington, in accordance with the provision of Supplemental Type Certificate (STC) No. 1429 NM, issued by the FAA Northwest Regional Headquarters, Seattle, Washington, on February 2, 1982.

Since the Heath Tecna assembly kit was designed to be used on all DC-9-32 airplanes, Heath Tecna had to apply for and received an STC. The materials, drawings, and plans contained in the assembly kit constituted a major overhaul of the airplane's interior. Since the DC-9-32 airplanes had been certificated before May 1, 1972, the manufacturer had to demonstrate that materials met the flammability standards of 14 CFR 25.853 (a) (b) as amended on May 1, 1972, in order to receive an STC; these standards still apply. (See appendix E.) The flammability tests were conducted in accordance with prescribed FAA standards, and all materials in the kit met the flammability standards. In addition, all wiring used in the kit met MIL W-81044 specifications previously approved by the FAA.

At the time of the accident, the airplane's seat cushion material was polyurethane foam, the window panes were transparent acrylic sheet, the interior cabin side walls were made of acrylonite butadiene styrene (ABS) plastic sheet, the ceiling panels were made of composite nomex honeycomb core with fiberglass facing materials, and the cabin sidewalls and ceiling panel facings were decorative vinyl laminate with Tedlar facings.

1.7 Meteorological Information

The 1700 National Weather Service (NWS) surface analysis for June 2, 1983, showed a west to east warm front in central Kentucky. At 2000, the analysis showed a warm front extending from southern Ohio through western Kentucky with associated rain and rainshowers.

Weather radar data from the Cincinnati Airport for 1830 and for 1930 indicated weather echoes containing rainshowers. These echoes were located south through west of Cincinnati Airport and extended out to about 100 nmi. The maximum echo tops were reported at 14,000 feet at 1830; at 1930, the tops were reported at 13,000 feet. According to the NWS, light rain began at the airport at 1734 and ended at 2024. Between 1900 and 2000, a trace (less than 0.01 inch) of rain was measured.

Surface weather observations for the Cincinnati Airport were as follows, for the times indicated:

1850 - 2,500 feet scattered, measured ceiling 8,000 feet overcast; visibility -- 12 miles, light rain; temperature -- 63° F; dewpoint -- 55° F; wind -- 190° at 7 knots; altimeter setting -- 30.04 inHg.

1930 - 2,500 feet scattered, estimated ceiling 8,000 feet overcast; visibility -- 12 miles, light rain; temperature -- 62° F; dewpoint -- 55° F; wind 180° at 5 knots; altimeter setting -- 30.03 inHg.

1.8 Aids to Navigation

Not applicable.

1.9 Communications

There were no known radio communications difficulties.

1.10 Aerodrome Information

The Greater Cincinnati International Airport, elevation 891 feet, is located 9 miles southwest of Cincinnati, Ohio, in Covington, Kentucky. The airport is certificated for commercial operations in accordance with 14 CFR 139, Subpart D.

The landing area consists of three runways: 18/36, 9R/27L, and 9L/27R. Runway 27L is 7,800 feet long and 150 feet wide, and has a grooved concrete and asphalt surface. Runway 27L has high intensity runway edge lights (HIRL), centerline lights, a medium intensity approach light system with runway alignment indicator lights (MALSR), and visual approach slope indicator (VASI-L). The touchdown zone elevation is 875 feet. Runway 27L is served by an ILS approach.

Standiford Field, elevation 497 feet, is 5 miles south of Louisville, Kentucky. The airport is certificated for commercial operations in accordance with 14 CFR 139, Subpart D. The landing area consists of two runways: 1-19 and 11-29. Runway 1-19 is 7,800 feet long and 150 feet wide, and has a concrete surface, HIRL, and an approach light system. Runway 11-29 is 7,429 feet long and 150 feet wide, and has an asphalt surface, HIRL, and runway end indicator lights (REIL). Runway 29 has an approach light system; runway 11 has a VASI, but no approach lights. Runways 11 and 19 are served by an ILS approach; runway 11 is served by a localizer (back course) approach.

1.11 Flight Recorders

The airplane was equipped with a Leigh VDR-2 digital flight data recorder (DFDR), serial No. 127, and a Fairchild A-100 cockpit voice recorder (CVR), serial No. 1613. Both recorders were removed from the airplane after the accident. The CVR was brought to the Safety Board's Audio Laboratory for processing and readout. Since the Safety Board's Washington laboratory is not equipped to readout the Leigh DFDR, the readout was performed at the Flight Research Laboratory, National Research Council (NRC), Ottawa, Ontario, Canada, and was observed by Safety Board personnel.

Cockpit Voice Recorder.--The CVR casing was damaged by fire and smoke; however, the crash-proof enclosure protected the tape and the quality of the recording was excellent. A tape was transcribed beginning at 1848:12 and ending at 1907:41 when the CVR ceased operating. Using the time signal recorded on the FAA's Indianapolis ARTCC's tape as a basis for comparison, the CVR tape timing was accurate to the second. (See appendix D.)

The entire CVR tape was examined for sounds of electrical arcing or other events which might be associated with the accident. About 10 minutes into the tape, at 1848:12, a sound resembling that of electrical arcing was recorded. The sound was repeated at 1848:15, 1851:03, 1851:05, 1851:14, 1851:42, 1859:59, and 1900. The crewmembers testified that they did not hear arcing sounds at these times.

The sprectral content of the first two electrical arcing sounds differed from those which followed. The early sounds were impulse-type and contained a broad band of frequencies resembling radio static. All of the later arcing sounds contained a 400 Hz component with harmonics extending through the frequency range of the recorder.

At 1905:35, an electrical pulse was recorded simultaneously on both the captain's and first officer's radio channels. The pulse, which lasted about 7 milliseconds, occurred about the time the captain said that the left a.c. bus was lost. Signals from the radio channels are taken from the captain's and first officer's audio selector panels.

Flight Data Recorder.--The recording medium of the Leigh DFDR is a 1/2-inch, continuous loop, 7-track magnetic tape. A total of 33.5 hours of data encompassing 76 airplane performance parameters are recorded. The recorder, which was not damaged, was opened at the NRC flight recorder laboratory; the tape was removed and then wound on a standard computer-tape reel. The accident flight was identified both by the recorded flight number and by tracing the altitude and heading time histories from the takeoff at Dallas. The data showed that the recorder stopped operating 1 hour 42 minutes into the flight while the airplane was at FL330.

The DFDR recording contained several anomalies that took the form of signal spikes or data losses in a number of recorded parameters. These anomalies were used to establish a correlation between the CVR and DFDR times. Since the DFDR did not contain microphone keying information, it was necessary to identify events that were common to both recorders. The DFDR anomalies were examined and charted together with the electrical signals which had been recorded on the CVR channels. The time increments between the specific events, as recorded on the CVR and DFDR, were compared and a correlation established. From this information, it was determined that the DFDR also stopped recording at 1907:41.

1.12 Wreckage and Impact Information

Both engines and their associated cowlings were intact, undamaged, and showed no evidence of exposure to abnormal heat or fire. There was no evidence of oil or fuel leakage, and the main engine fuel supply system did not leak when pressure tested. The engine fire extinguisher bottles had been discharged.

The APU was intact and was not damaged. The exterior of the APU and surrounding compartment were free of soot and other fire damage. The APU enclosure within the aft accessory compartment was not damaged by fire; however, the enclosure was coated slightly with soot.

Visual inspection and tests of the hydraulic and fuel systems revealed that neither system contributed to either the initiation or propagation of the fire. The empennage and wings were not damaged by either fire or heat. The leading edge slats and trailing edge flaps were fully extended. The nose gear was extended and locked. Except for the right axle where the splash guard had been cut away in order to tow the airplane from the runway, the nose gear was not damaged. The nose wheel tires were inflated. Both main landing gears were extended and locked. Except for the support bracket on the left main gear, which was bent and twisted slightly aft, the main landing gear was not damaged. However, all four main wheel tires had blown on landing.

1.12.1 External Fuselage

The cabin area of the upper fuselage down to below the level of the cabin windows was damaged heavily by fire; below that level the fuselage was relatively intact. The majority of the cabin windows were either missing or had partially melted out. (See Figure 3 and figure 4.) Forward of the aft pressure bulkhead, the upper areas of the cabin windows were discolored and burned away in several locations. The fuselage skin above the left aft lavatory was intact, but a rectangular area corresponding closely to the shape of the lavatory had been discolored to dark brown and a large area of paint had been burned away. The rectangular area began above the engine pylon and extended to the top of the fuselage. (See figure 3 and figure 4.)

Forward of the aft lavatory, between fuselage station (FS) 929 and FS 758, the top of the fuselage was damaged heavily by heat and had been burned away down to the top of the cabin windows. Between FS 758 and FS 484, the fuselage upper skin was intact but was buckled and discolored by heat at the very top between the 11 o'clock and 2 o'clock positions (aft looking forward). Between FS 484 forward to the cabin entry door (FS 200), the upper skin of the fuselage had burned away partially. Except for some sooting around the edges of the left and right forward cabin entrance doors, the fuselage forward of FS 200 was intact with no apparent heat or fire damage.

There were thick soot deposits along the lower side of the fuselage beginning at the cabin air outflow valve at FS 945 and from around the access door in the lavatory service panel at FS 965. The soot pattern trailed rearward along the airplane's side, including the tailcone. The cabin air dump valve. at FS 920, was open, and light soot deposits trailed aft from around the edges of the valve. (See figure 5.)

This image is not available at this time.

Figure 3.--Left side of the airplane.

This image is not available at this time.

Figure 4.--Left side of the airplane, rear view, depicting rectangular burn pattern and soot trail.

The lavatory service panel is just aft of the cabin outflow valve. The entire area inside the service panel access door was covered with soot and a black tarlike substance. The thickest deposits were on the inside surface of the panel access door adjacent to the vent tube and flush/fill pipe outlets. (See figure 6.)

An area of heat-damaged fuselage skin was found about 2 feet above the lavatory service panel and adjacent to the toilet area of the aft lavatory. The damage, which appeared to have been caused by heat from inside the fuselage, consisted of blistered paint, which was discolored and blackened, and warped skin. The discolored area extended from about 10 inches forward of to about 28 inches aft of FS 1,000 and extended downward from the left engine panel for about 9 inches.

1.12.2 Interior Fuselage Forward of the Aft Lavatory

All cockpit windows and windshield panels were intact; the pilot's and first officer's side windows were open. The entire cockpit area including the windows and windshield panels was sooted heavily. Except for some heat damage in the overhead switch and circuit breaker panel and to wire bundles just forward of the cockpit door, the cockpit was not damaged.

Except for the cabin floor and the aisle carpet, the entire passenger cabin back to the aft lavatory was either consumed or damaged by fire. The aisle carpet was covered by debris but had not been discolored or damaged by heat. Of the 100 passenger seats, only the seat frames and cushions of Nos. 12A and 12B remained intact. Seat Nos. 12A and 12B are adjacent to the left forward overwing emergency exit which had been opened during the passenger evacuation and had been used as access by firemen to apply water to the fire. The remaining seats were either completely or partially destroyed by the fire. (See figure 7 and figure 8.)

The aft lavatory steel potable water tank at FS 990 remained intact and attached to its ceiling mounts forward of the aft pressure bulkhead. The overhead ducting behind and above the tank was intact; however, forward of the tank the ducting had been burned away. Above the water tank, the fuselage insulation was partially in place; however, it was wet and soggy. The electrical wire bundles which were routed around the water tank were burned forward of the tank.

1.12.3 Aft Lavatory Area

The aft lavatory was on the left side of the cabin, and began at FS 965 and extended aft to FS 1019, or just forward of the aft pressure bulkhead. The lavatory's outboard wall conformed essentially to the shape of the airplane's fuselage. There was a vanity section containing a stainless steel sink and amenities located along and extending forward from the aft wall. The commode containing a flushing motor was located along the lavatory's outboard wall. A trash chute and container were located below and behind the sink, and a fresh air supply outlet was positioned below the sink in the door of the vanity. Also, below the trash container, an aluminum shelf was installed. In addition, there was an oxygen outlet located in the oxygen mask compartment in the amenities section. (See figure 9 and figure 10.)

This image is not available at this time.

Figure 5.--Soot trail deposits on left side of fuselage at lavatory service panel and outflow valve.

This image is not available at this time.

Figure 6.--Lavatory service panel with access door open.

This image is not available at this time.

Figure 7.--Cabin interior viewed aft from the forward galley area.

This image is not available at this time.

Figure 8.--Cabin interior viewed aft from the midwing area.

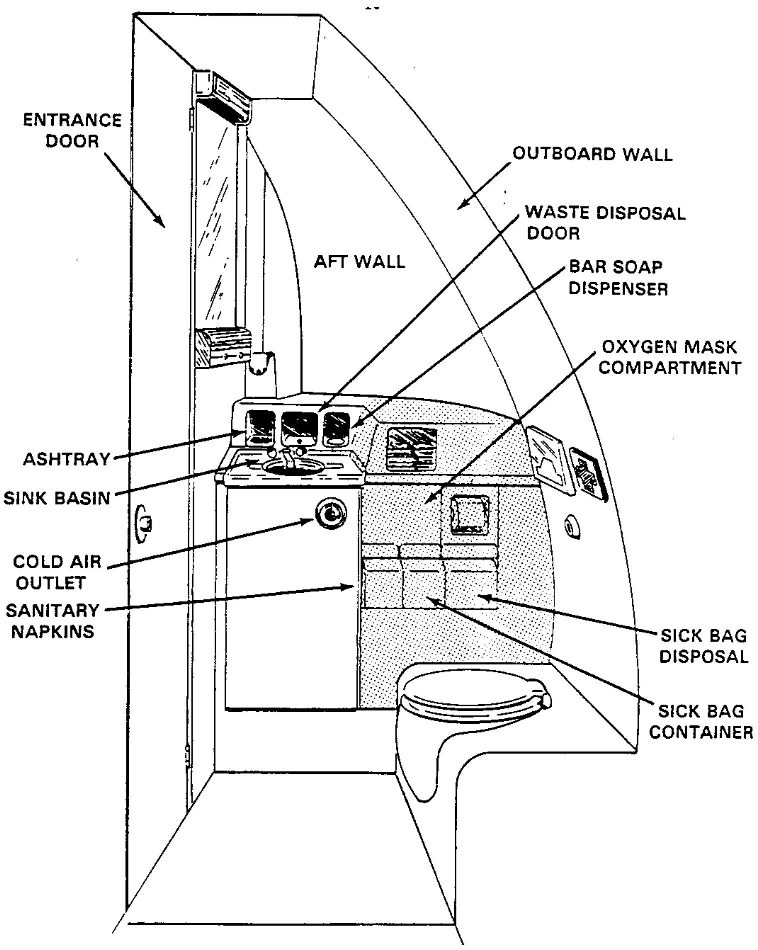

Figure 9.--Diagram of aft lavatory, viewed aft.

This image is not available at this time.

Figure 10.--Aft lavatory viewed toward aft and outboard wall. Lavatory sink door is open exposing trash receptacle. Toilet shroud has been removed showing the top of the flush motor between the commode and forward wall of the amenities section.

The aft lavatory was damaged extensively by fire and heat. Most of the lavatory's interior walls had been burned away. The entry door, which had been kept closed, was destroyed except within 16 inches of the floor. The aft pressure bulkhead and fuselage skin which comprised the outermost portion of the lavatory enclosure were intact, but were buckled and discolored to dark brown.

The stainless steel sink and the section of the vanity frame supporting the sink were intact against the aft lavatory wall. The plastic door on the front of the sink portion of the vanity was burned away. The cold air outlet nozzle mounted in the door was recovered in the debris and was in the closed position.

Except for the top of the trash chute, which had burned away at the point where it attached to the top of the sink at the waste disposal door, the trash chute and trash container behind and below the sink were intact. The aft side of the container was scorched, but not burned, and the paint on the inside surface of the container was blistered. Paper trash in the container was scorched but was not burned. The aluminum shelf below the container was intact; it was covered with debris, but exhibited little evidence of heat damage. The lavatory floor in this area was intact, but was covered with damp debris. Included in the debris were a plastic vial and a paper maintenance tag, neither of which was burned. These items were located on the floor under the sink area.

A Halon 1301 automatic fire extinguisher was mounted below the sink basin, and it had discharged automatically into the trash chute. The extinguisher is designed to discharge Halon gas through one, or both, of two heat activated nozzles. One nozzle discharges directly into the open area below the sink and the other into the trash chute. At temperatures in excess of 173°F. the nozzle tips will melt causing the Halon to be discharged under pressure.

The amenities section of the vanity extends from the sink to the lavatory outboard wall and from the commode to the lavatory aft wall. The section contains the oxygen mask compartment and containers or dispensers for paper towels, toilet paper, sanitary napkins, and sick bags.(See figure 9.)

The amenities section had been damaged extensively by fire and was almost completely disintegrated along the outboard corner. The oxygen mask compartment was damaged severely and parts of the compartment and its cover door were burned away.

The lowest level of the amenities section between the amenities compartments and the aluminum bottom shelf was a void space through which was routed the wiring for the commode's flush pump motor; the aluminum oxygen line to the oxygen mask compartment; the aluminum cold air supply line to the adjustable nozzle outlet below the sink; and a stainless steel pipe from the sink. The outboard top of this area had burned away. The outboard corner of the aluminum bottom shelf had partially melted away; the remainder of the shelf was intact. The lavatory aft wall below the bottom shelf was intact and was not burned.

Within this portion of the amenities section, the stainless steel drain pipe was intact. The oxygen line had been partially consumed where it entered the oxygen mask compartment and where it exited the amenities section; the remainder of the line within the amenities section was intact. The cold air supply line was intact from the divider wall between the sink and the amenities section to the area near the intersection of the pressure bulkhead and the outboard wall of the lavatory. In this area, a 1.5-inch-long elliptical-shaped hole was melted through the top of the line. The aluminum alloy used in the cold air supply line melts between 1,000° and 1,200° F.[9] The remaining outboard end of the cold air supply line was scorched and partially melted away about 2.5 inches beyond the elliptical hole. There was extensive heat damage to the vanity wall and floor in the area adjacent to the elliptical hole.

The plastic top and shroud of the commode were burned away. Except for some burning around its upper edges, the commode's fiberglass waste tank was relatively intact, was partially filled with debris, and contained about 6 to 7 inches of water. The flush pump and flush pump motor assemblies were recovered in several pieces among the debris in the waste tank.

The waste tank in the commode is serviced by a stainless steel flush and fill line which runs from the tank to its terminus in the lavatory service panel. The stainless steel pipe was intact, however, the flex hose and joints which connect the pipe to the waste tank had burned away. The plastic ball in the flush and fill pipe check valve had burned away and the brazed joint between the two portions of the check valve housing was partially melted. Soot and tar deposits were found on the lavatory service door directly opposite the flush and fill line outlet, and rivets on the pipe connector to the service panel had been melted.

The flush motor was found attached to its mounting flange which was attached to the pump well. The flush motor assembly was found in approximately its normal position in the waste tank next to, but detached from, the flush pump and filter assembly. The motor housing was completely melted. Large concentrations of molten metal were found on the forward side of the mounting flange facing the toilet bowl, and on the aft side where the 3-phase electrical leads enter the motor housing. A portion of the wiring harness which supplies a.c. power to the flush timer, flush motor, and flush button was encased in the molten metal on the aft side of the motor. The rotor section of the flush motor was encased in molten metal above the field windings; however, the rotor did not appear to have been damaged extensively by heat.(See figure 11).

The flush pump and filter assembly found in the waste tank was partially intact. The filter and pump mechanisms, which apparently had been located below the water line in the waste tank, were in good condition. Above the water line, the plastic housing for the pump and filter was melted away. This housing also encloses the filter gear train and is part of the assembly used to mount the pump and filter to the pump well. The exposed shaft and gears showed heat damage. The gears, which make up the filter gear train that connects the motor to the pump and filter, were found lying in the waste tank. The plastic mounting ring, which mates the pump and filter housing to the pump well, was found intact among the debris in the waste tank. There was some slight melting of the top surface of the mounting ring. All of the components of the flush motor and pump assembly were removed for further examination.

When the flush motor and its associated mounting were removed from the toilet tank, two wires in the motor harness and all of the wires in the power harness broke just aft of the motor housing due to brittleness. To facilitate removal of the flush motor assembly, the remaining wires of the motor harness were cut a few inches aft of the motor housing and tagged for identification.

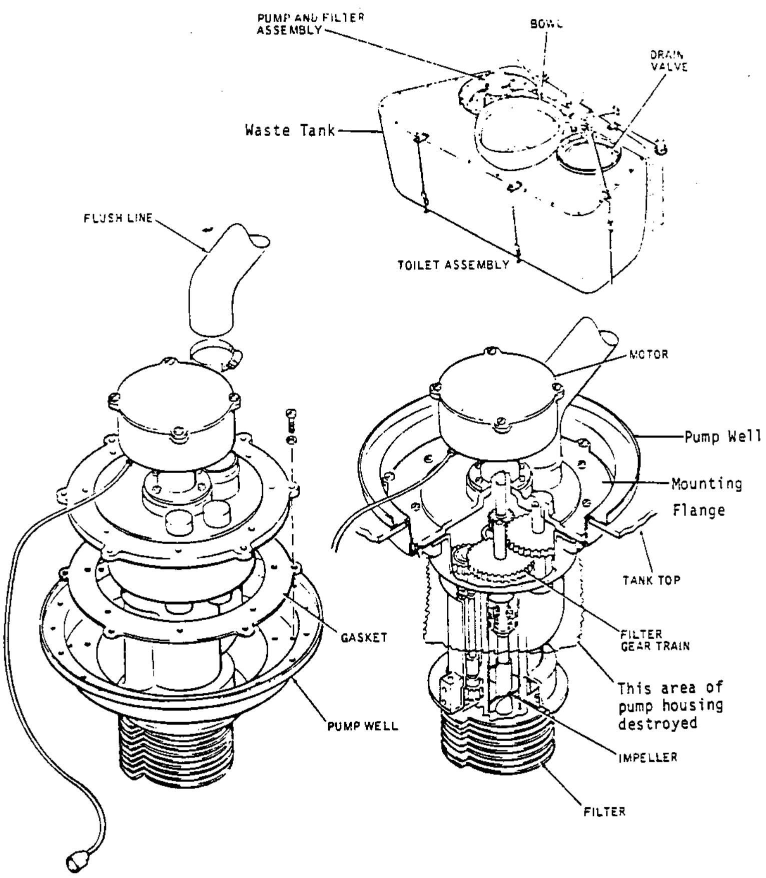

Figure 11.—Lavatory pump and filter system.

The flush timer was found intact, mounted in its normal position, on the inboard interior cabinet wall below and to the left of the sink. The timer's two electrical connectors and their respective wiring harnesses were connected to the timer. The timer and connectors showed evidence of external heat and smoke damage only. The connectors were removed and all mating connections were examined. No damage was observed at any of the connections. The timer was removed for further examination.

The wiring harness that supplies 3-phase power from the timer to the toilet flush motor was examined. The harness was undamaged between the timer and a point midway into the lower amenities portion of the vanity. The insulation had melted away from the wires on the wiring harness section between the midway point and the lightening hole10 where the harness leaves the vanity and connects to the motor. The exposed wires in this section were brittle.

The wiring harness that supplies a.c. power from the ground service bus to the timer and flush button was found partially intact. The harness was undamaged in the area from the timer outboard to the lower amenities portion of the vanity. From this point, continuing outboard and forward through the lightening hole in the vanity, the wire insulation and the wires were brittle. The harness was encased in molten metal from the aft end of the motor housing, across the width of the housing, to the forward end of the housing. The harness was not identifiable from a point just forward of the motor housing to slightly aft of where the harness leaves the lavatory forward bulkhead through an overhead lightening hole. From the overhead lightening hole, the harness was routed outboard and down to the cabin floor. Varying degrees of heat damage were observed on the harness in this area. The remainder of the harness, from a point just below the cabin floor forward along the left side of the airplane to the circuit breakers on the electrical power control panel, was undamaged. No wiring from this harness to the flush button could be identified.

The lightening hole between the amenities section and toilet section through which the flush motor's power harness passes was examined. The nylon alligator grommet covering the hole's surface was not found; however, this entire area was damaged severely by heat and fire. The bracket supporting the harness' nylon cable clamp was partially melted away with only the portion of the bracket that was riveted to the structure remaining.

An electrical continuity check was made of the harness using a volt-ohm meter. Because the insulation had burned off the wires in certain areas causing short circuits, the entire harness could not be tested. The harness was cut at a point 5 feet above the cabin floor, just forward of the aft lavatory forward bulkhead. Continuity was observed from this point to the circuit breakers. There was no evidence of line-to-line or line-to-ground short circuits.

Electrical splices were found on the power harness just aft of the flush motor housing. The splices appeared to be intact and electrical continuity was established on four of them. The remaining splices could not be tested because there was not sufficient wire protruding from the splices.

The power harness routing in this airplane differed from the McDonnell Douglas DC-9 installation drawings. These drawings indicate that the harness is routed from the lightening hole in the vanity, across the inboard side of the flush motor housing, and around the forward side of the housing. The harness is shown secured with support clips and cable clamps around the pump well. The harness in this airplane was routed across the outboard side of the motor housing. No support clips or cable clamps were found around the pump well. It could not be determined whether or not vibration induced insulation damage occurred at this point.

The wiring harness associated with the aft attendant communications panel was examined. A number of electrical wire splices were found just above the standpipe feed-through located near the inboard end of the vanity. This harness and the attendant panel were removed for further examination.

Electrical components normally located in the lavatory overhead area were found among the debris recovered from the lavatory floor around the waste tank. All components were heavily damaged by fire. The recovered components included portions of the upper and lower mirror light assembly, the circuit breakers and transformer to the aft reading lights, the razor convertor, and the control transformer for the aft miscellaneous lights.

All the overhead wiring from the aft pressure bulkhead forward to the cockpit was severely damaged by fire and heat. The wiring that penetrated the aft pressure bulkhead was spliced just forward of the bulkhead. All of the splices observed in the area of the aft pressure bulkhead and in the area of the aft lavatory were accomplished during repairs made to the airplane after the September 17, 1979, aft pressure bulkhead separation at Logan International Airport, and the splices were made in accordance with service sketch 2958. None of the wire splices in these areas showed evidence of arcing or shorting. Several samples of electrical wiring, all of which were spliced, were removed from the forward side of the pressure bulkhead for further examination. All of the wire splices removed and examined appeared to exhibit the same degree of extreme heat damage. The insulation covering was missing from all of the splices; however, no evidence of either electrical arcing or shorting was observed.

1.12.4 Aft Accessory Compartments and Cargo Compartments

The internal fuselage of the aft accessory compartment behind the aft pressure bulkhead was intact with little evidence of heat damage. The insulation on the aft side of the bulkhead was intact but discolored. Except for the buckling and discoloration that was noted in the area above the aft lavatory's vanity, the aft pressure bulkhead was intact. The systems, lines, and wiring were intact except for some slight heat damage to the wiring nearest the lavatory.

The forward cargo compartment was fully intact, and there was no evidence of either fire or heat damage. The rear cargo compartment also was intact. The fire and heat damage in this compartment was concentrated in the area below the aft lavatory.

The under floor blanket insulation along the aft tunnel area of the rear cargo compartment was scorched from the aft pressure bulkhead forward to about FS 945 and from the airplane's centerline outboard to the fuselage skin. The heaviest scorching was under the aft lavatory at the point where the lavatory's aluminum vent tube was routed. This tube, which vents air overboard from the lavatory, begins near the commode and beneath the toilet shroud and ends at a venturi in the lavatory service door. It enters the tunnel just aft of FS 980 and is routed forward to FS 965 and then to the venturi. Between FS 980 and FS 965 the tube is routed below the three generator feeder cable bundles. The vent tube had melted away to within 6 inches of its terminus in the lavatory service panel. The hydraulic, fuel, and pneumatic lines routed through this area were intact with no evidence of leakage.

The nylon conduits encasing the APU and the left and right generator feeder cables from the aft pressure bulkhead (FS 1019) to about FS 965 were melted away and the insulation on the exposed cables was scorched. The most intense scorching occurred between about 2 inches forward to 8 inches aft of FS 980. The generator feeder cables are routed through two lightening holes in a floor beam located at FS 980. The APU and right generator feeder cables pass through the inboard lightening holes; the left generator's three feeder cables pass through the outboard holes. A small notch, typical of the type of damage resulting from electrical arcing, was found in the outboard lower edge of the inboard lightening hole adjacent to one of the right generator feeder cables. The frame of the outboard lightening hole was burned away from around the bottom of the hole. The nylon support clamps for the feeder cable bundles were missing at both lightening holes. The clamp screws for the nylon support clamps were attached at the inboard hole, but were discolored by heat. At the outboard hole, the clamp screws were missing and the area where they attached was damaged by heat and partially burned away.

At FS 965, the nylon support clamps for the APU feeder cables were intact while those for the right generator feeder cables were only partially intact. The support clamp for the left generator feeder cables was missing; however, the clamp screw was attached at the lightening hole. There was some heat damage, but no evidence of arcing on either lightening hole at FS 965. The support clamps were intact and the generator feeder cables were supported properly at the remaining lightening holes observed.

The examination of the feeder cables of the two engine-driven and the APU generators showed that each had been damaged by intense heat in the area between FS 965 and FS 996. The feeder cables of the right generator showed evidence of arcing near FS 980. The nylon conduits containing the generator feeder cables are semi-rigid, pipelike structures. During the investigation, the support clamps in the lightening holes at FS 980 were removed from a sister DC-9-32. The conduits remained in place and did not contact the surfaces of either lightening hole.

The feeder cables of the engine-driven and the APU generators were disconnected at the generator relays and at the engine and APU firewall connectors. When tested, each line showed continuity and no line-to-line or line-to-ground short circuits were observed.

Eight-foot-long sections of the three generator feeder cable assemblies were cut out and removed for closer examination. Each feeder cable assembly exhibited an area about 2.5 feet long wherein its nylon conduit had melted away and the insulation within this melted area was brittle and charred heavily.

Examination of the left generator cable showed that the B- and C-phase lines had areas wherein the insulation had chafed. A metal globule was found on the exposed wire strands in this area. Another chafed area was in the C-phase line about 1/2 inch aft of the metal globule. There was some melting of the wire strands in this area; however, no evidence of arcing was found.

A small area of chafed insulation was found on the phase B line of the right generator feeder cable bundle. A metal globule, similar to that noted on the left generator lines, was found on the exposed wires.

The areas where the metal globules were found on the left and right generator lines correspond to where the lines appeared to have contacted the floor beam structure under the aft lavatory at FS 980. The APU feeder lines showed no evidence of chafed insulation or electrical arcing.

The examination of the airplane's electrical wiring included the components in the electrical and electronics compartment located below the cockpit. This compartment includes the components used for a.c. and d.c. bus power distribution and fault protection, and the electronic components used for communications, navigation, and flight control. There was light to moderate heat, water, and firefighting foam damage observed in the compartment; however, the wiring harnesses showed little heat damage. All components were intact and were mounted properly in their respective racks. The batteries, which had been disconnected by the firemen, were intact. The following were removed for further testing: the static inverter; the voltage regulators of the three generators; the left and right generator control panels; and the a.c. bus control panel.

1.12.5 Cockpit Controls and Instruments

The readings of the cockpit instruments, the positioning of the cockpit controls, and the positioning of the switches in the cockpit were also documented during the investigation. With regard to the air conditioning and pressurization packs, the ram air switch was off, the right air conditioning supply switch was off, and the left air conditioning supply switch was in the HP (high pressure) bleed position. The left air conditioning supply switch was reported originally to have been in the off position, and investigators could not determine if the switch had been moved.

1.13 Medical and Pathological Information

Blood samples were taken from the 18 surviving and 23 deceased passengers and were analyzed by the FAA's Civil Aeromedical Institute, Oklahoma City, Oklahoma, for carbon monoxide, cyanide, fluorides, and ethyl alcohol. The results of the analyses indicated that the deceased had elevated carbon monoxide levels ranging from 20 to 63 percent saturation; the threshold for carbon monoxide in the blood at which incapacitation occurs is between 40 and 50 percent saturation. The cyanide levels found in the blood samples of the deceased ranged from a low of 0.8 to a high of 5.12 micrograms/ml; the toxic level for cyanide in the blood at which incapacitation occurs is between 0.5 and 0.7 micrograms/ml. The fluoride levels ranged from 410 micrograms/100 ml to 63 micrograms/100 ml; however, the significance of these fluoride levels is unknown. Alcohol levels on three of the deceased were in excess of 0.10 percent concentration.

Blood samples were taken from the survivors about 2 to 3 hours after the accident. The concentrations of carbon monoxide and cyanide found in the survivors' blood samples were below 0.10 percent concentration and .06 micrograms/ml, respectively. Fourteen of the 18 survivors' blood samples tested negative for alcohol; the other 4 samples tested below 0.10 percent concentration. With regard to the blood alcohol levels, since the blood samples were taken 2 to 3 hours after the accident, these values may be low. Blood alcohol levels decrease at about 0.015 percent per hour after alcohol intake has ceased.

Autopsies were performed on five bodies under the direction of the Boone County Coroner, and an additional five under contract for Air Canada. No evidence of antemortem impact injuries was discovered during these examinations.

1.14 Fire Response

Although the fire on board Flight 797 began in flight, no one saw flames in the cabin until after the flight had landed and the survivors had left the airplane. The last passengers to depart the airplane through the left and right overwing emergency exits stated that they saw flames immediately after stepping onto the wing. The firefighter on scene commander stated that some of his men went to assist the passengers down from the wing and that, at that time, he saw flames in the cabin.

The crash-fire-rescue vehicles entered runway 27L at its approach after Flight 797 landed and followed behind the flight until the airplane was stopped. According to the fuel gauge readings noted during the cockpit documentation, the center wing tank was empty and there were 6,200 pounds and 6,050 pounds of jet-A fuel in the left and right wing main tanks, respectively. The airplane's fuel tanks did not rupture and the jet-A fuel was not involved in the fire.

Flight 797 came to a stop about 1920, and 7 airport crash-fire-rescue vehicles containing 13 airport firefighters were positioned at the airplane.(See Table 1.) Upon arriving at the airplane, the firemen saw heavy smoke rolling out of the overwing exits and front doors. About 1921, as surviving passengers and crewmembers were departing the airplane, the firefighters initiated an exterior attack on the fire. Foam was discharged from the turrets on the firetrucks onto the top of the airplane's fuselage and on the ground beneath it in order to cool the interior of the airplane and to provide a foam blanket in case of a fuel spill. Other firefighters assisted passengers at the escape slides and helped passengers off the wing to the ground.

When the on scene commander ordered an interior attack on the fire to be made for rescue purposes and to extinguish the fire, passengers were still leaving the airplane through the left forward cabin door and overwing window exits. The first interior attack was made through the left aft window for several reasons. According to the on scene commander who executed the order, he believed that most people would try to exit the airplane through the left forward door; therefore, he did not want to block that exit with a ladder and hose. Also, with the escape chute deployed, it would have been difficult for the firefighters to enter at that door with their protective equipment and hoses. The on scene commander testified that it would have been possible, "but it would have slowed us down."

The on scene commander also testified that he wanted to enter the airplane through the overwing window exits, "because we wanted to get in between the passengers and the fire to make their chances (to escape) better."

Within minutes of arriving at the airplane and after the passengers were off of the left wing, two firefighters mounted the left wing carrying a 1.5-inch handline, opened the left aft overwing emergency exit, and applied foam into the cabin. The firefighters were wearing proximity suits with self-contained breathing apparatus; however, they were not wearing the proximity suits' protective hoods because the hoods did not fit over their breathing apparatus. After applying the foam into the cabin, they attempted to enter it through the overwing exit but were driven back by the intense smoke and heat. According to one of the firefighters, he did not see any flames during this attempt to enter the cabin. About 2 to 3 minutes after the attempt to enter the cabin from the wing failed, the tailcone was jettisoned, and these two firefighters, using a ladder, entered the aft fuselage with a 1.5-inch handline. The rear pressure bulkhead door was opened; however, the firefighters were driven back by the intense heat. The firefighters attempted to reenter the left overwing exit and then the forward left cabin door; both attempts were unsuccessful.

Table 2. Responding Airport Crash Fire Rescue Equipment

Vehicles/Unit No.	Agent Capacity (gallons)	Discharge Rate (gpm)	Quantities Used (gallons)
Crash truck			
Unit 907	3,000*	750*	3,000+
	500 AFFF**		
Unit 913	3,000*	750	3,000+
	500 protein		
Quick Reaction Vehicles			
Unit 967	100 AFFF		0
	450 pounds Purple K.***		0
Engine Companies			
Unit 951	1,000*	1,000	1,000

Ladder Companies			
Unit 960	300*	1,500	300
Ambulances			
Unit 964	n/a	n/a	n/a
Rescue Squads			
Unit 980	n/a	n/a	n/a

*Water

**Aqueous film forming foam

***Dry chemical extinguishing agent

+Indicates more than the cited amount was used.

At 1925, the on scene commander called for firefighting and ambulance mutual aid assistance. Although the call went out as "ambulance only," two firetrucks arrived on the scene about the same time as the ambulances. Before the fire was extinguished, 12 pieces of firefighting equipment and 53 firefighters had responded in mutual aid from neighboring towns.

According to the on scene commander, the firemen "had the fire pretty well under control..." when water and extinguishing agent additive were almost exhausted. According to the commander, supplies began to run out about 10 minutes after firefighting efforts were begun, and at 1952, the on scene crash-fire-rescue units depleted their water supplies. The units were replenished through supply lines laid by airport and mutual aid personnel to a hydrant located about 800 feet from the airplane. At 2017, 56 minutes after the firefighting began, the fire was extinguished.

The amount and type of firefighting equipment required at an airport is described in 14 CFR 139.49 and is based on of the longest airplane having five or more daily scheduled departures from the airport. At the time of the accident, the Greater Cincinnati International Airport was classified as an Index C airport. (Index C: airplanes more than 126 feet and not more than 160 feet long.) Therefore, the airport fire department was required to have one lightweight vehicle providing at least 500 pounds of dry chemical extinguishing agents, or 450 pounds of dry chemicals and 50 gallons of water for aqueous film forming foam, and two additional self-propelled fire extinguishing vehicles. The total quantity of water for foam production required for Index C is 3,000 gallons. At the time of the accident, the firefighting equipment at the airport exceeded Index C requirements and met those of Index E (airplanes more than 200 feet long). Standiford Field, Louisville, Kentucky, is also classified as an Index C airport.

1.15 Survival Aspects

The procedures to be followed by Air Canada flight attendants during emergency situations are set forth in Air Canada Publication 356. Flight attendants are directed to "secure the nearest appropriate type hand fire extinguisher and immediately attack the fire," and simultaneously to call or signal another flight attendant to notify the captain immediately. A flight attendant must maintain continuous communication with the captain. The procedures also relate the need to "use the axe to obtain access if necessary. Rapid access to the fire may require local destruction of various panels."

The flight attendant in charge testified that he had been taught how to use the fire axe during initial training; however, he was not taught which lavatory panels could be removed or destroyed without endangering critical airplane components. The flight attendant in charge also testified that it was obvious that the fire was contained behind the lavatory paneling, but that he did not consider using the crash axe because he would have had to destroy the whole area of paneling in the lavatory to "get to it." Although the procedures do not indicate that the use of the fire axe must be authorized by the captain, the flight attendant in charge testified that since the axe is stowed in the cockpit behind the captain's seat, there would be no way to get the axe without the captain's knowledge.

Air Canada Publication 356 contains both pictures and descriptions of the fire extinguishers used on their airplanes; it also depicts where each fire extinguisher is located on each airplane operated by the company. Publication 356 explains and depicts how each fire extinguisher operates and what type extinguisher should be used to fight different types of fires. With regard to a lavatory fire, Publication 356 states, in part, "Execute flame knockdown by repetitive discharges of a carbon dioxide (CO_2) or dry chemical extinguisher." The publication also contains directions for the most effective use of each type of extinguisher. According to the manual, the user of a CO_2 extinguisher should, "AIM the gas at the outside edge (of the fire) and then in a circling fashion towards the center."

All Air Canada flight attendants receive "hands on" training in the use of all fire extinguishers during initial and recurrent training. In addition, during initial training they are required to extinguish an actual fire.

Publication 356 also states, in part, that if excessive smoke and fumes are present in the cabin, the flight attendants should "relocate passengers away from the area of severe smoke and fumes if possible." The passengers had been moved forward in the cabin, and no passenger was seated farther aft than row 12. The two passengers in seats Nos. 12D and 12E refused to move forward because their seats were next to the right forward overwing exit window.(See figure 12.)

Once the passengers had been repositioned and the cabin air vents opened and directed aft, the smoke appeared to lessen, but shortly thereafter the smoke began to increase rapidly. Several passengers stated that the cessation of airflow from the vents coincided with the increase in the smoke. Other passengers stated that it occurred at the beginning of the descent or sometime shortly after the airplane began descending.

Air Canada emergency procedures state that the oxygen masks should not be deployed below 10,000 feet as a means of avoiding smoke inhalation. Below 10,000 feet less than 1 liter per minute is being supplied through the mask, and therefore, due to the design of the mask and the low altitude, the user is merely breathing ambient cabin air. The company procedures also state, "When fire conditions exist, dropping the masks and pressurizing the oxygen manifold may contribute to combustion." The procedures further note, "If loss of cabin pressure has caused the masks to drop...," the passengers should remove them as soon as practical once the cabin pressure altitude drops below 13,000 feet.

The flight attendants designated several male passengers to open the overwing exit windows after the airplane landed and stopped. None of those designated could recall whether the attendant had given them specific directions as to how the exits were to be opened. However, nearby passengers recalled hearing a flight attendant describing the operation of the overwing emergency exit windows. Three of the four emergency overwing exit windows were opened by passengers, and none encountered difficulties in operating and removing the window exits.

During descent, the cabin filled with black, acrid smoke from the ceiling down to about knee level. Passenger and flight attendant testimony and statements indicated that all of the surviving passengers had covered their faces with either wet towels distributed by the flight attendants or articles of clothing. They all attempted to breath as shallowly as possible, and all reported that the smoke hurt their noses, throats, and chests and caused their eyes to water. By the time the airplane landed, they could not see their hands in front of their faces while seated or standing. Some of the passengers said that they leaned forward in their seats and put their heads down and that this seemed to relieve some of the distress they were experiencing. One passenger was experiencing severe distress trying to breathe. He was brought forward and seated on the forward flight attendant jump seat, and the flight attendant in charge administered oxygen to him from the portable bottle.

(Denotes Location of Survivors Before Leaving Airplane and Location of Fatalities After the Accident)

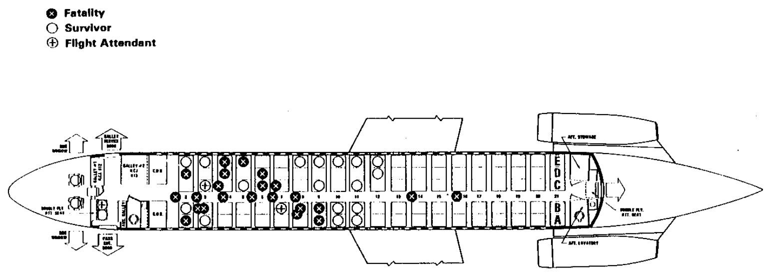

Figure 12.—Diagram of passenger seat locations.

The Air Canada Land Emergency Procedures require the flight attendant in charge to make numerous announcements advising the passengers of what they are required to do during a forthcoming emergency landing and airplane evacuation. The announcements include, in part, a description of the brace positions, the location of the doors and exits, instruction to passengers to remain in their seats until the flight attendants direct them to move toward the doors and exits, instruction on which exits to use during the evacuation, information on how to get off the airplane wing after using an exit window, and what to do after leaving the airplane. According to company procedures, the public address (PA) system should be used for all announcements before the airplane has been stopped and before the doors and exits have been opened.

A megaphone, which was stowed in the right overhead luggage rack above row 2, was not put to use. Air Canada emergency procedures state that the "megaphone is to be used inside the airplane if the PA system is not working, and outside the airplane to give instructions after the evacuation," and the flight attendant in charge is responsible for removing the megaphone. According Publication 356 and the Air Canada director of flight attendant training, the megaphone is not to be used to issue evacuation commands once the airplane doors and exit windows have been opened.

At the Safety Board's public hearing into the accident, the flight attendant in charge testified that he tried to use the aft PA microphone "after the smoke subsided and it didn't work." He also testified that he had thought of using the megaphone; however, by that time the airplane was in a steep descent, the smoke was advancing rapidly, and he thought it would have been "unwise to waste valuable time..." to try and go back and get the megaphone.

The Air Canada DC-9 emergency evacuation procedures call for three flight attendants on the airplane. A flight attendant in charge is positioned on the forward jump seat, and he or she is to open both forward doors and inflate the escape slides. The No. 2 attendant's position is in seat No. 13C, and he or she is responsible for supervising the removal of the overwing exit windows and the evacuation through the overwing exits. The No. 3 attendant's position is the aft jumpseat, and he or she is responsible for either directing the passengers to move forward or to open the alternate tailcone exit should the other exits be blocked. However, the procedures also state that if the No. 3 flight attendant is unable to occupy the aft jumpseat, seat 13B will be used if it is available. Seat 13B is the aisle seat of the two seats adjacent to the left aft overwing exit window.

Sometime before landing, the first officer told the flight attendants to sit down. When the command was given, the flight attendant in charge was seated in the forward jumpseat aiding a sick passenger, and he stayed in that seat. The No. 2 and No. 3 flight attendants were distributing wet towels. The No. 2 flight attendant moved aft and sat in an aisle seat at approximately row 8; the No. 3 attendant sat in seat 3C. While seated in 3C, she briefed a passenger in row 2 to restrain the passengers from moving toward the airplane forward doors until they had been opened and until he had received instructions to move toward and out of these doors. Shortly thereafter, she got up and moved aft checking passenger seatbelts. When she reached the vicinity of row 9, she was joined by the No. 2 attendant, and they both moved forward rechecking seatbelts and comforting passengers. When they reached the forward cabin area, the No. 2 flight attendant sat down in row 3C and remained there until the airplane landed. The No. 3 flight attendant moved aft again. She sat down in an aisle seat in rows 7, 8, or 9 and remained in that seat until the airplane landed. While seated, she shouted "brace" instructions to the passengers before the airplane landed. Several passengers said that they heard these instructions.

After the airplane landed and stopped, the flight attendant in charge opened the left forward cabin door, inflated the slide, and sent a passenger seated on the jump seat down the slide. He then positioned himself in the doorway and shouted for the passengers to, "come this way." One of the passengers recalled hearing that order. Another passenger testified that by this time, given the conditions in the cabin, it was doubtful if anyone could draw sufficient breath to shout loud enough to be heard at any distance.

With regard to the flight attendant's duties during a "Land Evacuation With Warning," Publication 356 states, "Flight attendants should do all possible to evacuate everyone, but are not obliged to risk their own lives." The flight attendant in charge testified that he stayed in the left cabin entrance doorway until no more passengers were coming. At that time, the heat was becoming too intense to remain, and he exited the airplane. The No. 2 flight attendant went forward after the airplane stopped. She saw the attendant in charge open the forward door and deploy the slide. She saw a male passenger exit through the door, and she followed him out of the airplane. Thereafter, she helped and supervised other passengers as they left the airplane. The No. 3 flight attendant got to her feet after the airplane stopped. The smoke was so thick that she could not see. She testified that she "did not think to go back to the overwing exits, so she felt her way forward." She went to the right forward cabin entrance door, opened the door, and inflated the slide. She stood in the doorway, yelled, "Come this way," waited 3 to 4 seconds, and then exited the airplane down the slide. She waited a couple of seconds at the bottom of the slide and when no one came, she ran around to the left side of the airplane and began to assist the other crewmembers in rendering aid to the survivors.

Seven passengers and two flight attendants exited the airplane through the left forward cabin entrance door and slide; one flight attendant exited through the right forward door and slide; four passengers exited through the right forward overwing emergency exit window; one passenger exited through the right aft overwing emergency exit window; and six passengers exited through the left forward overwing emergency exit window. The three overwing exit windows were opened by designated passengers. The smoke in the cabin was reportedly so thick that most of the passengers had to get to the exits by using the seatbacks to feel their way along the aisle. None of the passengers noticed if the emergency lights were illuminated. Several passengers said that, when they either bent forward or got on their hands and knees, they were able to breath and see a little better, but it was not much of an improvement. One of the passengers who used an overwing emergency window exit said that she was able to locate it when she saw a very dim glow of light coming through the aperture. Another stated that she was able to locate the overwing emergency exit window when she felt a slight draft on the back of her knees.

During the evacuation, passengers in the seats 2-B, 2-E, 3-A, 3-C, 3-E, 5-C, and 8-C exited through the left forward cabin door: passengers in seats 9-E, 10-A, 10-B, 11-A, 11-B, and 11-E exited through the left forward overwing window exit; passengers in seats 10-E, 11-C, 12-D, and 12-E exited through the right forward overwing window exit; and the passenger in seat 9-C exited through the right aft overwing window exit.

Except for two fatalities found in the aisle at rows 14 and 16, the majority of the fatalities were found either in the aisle or seated in rows 2 through 9. (See figure 12) The fatalities at rows 14 and 16 had been seated in seats 8-B and 9-B, respectively.

1.16 Tests and Research

1.16.1 Federal Bureau of Investigation (FBI) Laboratory Tests

The following items from the aft lavatory of Flight 797 were delivered to the FBI laboratory for analysis: samples of waste tank water; fiberglass insulation from the aft lavatory; a plastic vial and tag recovered from the lavatory floor; an aluminum shelf; fiberglass flooring; and soot deposits from the inside of the lavatory service panel access door.

The results of the examination were as follows: No flammable accelerants were identified on the items listed above. The source of the spots on the fiberglass flooring could not be determined. The soot deposits contained residues which were characteristic of a phenolic residue, resulting from the burning of phenolic resins such as those contained in the cabin and lavatory walls and other materials.

1.16.2 Electrical System Components

The electrical system components removed from the forward electronic compartment beneath the cockpit were tested under Safety Board supervision at the Westinghouse Electric Corporation, Lima, Ohio.

Functional testing of the a.c. bus control panel, and the voltage regulators and generator control panels of the APU and the left and right engine-driven generators showed that these units were operational.

Inspection of the APU generator control panel revealed that connectors on the printed circuit board had corroded and that the electronic components on one of the printed circuit boards had been damaged by water and foam. The Safety Board concluded that this was damage incurred after landing as a result of the firefighting activities.

Tests of the two engine-driven generator control panels showed that the differential control circuitries in each of the panels had detected faults on their respective a.c. buses, displayed the faults on the control panels, and then tripped each generator off its respective bus. The differential current circuitry of a generator control panel is designed so as to trip the associated generator from the line within 0.1 second after detecting a 20- to 40-ampere fault current. During the test of the generator control panels, the protective trip occurred within the prescribed limits.

The static inverter used to provide emergency a.c. power was tested functionally by the Safety Board at Air Canada's Maintenance Base, Dorval, Quebec, Canada. The 28-volt d.c. power terminals were found to be short circuited, and the unit was torn down for detailed examination and testing. Two of the eight power transistors were found to be short circuited. When the shorted transistors were replaced, the inverter functioned normally. The Safety Board could not determine the cause of the short circuits.

1.16.3 Flush Motor and Lavatory Components

The flush motor, flush motor components, and various other electrical components removed from the airplane were taken to Transport Canada's Safety Engineering Laboratory in Ottawa, or to Air Canada's Maintenance Base, Dorval International Airport, Quebec, and examined and tested. The tests and examinations were performed under the supervision of Safety Board personnel.

X-rays of the aft lavatory flush motor were taken before it was disassembled. The X-rays revealed no evidence of internal melting or shorting of motor components. Solidified melted metal was observed which appeared to be melted motor housing. Solidified melted metal deposits were removed from inside the motor, below the rotor. The motor shaft appeared to be encased in solidified melted metal; however, it could be rotated very slightly. A wire was still attached to a ground stud inside the motor. When the stud was removed, the wire broke due to brittleness. There was no evidence of electrical arcing observed on the ground wire or the stud.

A portion of the solidified melted metal which partially encased the stator was removed, and the stator was rotated about 180°. The fiberglass insulating material around the stator windings and the silicone glass was intact but scorched. The stator assembly was intact and showed no visible signs of electrical arcing.

When the remainder of the solidified melted metal deposit which partially encased the stator was removed, two wire segments were found which had been encased partially within it. One additional wire segment was loose under the metal deposit. The source of the metal deposit apparently was a portion of the motor housing which had melted, flowed downward, and entrapped the wires between the motor mounting flange. When the metal deposit was removed from the mounting flange, 180° of the wire's circumference was visible. The fiberglass insulation on the visible portion of the wire segments was intact, but showed evidence of scorching. Wire splices were found in the two wire segments encased in the molten metal as well as in the loose wire segment. The splices were located just outside the solidified melted metal deposit. No evidence of electrical arcing was observed on the exposed wire segments or on the splices. X-rays were taken of the solidified melted metal deposit and wire segments; the x-rays revealed no evidence of electrical arcing.

The motor was removed from its mounting flange. The gasket between the motor mount and the mounting flange was brittle and scorched. The remaining solidified melted metal from the motor housing appeared to have flowed down around the rotor shaft and formed a deposit around the motor mount. The mating face of the motor mount was intact and showed no evidence of melting.

The motor's stator assembly was removed and inspected. The cable clamp that routes the power leads from the timer harness to the motor stator was still intact around four wires. The mounting hardware was still attached to the clamp; however, the attachment point at the motor housing could not be found; it apparently had melted away. The four power leads still were routed to the stator windings. X-rays of the stator assembly revealed no evidence of electrical arcing or internal melting. The stator windings, where the power leads were connected, was partially disassembled. The enamel insulation around the wire used in the stator windings had been melted away, and bare copper wires were exposed. No evidence of arcing was observed at the power lead stator connections or in the stator windings.

Six segments of wire from the flush motor timer harness were found in the pump well next to the motor mount. Four of the segments had splices in them; the other two wires had no splices. The two wire segments that had not been spliced were considerably shorter than the four segments with splices. The insulation sleeving around the splices appeared to have been melted away; however, the mechanical connections of the splices were intact. The splices showed no evidence of electrical arcing or shorting. However, three of the wire segments showed signs of electrical arcing—the wire ends were melted into the shape of a globule. The metallic globules, which were located on the wire segments at the point where the wires traversed the lightening hole in the partition between the toilet and amenities section, were examined using a scanning electron microscope (SEM). The X-ray energy dispersive analysis indicated that they were copper. The flush motor wiring harness was examined closely for any evidence of electrical arcing or shorting. The connector at the flush timer end of the harness showed evidence of damage from intense heat. Except for a small tear 25 inches from the connector, the sleeving which surrounded the wires was found intact from the connector to a point 35 inches away. The teflon insulation on the individual wires within the harness was found intact from the connector to a point 38 inches away. From that point to the end of the harness, the sleeving and teflon insulation had melted away progressively, and toward the end of the harness, bare wires were exposed. No indication of electrical arcing or shorting was observed on any of the wires.

The 5-ampere phase-A, phase-B, and phase-C flush motor circuit breakers were removed from the cockpit and were X-rayed, revealing no internal damage. During a functional test, all three circuit breakers tripped when the electrical load exceeded the 5-ampere rating. The circuit breakers were connected to a power source and load and subjected to a 100-percent 10-ampere current overload. Only the phase-A circuit breaker exceeded the time limit designated in the specifications before it tripped. The Safety Board could not determine the reason for the failure of the phase-A circuit breaker to meet its specifications; however, all three circuit breakers showed evidence of damage due to an external heat source.

The flush motor timer was examined. A continuity check of the timer's three-phase power relay contacts showed that they were open -- the normal position of the relay when the flush button is not engaged.

A 3-foot, 5-inch portion of the flush timer's wiring harness, from the connector at the timer to just outside and forward of the lightening hole in the vanity structure, was removed and examined for any evidence of electrical arcing and shorting. The first 2 feet of the sample was relatively intact. From a point 2 feet 6 inches to a point 3 feet 5 inches from the connector, the outer insulation layer of the individual wires had been gradually melted away; however, the fiberglass inner insulation remained intact. The wires were bare of insulation over the last 5 inches of the harness, and when the harness was removed, the wires broke due to brittleness. No evidence of arcing or short circuiting was observed on any of the wires.

The following electrical components were removed from the lavatory and examined for electrical arcing and short circuiting: the lower mirror light assembly, the upper mirror light and dimming switch assembly, the aft reading light transformer and circuit breakers, the razor outlet converter, the aft attendant panel, and the aft miscellaneous lights control transformer. All of these components and their associated wiring were damaged by heat, and portions of some of them were missing; however, no evidence of electrical arcing was observed on any of the wires.

In addition, several samples of spliced electrical wiring were removed for examination from the forward side of the aft pressure bulkhead. All of these samples exhibited evidence of exposure to extremely high temperatures. The insulation covering was missing from all of the splices; however, no evidence of electrical arcing or shorting was observed.

1.16.4 Flush Motor Seizure Test

At Air Canada's Dorval Maintenance Base, the Safety Board simulated the conditions produced by a seized or frozen flush motor assembly drive shaft. A Western Gear Motor, Model 353JC2, identical to that on Flight 797, was connected to a test fixture which provided 115-volt a.c. three-phase power through 5-ampere circuit breakers connected to the motor power leads. The rotor shaft was locked, the motor was operated, and the internal motor temperature and motor case temperature were measured.

The internal motor temperature began to rise as soon as power was applied. At 1 minute 30 seconds after power was applied, smoke was visibly emanating from around the motor cover plate. At this time, the motor temperature was 331° F. At 6 minutes 15 seconds after power was applied, maximum rotor temperature of 617° F was reached. A few seconds later, two phases of the motor stator windings opened. At 7 minutes after power application, maximum motor case temperature, 405° F, was reached, at which time both rotor and case temperatures began to decrease. Both temperatures continued to decrease until the test was terminated. At 27 minutes 16 seconds after power application, the remaining motor stator winding opened. Since no further current flow was observed in any of the three-phase motor leads, the test was terminated. The rotor temperature observed at this point was 546° F and the case temperature was 374° F. The 5-ampere circuit breakers did not trip during the test. The maximum current flow recorded during the test was 1.85 amperes per phase.

After the motor assembly cooled, it was examined. Examination revealed that the rotor was heavily darkened around the circumference of the rotor area which aligns with the stator. The rotor was intact and appeared undamaged. The stator exhibited a heavily darkened area around its circumference where it aligned with the rotor. X-rays of the stator did not reveal any internal electrical arcing or melting.

1.16.5 Fire and Heat Tests

During the investigation, the Safety Board conducted flammability test on the materials contained in the Heath Tecna cabin interior assembly kit. In addition, tests were conducted to determine the effects of fire and/or heat flux on DC-9-32 lavatory components, flush motor pump components, wiring bundles, wire insulation, and waste materials. These tests were conducted at the FAA Technical Center, Pomona, New Jersey.

Cabin Materials Burn Tests. --The materials contained in the Heath Tecna Kit were subjected to the current standard Bunsen Burner tests as set forth in 14 CFR 25.853. (See appendix F.) All of the materials tested met prescribed standards.

A piece of polyurethane seat cushion, similar both in time of service and in composition to the seat cushions on Flight 797, was subjected to vertical and horizontal Bunsen Burner tests. The material failed the vertical test but passed the horizontal test. The FAA project manager in charge of full-scale fire testing at the Technical Center was asked why the material had failed the test after only 18 months in service. He speculated that the particular piece of foam tested had lost some of its fire-retardant capabilities because of the effects of wear and body moisture on the outer surface. He testified at the Board's public hearing that Center technicians had encountered similar failures when testing older seat cushion materials and that he did not believe that the degraded capability of the seat cushion would have contributed to the propagation of the fire on Flight 797.

Cold Air Supply Line Tests. --The susceptibility to heat of a cold air supply line similar to the one that had melted through on Flight 797 was evaluated. A sample cold air supply line was placed near an electrically powered heat element capable of producing a radiant heat flux of about 7 BTU/ft^2-sec. The amount of heat flux was controlled by placing the subject line at predetermined distances from the heat source. The cold air supply line was capped at one end, and as the line heated, a constant internal pressure of 1 psi was maintained by manually opening a relief valve. During each test, the aluminum cold air supply line was held stationary for about 15 minutes until there was no noticeable increase of pressure within the line.

Three tests were conducted. The heat fluxes in the cold air supply line were about 2, 5, and 7 BTU/ft^2-sec. There was no evidence of heat damage to the line and hardness test results showed that the line remained within its specified tolerances.

The BTU's generated from burning paper towels were also evaluated. Three paper towels were crumpled by hand and ignited by a match, and the heat flux was measured. The maximum measured heat flux was about 4 BTU/ft^2-sec, and the temperature was about 1,200° F. The heat generated by burning towels with and without airflow was also evaluated; the maximum heat flux remained at 4 BTU/ft^2-sec.

DC-9-32 Lavatory Mockup Tests. --A partial DC-9-32 lavatory was constructed with actual airplane hardware. Tests were conducted to explore the effects of radiant heat from a toilet flush motor on adjacent lavatory components, and the effects of fire impinging on the flush system power harness. Thermocouples were placed at various locations within the mockup to monitor temperatures. No air flow was used for these tests.

A Western Gear Flush Motor, Model 353JC1, Serial No. 2984, was used in the first test. In order to simulate an overheated motor condition, the rotor shaft was mechanically restricted. The motor was then mounted on a pump assembly utilizing a cast aluminum mounting flange and installed in the waste tank. Except for the restriction of the rotor shaft rotation, these conditions simulated exactly the assembly of the accident airplane.

Three-phase 115-volt a.c., 400 Hz power was supplied to the motor through a wiring harness of the same length and type as that installed in the accident airplane. The power supply end of the harness was protected by the use of three 5-ampere circuit breakers. The wiring harness in the lavatory mockup was routed similarly to the installation in the accident airplane. A flush timer was not used for this test; however, the power harness was routed to the location, in the vanity, where the timer was installed. The power harness was mated to the flush motor through the use of a junction box and normally used connectors.

Three-phase power was applied to the motor until all three stator windings of the motor had failed open. Light smoke was observed coming from the toilet bowl about 5 minutes 45 seconds into the test. Subsequently, the phase-A, -B, and -C stator windings failed open at 6 minutes 40 seconds, 17 minutes 45 seconds, and 11 minutes 25 seconds, respectively. The maximum motor case temperature -- 431° F -- was reached at 9 minutes 45 seconds after power was applied. The maximum temperature on an adjacent lavatory component (toilet shroud) of 157° F was reached 13 minutes 55 seconds after power was applied. Twenty-five minutes of data was recorded at which time the test was terminated. No evidence of any deformation, discoloration, or overheating of any of the vanity or waste tank components was observed.

The flush motor was removed from the lavatory mockup and examined. Oily residue was found below the motor case on the mounting flange. When the top cover plate of the motor was removed, evidence of overheating of the cover gasket, rotor, and stator assemblies was apparent. The rotor appeared locked when hand rotation was attempted; but when additional torque was applied to the shaft, the rotor turned freely. The rotor assembly was removed and evidence of arcing at numerous points along its top outboard face was observed. The stator assembly was removed from the motor case and examined. The lower gasket under the stator assembly was intact; however, oily residue was observed. An electrical continuity check was made of the stator windings; no continuity was observed phase-to-phase or each phase-to-neutral. However, there was high resistance continuity between the phase-B winding to the stator assembly case, and the phase-C winding to the case. These resistance readings were greater than 2 megohms and 1.3 megohms, respectively. The wire harness which provides power to the stator assembly showed no sign of damage.

In the second test, a flush motor housing containing a controllable electric heating element was placed in the waste tank in the lavatory mockup. The voltage to the heating element was then increased until the temperature on the outside the motor case reached a maximum of slightly above 800° F. This temperature exceeds by nearly 100 percent the highest temperature that has been reported on this type of motor.

The maximum temperature of 803° F was reached 42 minutes into the test. Forty-four minutes into the test, the maximum temperature on an adjacent lavatory component -- the toilet shroud -- had reached 255° F. Power was removed from the heating element.

The only observable change to any lavatory component was in a 5-inch-square area in the aft outboard corner of the toilet shroud directly above the flush motor. This area was deformed upward to a height 2 1/4 inches above the shroud support bracket on the forward face of the vanity. There was no discoloration, melting, or any other deformation of the shroud; however, some adhesive material, used to bond a doubler to the underside of the shroud around the toilet bowl cutout, flowed from the bond line and dripped onto the flush motor case. The adhesive also dripped onto the elastomeric hose running from the flush pump mounting flange to the toilet bowl.

The motor case remained intact; however, obvious signs of overheating were present. The name plate on the top cover was completely blackened, and the inside of the cover was brown around the outer edge, becoming lighter toward the center.

Flush Motor Power Harness Fire Test. --A test fixture was constructed using a piece of 0.030-inch sheet aluminum 21 1/2 inches by 6 inches. A 1 1/2-inch diameter lightening hole was cut in the fixture, an alligator grommet was installed around the lightening hole, and a nylon cable clamp was installed above the hole. A flush system power harness and a flush motor harness supported by the cable clamp were routed through the lightening hole perpendicular to the test fixture. This configuration simulated the lavatory vanity structure, lightening hole, and flush system wire routing in the lower outboard forward vanity area of the accident airplane.

The flush system primary power harness used for this test consisted of eight conductors of MIL-W-5086 type wire bundled in heat shrink tubing. One end of the harness was connected to a 115-volt a.c., 3-phase, 400-Hz electrical power source and to ground. The harness was protected through the use of three 5-ampere circuit breakers connected at the power supply end of the circuit. The other end of the harness was not connected so as to simulate power being supplied to a flush timer that was not activated (flush button not pushed). The test fixture was electrically grounded to the same point as the harness.

A portable propane torch was used as the heat source. The torch was positioned under the fixture and the nozzle was removed from the torch in order to produce a broader flame pattern. The torch was adjusted so that the flame's vertical height covered the entire height of the test fixture and the width of the flame was sufficient to cover the diameter of the lightening hole and adjacent structure.

Three-phase a.c. power was applied to the test fixture, and the test began when the propane torch was placed under the test fixture. After 28 seconds, the nylon cable clamp began to melt and drip. After 40 seconds, the wire bundles fell and rested on the bottom of the lightening hole. At 4 minutes 7 seconds into the test, audible arcing was heard and electrical arcing was visible where the wire bundles contacted the bottom of the lightening hole. Less than a second later, all three circuit breakers tripped in rapid succession. The flame impinging on the power harness and flush motor harness self-extinguished. The heat generated by the torch was measured using a calorimeter and thermocouple. The heat flux from the flame area that impinged on the wires was 4.4 BTU/ft^2-sec at a temperature of 1,650° to 1,700° F.

A continuity check was made of the power harness before it was removed from the test fixture. Phase B-to-ground measured 175 ohms, and phase C-to-ground measured 90 ohms.

Both wiring harnesses were removed from the test fixture and examined. The power harness was discolored for about 2 1/4 inches. The length of harness that was actually burned was 1 3/8 inches. The area of the harness that had burned through was examined under high magnification. At least one conductor clearly showed evidence of electrical arcing -- a copper ball could be seen on the wire. The flush motor harness was discolored for 2 inches and was actually burned for about 3/4 inch.

Chafe Tests of the Flush Motor Power Harness.--The Safety Board conducted chafe tests of the flush motor wiring harness at the FAA Technical Center using an exemplar power harness from an Air Canada DC-9. In order to simulate a flush timer in its normal state with a deactivated flush button, the harness was powered; however, no load was connected. The harness was routed through the lightening hole between the amenities and toilet sections and then pulled back and forth vigorously through the hole by two persons. During the pulling, which encompassed a distance of 2 inches, a heavy downward force was exerted against the structure of the lightening hole.

The first chafe test was conducted with the nylon alligator grommet around the surface of the lightening hole. After 10 minutes of rubbing, the outer heat shrink cover of the harness was penetrated. The outer nylon insulation of two of the eight wires in the harness had been chafed slightly; however, the insulation had not been penetrated.

The same test was conducted with the alligator grommet removed. After 2 minutes of rubbing, the heat shrink outer covering had been penetrated and the nylon outer insulation of one wire was chafed. After 3 minutes, the insulation of one wire was penetrated exposing bare conductors; however, no electrical activity was observed. After 4 minutes, the exposed wire broke. After about 8 minutes, electrical arcing occurred between another wire in the harness and the structure of the lightening hole, but none of the circuit breakers tripped. The test was resumed, and 2 seconds later, the exposed wire severed at the point of contact with the lightening hole. The phase-B circuit breaker tripped simultaneously with the severing of the wire.

The method used to expose the wires in the harness during the two tests was not intended to duplicate what would occur during actual operating conditions had either the harness support failed, or had the alligator grommet been missing, or both. Given the light weight of the harness, even had the support and the grommet been missing, the harness would not have been subjected to the abuse during actual operating conditions that it was subjected to during the tests. The tests were conducted to determine what would occur if the wires in the harness were exposed and to determine the effort required to abrade the insulation and chafe the wires.