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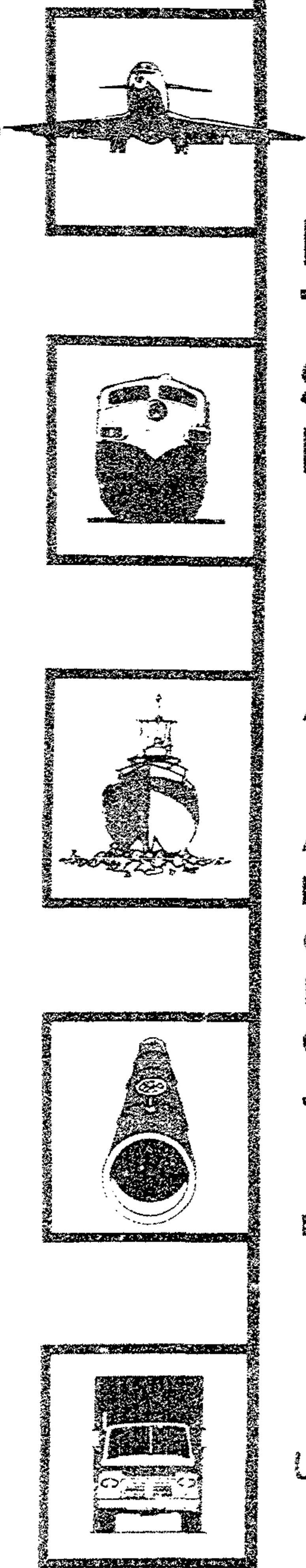

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

AIR CANADA FLIGHT 797
McDONNELL DOUGLAS DC-9-32, C-FTLU
GREATER CINCINNATI
INTERNATIONAL AIRPORT
COVINGTON, KENTUCKY
JUNE 2, 1983

NTSB/AAR-84/09

UNITED STATES GOVERNMENT

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16. 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 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.

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Abstract Cont'd

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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 conflicting fire progress information provided to the captain.

Contributing to the severity of the accident was the flightcrew's delayed decision to institute an emergency descent.

1. FACTUAL INFORMATION

1.1 History of the Plight

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 deviaticn to the south oi 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.

X: 1851:14 eastern deylight time 2/, 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 io- protective purposes.) After identifying the circuit breakers, the captain immediately made one attempt to reset them; the circuit breakers would no: reset. The captain assumed that rhe fiush 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 t.o the cockpit voice recorder (CVR), he told she 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 attendant 3/ to identify e strange odor. The flight attendant though: the odor was coming from the aft lavatory. She took e CO_2 fire extinguisher from the csbin wall and opened the iavatory 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 lavetory, she inhaled some smoke end closed the door. The So. 3 flight attendant then saw the No. 2 flight attendent 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 toid there was smoke or fire in the lavatory; however, when she reached the flight attendan: 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 fiight attendant to inform the captain and then to assist the No. 3 flight attendan: 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 cherge 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 ?he top of the wash basin behind the vanity and a: the ceiling.

1/ All altitudes herein are altitude above mean sea level, unless otherwise indicated.
2/ All times hereafter are eastern daylight time based on She 24-hour clock.
3/ There were three flight attendants on this flight—?he flight attendant in charge, a flight attendant designated No. 2, and a flight attendant designated No. 3 (see section 1.15 for an explanation of these designations).

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 closer! ?he lavatory door.

At 1902:40, the No. 2 flight attendant reached the cockpit and told the csptain, "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 cf 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 tine 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, end that. he had not been able to see the source of the smoke before closing the door. He told the firs? office:, however, that he did not believz the fire was in the lavatory's trash container. The first officer told the flight attendant in charge that he was going forward to ge? smoke goggles.

At 1904:07, the first officer returned to the cockpit and told the captain thet 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 cnarge came to the cockpit and told the captain that the passengers had Seen moved fcrward and that the captain didn't "have to worry, I think its gonna be easing up." The firs: cfficer 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 cleai 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 srored 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 sea:. Sinee 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 discus the type of fire at ell" during the time he was in the cockpit before Te went to the lavatory the second time.

A? 1906:52, while the first officer was out of the cockpit, the flight attendant in charge told the ceptain 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. **tie** 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 io 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 end got into his seat, and *a?* 1907:11, ne 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 ha3 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% 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 4.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 end 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 toid 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 informetion 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 attitude D (LEX-D) controller called the approach eontroller at the Cincinnati Airport's Terminal Radar Control (TRACON) facility to alert him of an impending handoff in his southwest sector. *Six* seconds leter, ?he **LEY-D** controller told the approach controller at Cincinnati he had a "code for you," and at 1909:25, the LEX-D controller then toid 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-0 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

4/ The international radiotelephonic distress signal. When repeated three times, it indicates imminent and grave danger and that immediate assistance is requested.

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 bosrd 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 approacn 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 35 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 bosrd, 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 iight 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 controiler 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.)

5/ No gyro approach/vector — A radar approach/vector provided in case of a malfunctioning gyro compass or directional gyro. Instead of providing the pilot with headings to be flown, the controller observes the radar track and issues control instructions "turn right/left" or "stop turn" as appropriate.

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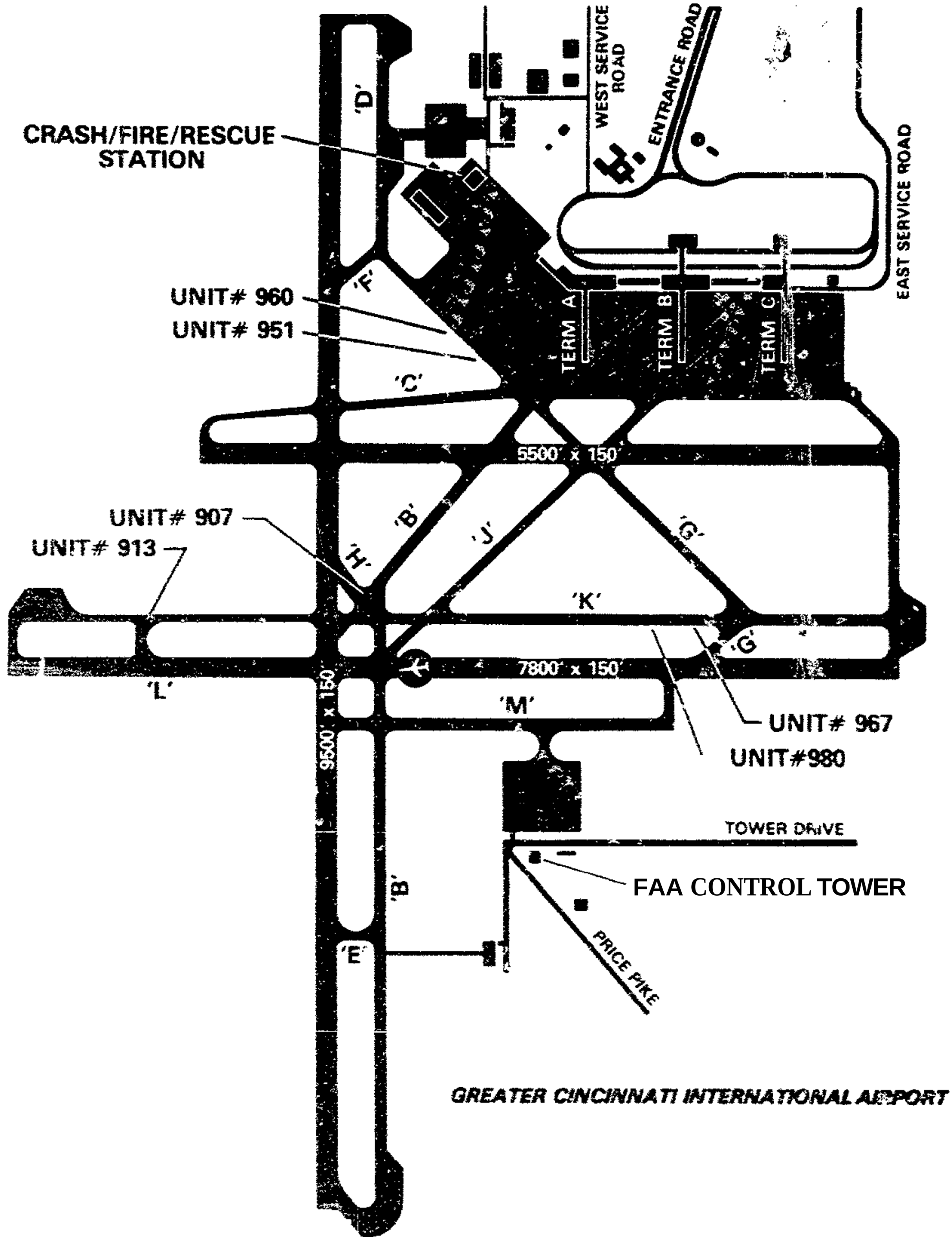

Figure 1.—Standby Positions of Crash/Fire/Rescue Units.

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 rnnge 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 Plight 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 ai-plane.—As the airplane descended, the smoke front continuously moved forward filling the passenger cabin an3 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 end 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 ked difficulty seeing the instruments because of the smoke in the cockpit and had to lean fcrward 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 then!. The firs; officer also wore his oxygen mask during the descent and set his oxygen system regulator to the 130-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 idie and the speed brakes were extended. However, wher 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 hac no effect OR the airspeed during the descenr but it increased the descent rate. The descent was flown at 310 knots indicated airspeed (KIAS), end since the needle on the instantaneous vertical speed indicator (IVSI) was pegged, the rate of descent exceeded 6,030 feel per minute (fpm).

According to the flightcrew, Flight 797 was ope-sting in visual meteorological conditions before the emergency descent. The captain said that the airplane was alm... totally in clouds from about FL 250 to about 3,009 feet: however, it did not encounter either turbulence or icing. At leveloff at 3,000 feet, the airplane was in end 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 3,003 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 end 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 ana my reasoning was I have to do something. ..." He said that he thought the packs were feeding the fire. A few moments afterwaid, he opened his sliding window in an effort to clear the smoke Prom 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.

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 143 KIAS and completed ?he 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 end R-I 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		
Serious	0	3		
Minor	0	13		
None	5	2		
Total	5	41		

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 report 7/, 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 additioc, 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 tine 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 End 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 e bad solder connection between circuits on the under frequency protection printed circuit board.

6/ National Transportation Safety Board Accident Report AAR-80-13.
7/ Air Canada Engineering Report No. 920-754-3, December 10, 1979.

Between May 7, 1983, and Yune 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 dune 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 eft 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 transparen? 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 end ended at 2024. Between 1900 ana 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; ternperature — 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; temperattire -- 62° F; dewpoint -- 55° F; wind 180° at 5 knots; altimeter setting -- 3C.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: 16/36, 9R/27L, and 9L/27R. Runway 27L is 7,800 feet long and 150 feet wide, snd has a grooved concrete and asphalt Runwây 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 epproach.

Standiford **Field,** elevation **437** feet, is 5 miles south of Louisville, Kentucky. The airport is cerrificated for commercial operation: in accordance with 14 CFR 139, Subpart D. The landing mea consists of two runways: 1-19 and 11-29. Runway 1-19 is 7,803 feet long end 150 feet wide, and has ***e*** concrete stirface, HIRL, and an approach light system. Runway **11-29** is **7,429** feet long and 150 feet wide, **end** 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 easing 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 heer 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 hermocics 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 ceptain said that the left a.c. bus was lost. Signals from the radio channels sre taken from the captain's and first officer's audio selector panels.

Flight Data Recorder.—The recording medium of the Leigh DFDX 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 ?he recorder stopped operating 1 hour 42 minutes into the flight while the airplane was at FL 330.

The DFDR recording contained several anomalies rhat took the form of signal spikes or data losses in a number of recorded parameter;. These anomalies were used to establish a correlation between the CVR end DFDR times. Since the DFDR did not contain microphone keying informetion, 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 XPU 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 mea of the upper fuselage down to below the level si the cabin windows was darnaged 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* figures 5 and 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 e large ares of paint had been burned away. The rectangular area began above the engine pylon end *extended* to the top of the fuselage. (See figures 3 and 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 hea? at the very top between the 11 o'clock an3 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 sway 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 *e?* FS 965. The soot pattern trailed rearward along the airplane's **side,**

Figure 3.—Left side. of the airplane.

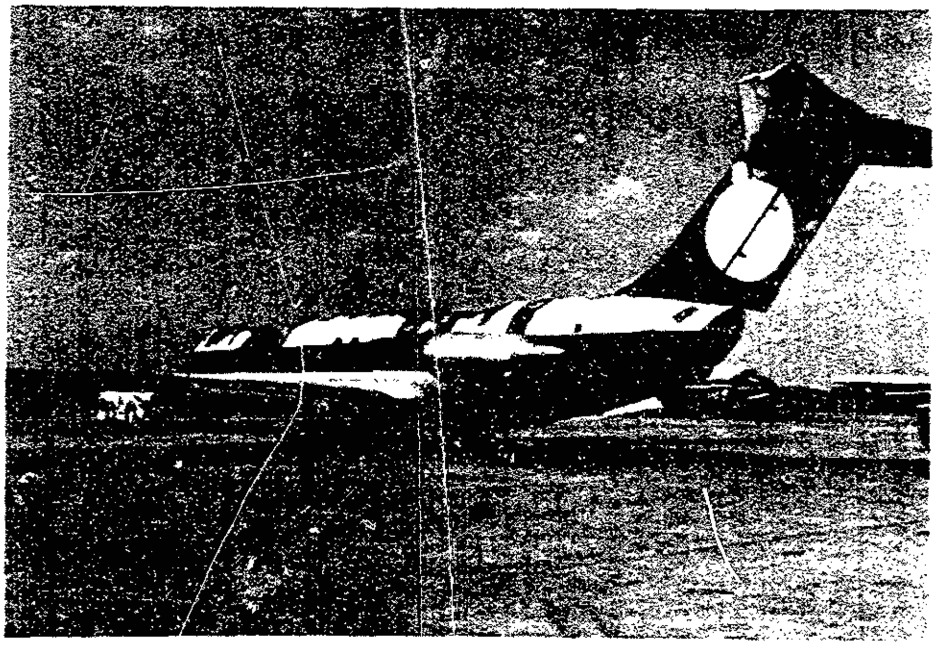

Figure 4.—Left side of the airplane, rear view, depicting rectangular burn pattern and soot trail.

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.)

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 figures 7 and 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 figures 9 and 10.)

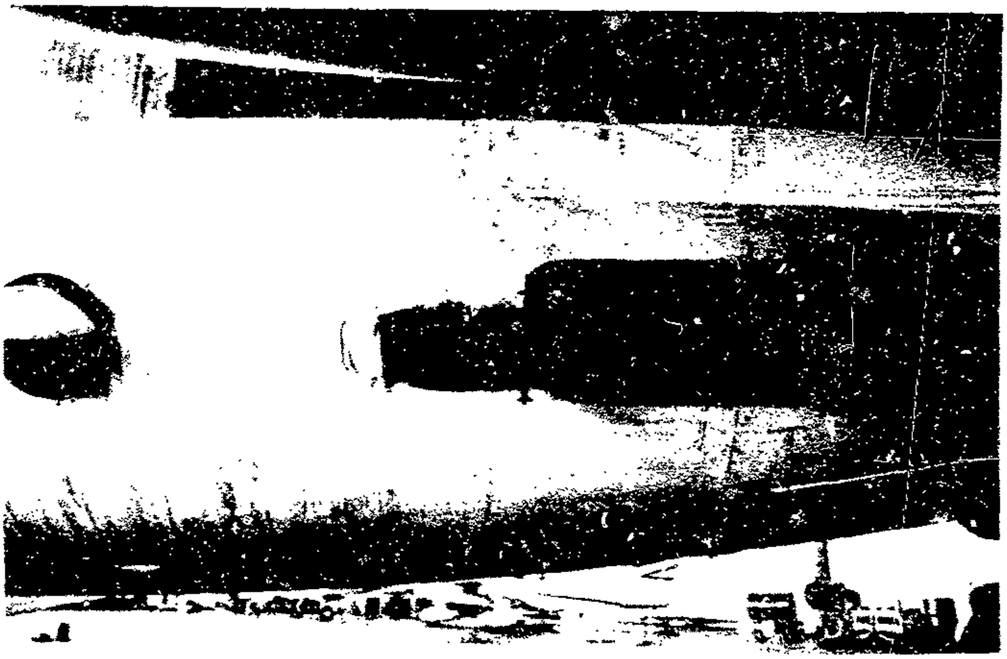

Figure 5.—Soot trail deposits on left side of fuselage at lavatory service panel and outflow valve.

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

Figure 7.—Cabin Interior viewed aft from the forward galley area.

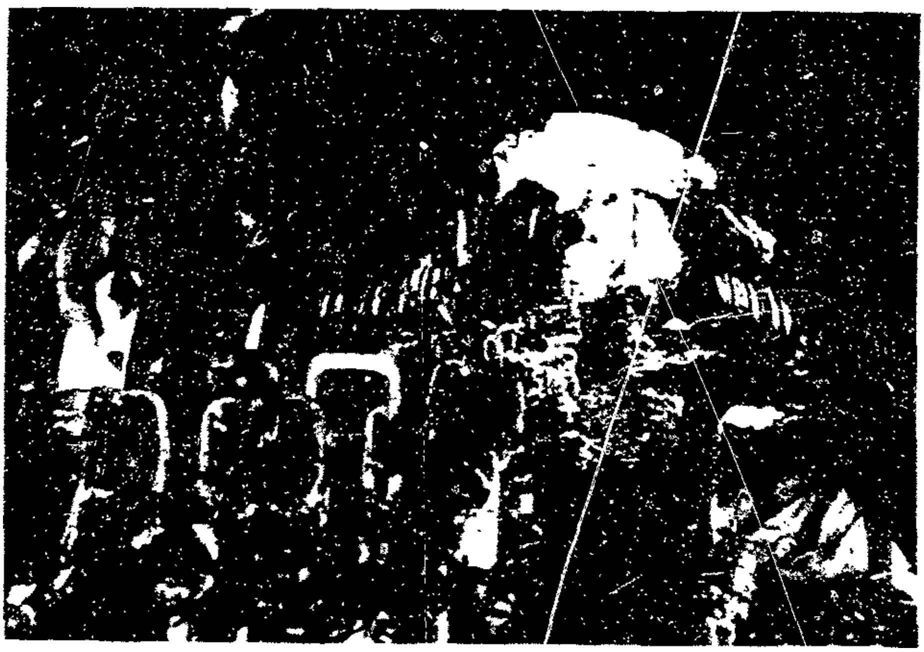

Figure 8.—Cabin interior viewed aft from the midwing area.

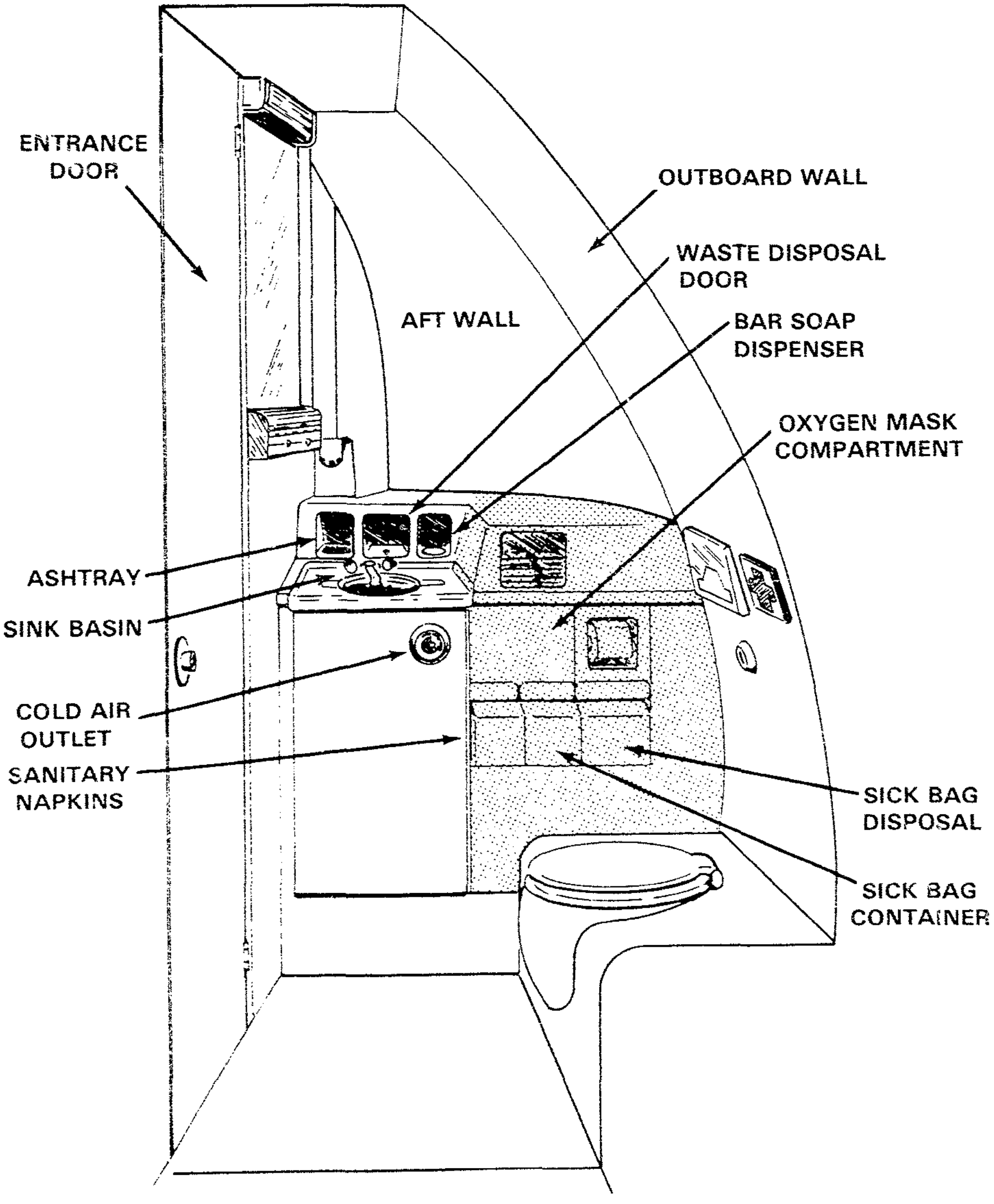

Figure 9.—Diagram of aft lavatory, viewed aft.

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 sectio.., 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.

9/ ASM Metals Handbook, Vol. 2, Edition 9.

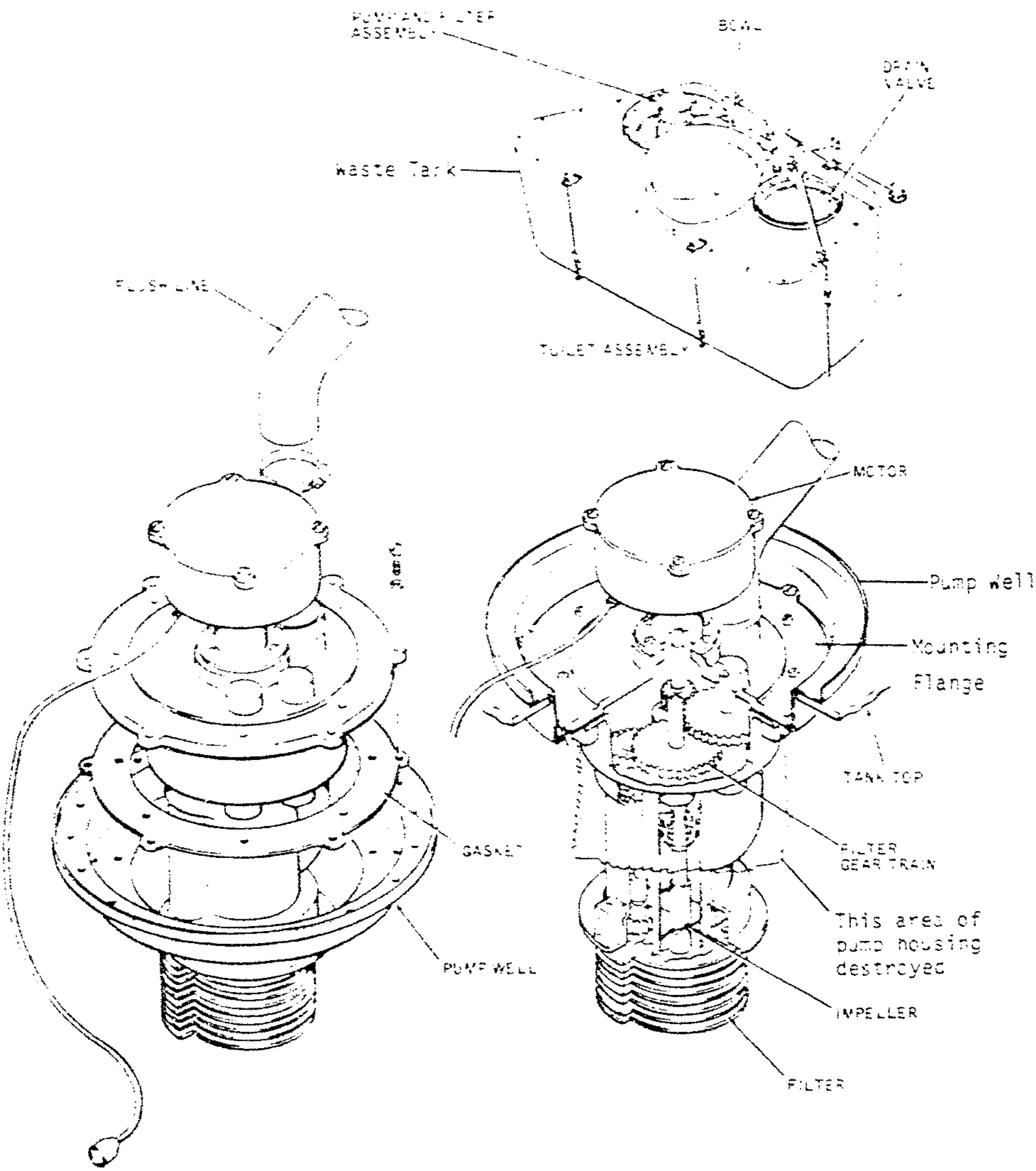

Figure 11.—Lavatory pump and filter system.

The flush timer was found intact. mounted in its normal position, on the inboard interior cabinet wall below and to the ieft 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 end all meting connections were examined. No damage was observed at any of the connections. The timer was removed for further examination.

Tie wiring harness that supplies 3-phase power from the timer to the toilet flush ... examined. The harness was undamaged between the timer and a point ... amenities portion of the vanity. The insulation had melted aweg from th... the wiring harness section between the midway point and the lightening hole 10 where the harness leaves the vanity and connects to the motor. The exposed in this section were brittle.

The wiring harness that supplies a.c. power from the ground service bus to the timer *.".e his!! button was found partially intact. The harness was undamaged in the area from the timer outboard IO the lower amenities portion of the vanity. From this point, continuing outboard and forward through the lightening hole in the vanity, the wire insulation end 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 e 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 tie harness in this area. The remainder of the harness, from a point just below the cabin floor forward along ?he 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 end toilet section through which the flush motor's power harness passes was examined. The nylon alligator grommet covering the hole's suriace 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 on', the portion of i5e bracket that was riveted to the structure remaining.

An electrical continuity check was made of the harness using e volt-ohm meter. Because the insulation had burned off ?he 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-io-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 irom the splices.

10/ A hole resulting from the removal of non-load carrying metal in airplane members for the purpose of weight reduction.

The power harness muting in this airplane differed from the McDonnell Douglas DC-9 installation drrwings. 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 seared with support ups and cable clamps around the pump well. The harness in this airplane was routed across rhe 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 wit:? the aft attendant comrnrnications 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 pane! 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 thet penetrated the aft pressure bulkhead was spliced just forward of the bulkhead. All of the spiices observed in the area of the eft pressure bulkhead and in the area of the aft lavatory were accomplished during repairs made to the airpiane 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 esamination. 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 interns! 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 beiow the aft iavatory.

The under floor blanket insulation along the aft tunnei 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 end ends at a venturi in the iavatory 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 anti 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 eondeits 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 tnrough 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 tie 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 APT' 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 nyion 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 ?he APU generators were disconnected ai the generator relays and at the engine and XPU 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 cui out and removed for closer examination. Each feeder cabie 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 ?his area. Another chafed area was in the C-phase line about 1/2 inch aft of the mete! 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 lavetory 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 inciudes the components used for a.c. and d.c. bus power distribution and fault protection, and the electronic components used for communications, cavigation, 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 lei: and right generator control panels; and the a.c. bus control pane!.

1.12.5 Cockpit Controls and Instruments

The reedings 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. Kith regard to the air conditioning and pressurization packs. the rem air switch was off, the right air Conditioning supply switch was off, an2 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 16 surviving and 23 deceased passengers and were analyzed by the FAA's Civil Aeromedical Institute, Oklahoma City, Oklahoma, for carbon monoxide, cyenide, fluorides, and ethyi alcohol. The results of the analyses indicated that the deceased had elevated carbon monoxide levels ranging from 20 to 63 percent saturetion; 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 0.6 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 oi 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 beiow 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 contrsct 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 tine cabin until after the flight had landed and tine survivors had iett the airplene. 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 ?he 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 et 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 e 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 tc 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 peopie would try io exit the airplane through the left forward door; therefore, he did not want to block that exit with a !adder 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."

Tte on scene command-r also testified that he wanted to enter the airplene 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 aftar the passengers were off of ?he 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

Table 1.--Responding **Airport** Crash Fire Rescue Equipment

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

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.

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 firs 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 abou: 800 feet from the airplene. 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 arid is based on of the iongest airplane having five or more daily scheduled departures from the airport. At the tine of the accident, the Greater Cincinneti 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 depa-tment 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 fiim forming foam, and two additional self-propelled fire extinguishing vehicles. The total quantity or' 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 tyoe 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, :here would be no waj 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 ana depicts how each fire extinguisher operates and what type extinguishe: should be used to fight different types of fires. With regard to a lavatory fire, Publieation 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 tine 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 he 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, drcpping 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 esits 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 tne 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

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

⊗ Fatality
◯ Survivor
⊕ Flight Attendant

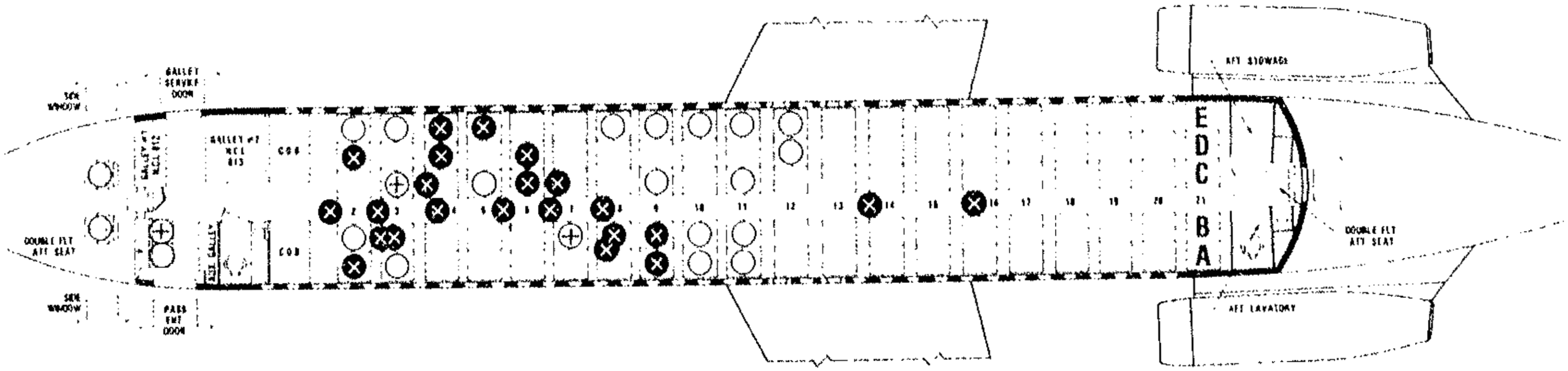

Figure 12.—Diagram of passenger seat locations.

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 the: 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.

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 Seen opened,

X 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 imtructions after the evacuation," and the flight attendant in charge is responsible for removing the megaphone. According Publication 355 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 beer! 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 evacustion procedures call for three flight attendents 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 13E is the aisle seat of the two seats adjacent to the left eft 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 Nc. 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 end 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 seatbeits 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 ieft 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 &re 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 corning. **At** that time, the heat was becoming too intense to remain, and he exited ?he 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 ?he airplane. Thereafter, she helped and supervised other passengers as they left the airplene. 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 infiated 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 attendents 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 exi: 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 scatbacks 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: So 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 ?he a.c. bus control panel, and the voltage regulators and generator control panels of the APU ana 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 cf 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 meta!; 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 front its mounting flange. The gasket between the motor mount and the mounting flange was brittie 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. Tne 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 nc 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 exemined using a scanning electron microscope (SEM). The X-ray energy dispersive analysis indicated tnat they were copper. The flush motor wiring harness was examined closely for any evidence of electrical arcing or shorting. The connector ai the flush timer end of tne 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 individuai 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 end were X-rayed, revealing no interne! 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 ?he time iimit designased in the specifications before it tripped. The Safety Board could not determine the reason for tne 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-phsse 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 indiviouai wires hed Seen gradually melted away; however, the fiberglass inner insuiation remained intact. The wires were bare of insulation over the iast 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.

Tne 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 eft 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, identicnl to that on Flight 797, was connected to a test fixture which provided 115-volt a.c. three-phase power through 5-ampere circuir 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 I minute 30 seconds after power was applied, smoke was visibly emanating from eround the motor cover piate. 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 stetor 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 tes: 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 no? reveal any internal electrical arcing or melting.

1.16.5 Fire and Heat Tests

During the investigation, the Safety Board conducted flammability tests 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 flus 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, Sew Jersey.

Cabin Materials Burn Tests.--The materials contained in ?he 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 io the seat cushions on Flight 797, was subjected to vertical and horizontal Bunsen Burner tests. The materia! failed the vertical test but passed the horizontal test.

The FAA project manage; 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 :he particular piece of foam tested hac 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 ana 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 io 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 tine 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 suppiy line were about 2, 5, **and** 7 BTU/ft^2-sec. There was no evidence of heat damage io the line and hardness test results showed that the line remeined 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, end the heat flux was measured. The maximum measured hear 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 **flus** remained *e;* 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 io 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. So air flow wes **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 shait rotation, these conditions simulated exactly the assembly of the accident airpiene.

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 :he accident airplane. The power supply end of the harness was protected **by** the use of rhree 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 io the location, in the vanity, where the timer was installed. The power harness was mated to :he flush motor through the use of H 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 Sow! about 5 minutes 45 seconds into the Zest. 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* shroudj of 157° F was reached 12 minutes 55 seconds after power was applied. Twenty-five minutes of data was recorded at which rime the test was terminated. So evidence of any deformation, discoloration, or overheating of any or' the vanity or waste tank components was observed.

The flush motor was removed from the lavatory mockup and examined. Oily resid–e was found below the motor cese on the mounting flange. When the top cover plate of the motor was removed, evidence of overheating of the cover gesket, rotor, **end** 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 **end** evidence of arcing at numerous points along its top outboard face was observed. The stator assembly was removed from the *motor* ***cese*** and exsmined. 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-5 winding to the stator assembly case, and the phase-C winding to the case. These resistance reedings were greater than 2 megohms ana 1.3 megohms, respectiveiy. The wire harness which provides power to the stator assembly showed no sign of damage.

In ?he seccnd test. ***e*** flush motor housing containing a controllable electric heating element was placed in the waste tank *in* the levatory mockup. The voltage to the heating element was then increased until the temperature on the outside the motor case reached a maximum or' 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 left 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 double: to the underside of the shroud around the toilet bowl cutout, flowed from the bond line and dripped *onto* the flush motor case. Tne 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, end 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 io 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 Chat 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 visibie where the wire bundles contacted the bottom of the lightening hole. Less thsn 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 YO ohms.

Both wiring harnesses were removed from the test fixture and examined. The power harness was discolored for about 2 1/4 inches. The iength of harness that was actually burned wes 13/8 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 bail could be seen on the wire. The flush motor harness was discolored for 2 inches and was actualiy 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 FAX 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 hoie 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 aistance 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 a? 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 Seen 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.

1.16.6 <u>*Airplane* **Cabin Fire Research**</u>

Small scale individual fire tests of cabin materials do not replicate the dynamic range *of* conditions present in actual cabin fires. Consequently, about 1978, tie FAA instituted a research program at its Technical Center involving full scale cabin fire tests. The tests are conducted in a full scale, wide–body test platform, constructed from *e* surplus McDonnell Douglas **C–133** airplane. The purpose of the tests has been to understand ana demonstrate the behavior of cabin materials in a postcrash fire. The results of these tests were described at the Safety Board's public hearing by the FAA project manager in charge of full-scale fire testing and are also contained in the Advisory Group for Aerospace Research and Development (AGARD) Report LS-123, "Aircraft Fire Safety." Of particular relevance to this accident are those data relating to flashover, fleshfire, seat-blocking, and cabin hazards crested *by* burning interior materials.

The **FAA** project manager testified that two main phenomena occur when large fires are expanding; one is the flashover, the other is flashfire, and mosi often, they occur in combination. Flashover in an airplane cabin environment occurs when enough heat has built **up** along the ceiling so that the radiant flux down to the materials below the heat layer reaches a level that is high enough to cause an almost instantaneous ignition of the material. FAA research has indicated that fleshover produces nonsurvivable conditions throughout the cabin within a mutter of seconds.

Flashfire is the burning of combustible gases. According to the **FAA** project manager, it "is really a mild explosion." Flashfire occurs when materials in a localized area burn and emit combustible gases. The combustible gases, a result of incomplete combustion, accumulate until they reach a flammable limit and will, if there is a source of ignition, ignite. The resultant fire will propogate rapidly, usually at the ceiling where the combustible gases have collected. With regard to the ignition source, the FAA project manager testified that the fire itself usually provided the source of ignition. Again, conditions inside rhe cabin will become nonsurvivable within a metier of seconds. Since flashfire is dependent on the concentration of heat and combustible gases in the upper levels of a cabin, airflow through the cabin would reduce the buildup levels by dispersing and venting some of the products overboard. The FAA project manager testified that airflow through a cabin would have a "vast influence on delaying" a flashfire.

The AGARD Report presents a survival model relating the effect of height above floor levei on survivability. The model tekes into consideration the effects of heat. carbon dioxide, carbon monoxide, hydrogen cyanide, and irritent acid gases such as hydrogen fluoride and hydrogen chloride. The report states that the survival model is hypothetical and its main purpose is to provide a means of predicting the time-of-incapacitation within a fire enclosure based on measures of elevated temperature and toxic gas concentration which change, in some cases substantially. with time. Thus, it is a tooi for reducing a fairly large number of somewhat abstract measurements into a single, cogent parameter: time-to-incapacitation, or the hypothetical time at which an average individual can no longer escape unassisted. How well the model relates to escape potential under actual fire conditions is unknown and, realistically, cannot be determined. It has been long recognized that a zone of safety exists near the floor inside an enclosure *in* which there is a fire. The validity of this belief was examined by measuring the major hazards at three elevations and calculating the survival time at each elevation. The calculated data showed that the survival times at 1 fee: 6 inches, at 3 fee: 6 inches, and at 5 feet 6 inches were 202 seconds, 193 seconds, end 159 seconds, respectively. 11/

1.17 Other Information

1.17.1 Air Canada Operational Procedures

Air Canada flightcrew's normal, abnormal, and emergency operational procedures are contained in its DC-9 Airplane Operating Manual (AOM). In addition to the flightcrew's normal, abnormal, and emergency procedures, the AOM contains descriptions of, and procedures for, cperating the airplane's systems and components. Unless otherwise noted, all procedures cited or excerpted herein are from the AOM.

Electrical System.--Two a.c. generators, one on each engine. provide electrical power for ?he airplane. A third a.c. generator, driven by the APU, serves as a standby a.c. electrical power source when the airplane is in flight. Four iransformer rectifier (TR) units transform and rectify the a.c. power output of the generators to provide a supply for all d.c. operated services and units. Automatic protective circuits will isolate the affected part of the a.c. system if certain faults occur and advisory annunciator panel lights located on the annunciator panel will indicate these conditions to the flightcrew.

Two nickel cadmium (Nicad) batteries are installed to supply a limited portion of the d.c. distribution systems under certain abnormal conditions and the batteries art maintained in a charged condition by a battery charger unit.

in the event all a.c. generating capability is lost, the flightcrew can piace the emergency power switch to "on" and route battery power to the emergency d.c. bus and emergency inverter. The emergency inverter, in turn, powers the emergency a.c. bus and provides a.c. power to essential airplane components among which are the airplane's attitude and heading indicating instruments.

11/ AGARD Report LS-123, page 6-18, Figures 9(a) and 9(b).

Individual units are protected by individual trip-free circuit breakers. These, when tripped, cannot be electrically reset until cooled. Those uni' , requiring three-phase supply will have individual breakers in each phase.

Electrical System Abnormalities.—The procedures to be followed in the event of circuit Sreaker trip(s) are contained in the abnormal operation section of the AOM. Unless directed otherwise in e specific abnormal operation, the pilots may attempt to reset any tripped circuit breaker. The procedure notes that it may be necessary To allow about 3 minutes cooling time before a circuit breaker will reset. It also states, "If the breaker will not latch or trips immediately efter reset, leave the breaker open (out)." The procedure also contains the following note, "Ail circuit breakers protecting a single phase ere trip free. Manually holding in a breaker which will not latch. will not complete a circuit."

The Air Canada Manager of Flying Operations testified that if a circuit breaker cannot be reset, flightcrews are instructed to wait for "an appropriate cooling period" and then try to reset it. If the reset fails, the circuit breaker is left out. He testified that "no more investigation is required because the electrical power to the malfunctioning circuit has been cut off and you don't want to do anything that might restore it."

The emergency procedures section of the manual contains a checklist for detecting the source of electricai smoke or fire. The 4-page checkiis: essentially requires the pilots to shut down each of the airplane's electrical system. assess the quantity of smoke, and then turn on each component of the system one ai a tine in order to ascertain which component is the source of the smoke.

Smoke Removal Procedures.--The following abnormal procedures concern the remove! of smoke from either the cockpit or the passenger cebin of the airplane:

The procedure used by Air Canada for removing smoke from the passenger cabin by opening the right forward galley door and eft pressure bulkhead door was developed by McDonnell Douglas. Its DC-9 cabin smoke remove! test flights showed that when the right forward galley service door and the aft pressure bulkhead door were unseated. smoke introduced into the cabin by smoke generators was forced forward and out of the galley service door. This flow patter:, was the result of the differential in airflow outside the two doors. The higher local airflow outside the galley service door produced a lower outside ambient pressure at the galley service door relative to the ambient pressure inside the tailcone at the aft pressure bulkhead door, thus forcing the smoke forward and out :he galley service door. The procedure was presented to the FAA for approval as an emergency procedure end was rejected. .According to the FAA DC-9 project manager test piiot, FAA disapproval was not based on the efficacy of the smoke removal capabiiity, but on the fact that it required a flight crewmember io leave the cockpit lo operate the doors during a period wherein it believed his presence was required in the cockpit. According to the test pilot, the FAA flight test personnel were not euthorized to judge whether or no! the door operation could be performed by flight attendants: therefore, based on the foregoing, the procedure was disapproved. However, the regufations did not preclude the manufacturer from providing the procedure to DC-9 operators as a manufacturer's recommended procedure. McDonnell Douglas provided the procedure to its DC-9 operators, and Air Canada, with tile approval of Transport Canada, incorporated the procedure in its AOM.

During the public hearing, a fire protection engineer who had participated in the on-scene investigation as a member of the Safety Board's structures group testified that in his opinion, if these doors had been opened as envisioned in the abnormal procedure, "there's a very strong potential that (the forward airflow) would have pulled the fire out of *the* lavatory into tne cabin and certainly would have moved the smoke forward and faster over the passengers heads." He stated that it would have endangered the passengers and also the safety of the airplane.

According to the captain, and the Air Canada manager of flight operations, ?he company did not advocate using the cabin smoke removal procedure unless the fire was out. The captain also testified that the procedure required the first officer to leave the cockpit in order to either supervise the opening of the doors or to open them. In the circumstances of *the* accident flight, given the airplane's electrical and mechanical problems, he Selieved the first officer was needed in the cockpit. Therefore, the captain did not consider ordering the crew to use the cabin smoke removal procedure.

Emergency Descent Procedures

EMERGENCY DESCENT

If structural integrity is in doubt, limit speed as much as possible and avoid high maneuvering loads

*	IGN Selector	OVERRIDE
*	CABIN SIGNS	ON
*	AUTO PILOT	OFF
●	THROTTLES	CLOSE
*	SPEED BRAKES	EXTEND
*	Initiate Descent	0 76 M/320-350 KIAS
●	Do not exceed 10° pitch down	
*	Do not retrim horizontal stabilizer	

AFTER DESCENT

When at minimum altitude, advise Flight Attendants to resume restricted operations and oxygen therapy as required

Cabin altitude below 10,000 ft.	CREW OXYGEN MASKS STOW
PA Announcement	AS REQUIRED

Air Conditioning and Pressurization System--Airplane pressurization and air conditioning is provided by the ieft and right air conditioning and pressurization packs (packs; which are supplied bleed air from their respective engines. Normally, the right system supplies the air requirements of the cabin and the left system suppiies the air requirements of cockpit.

The AOM states, "The distribution of conditioned air to the flight compartment is designed as a continuous smoke removal system." With ?he packs operating, conditioned air enters the cabin through ceiling outlets. The air is esheusted through perforated panels at the cabin floor line and through the left and right tunnels in the cargo Says to the outflow valve. The outflow valve controls the exhaust rate *to* the atmosphere. The airflow in the cockpit is similar to that of the cabin. Opening tne outflow valve, either manually or electrically, causes the airplane to depressurize.

Engine bleed air is furnished to the packs from the engine's 8th stage (low pressure) or 13th stage (high pressure) bleed air manifolds, depending upon engine power settings and the demands on the pneumatic supply. If the pack supply switch is in the "auto" position and the low pressure bleed air decreases to about 18.5 psi or less, the system's augmentation valve opens and high pressure bleed air is introduced into the system to maintain 18.5 psi. When bleed air pressure returns to 18.5 psi, the augmentation valve will close. (The augmentation valves are powered by the left and right d.c. buses and will fail closed if electric power is lost. The other two valves in the system -- the flow control and pressure regulation valves -- are powered by the d.c. emergency bus and will fail open if electric power is lost.) During a descent, if the. engines are at flight idle thrust, high pressure bleed air is required to maintain the minimum system pressure. At level flight thrust settings, at any altitude, the low pressure bleed air will maintain the pneumatic pressure at or above 18.5 psi.

At 33,000 feet, in level flight and with the pack switches in "auto," the entire cockpit and cabin air volume (4,391 cubic feet) is exchanged every 2.2 minutes. During descent to 3,000 feet with the engines at flight idle thrust, the time required to exchange completeiy the cabin and cockpit air varies from 2.3 *to* **2.7** minutes. In level flight at 3,000 feet. the exchange would be completed within 2.2 minutes.

The positions of the flow control and pressure regulation valves during flight could not be determined from their positions after landing. Regardless of the position of their respective pack supply switches. with no pneumatic pressure in the systems and with all electric power off the airplane, these valves would have returned to the open position. (There was no evidence that smoke entered the cabin through the air conditioning systen.)

With regard to the aft lavatory, the air supply enters the aft lavatory through the louvered door and from the overhead duct. it is vented out of the lavatory through the floor and the aluminum vent Tube within the toilet shroud. In addition, the flow of air in the amenities section of the vanity flows forward into the toilet area below the shroud and is also vented out of the airplane through the vent tube. Given this flow pattern, the **FAA** project manager was asked what effect opening the lavatory door and then chopping away the lavatory waii panels would have had on the fire. He testified that since he did not know the exact location of the fire or its intensity? it would be difficult to determine what effect opening the door would have had on the fire. "However, because there is a vast amount of ai? supplied through the vents in the lavatory," he did not believe that opening the door would have provided a large amount of addirional air to the fire. Consequently, opening the door might have allowed some smoke and some flames, if there were Flames in the area, to escape for a short period of time while the door was open. With regard to removing the lavatory paneling, he testified that *the* lavetory area is not a closed container; there is already airflow in the area behind the sidewalls. He suspected that opening the area by removing the paneling "would not sufficiently intensify (the fire). It may initially get it burning a little bit, but anything that you could do to get at the fire to fight it, if you had the means of doing so, and you could do it, should be done.:'

1.17.2 Use of Aft Lavatory

Passenger interviews indicated that the left aft lavatory was used several times during the flight. The last known passenger to use the lavatory stated that she had operated the toilet while she was in the lavatory and that it had operated normally, and she heard no unusual noises while the toilet was operating. She observed nothing unusual while she was in the lavatory and when she exited there was a male passenger waiting to enter. The male passenger **could** not be identified.

According to the passenger. about 25 minutes after she left the lavatory, she "heard *a* commotion in the back of the airplane." The passenger also stated that she does not smoke.

1.17.3 Smoke Detectors

The lavatories on board Flight 797 were not equipped with smoke detectors nor were they required to be so equipped by either Canadian or United States regulations. With regard to the capability of a smoke detector to detect the fire on board Flight 797 during its early stages, the FAA project manager testified that it would have depended upon the location of the detector. Had a smoke detector been placed under the lavatory seat, it might have detected a fire in that area very early after ignition. However, if a fire was in the lavatory itself, a detector under the seat might not have detected it early. He testified that, if the fire had been behind the walls of the lavatory, a detector installed below the lavatory seat might not have detected the fire because the airflow in the area might have been very small and flowing down the sidewall out of the lavatory and away from the detector rather than toward it.

The evidence developed by the Safety Board during the investigation showed that while technology has reached a point where smoke detectors that could be used in airpiane lavatories are available, unresolved problems curtail their acceptability. Among the problems noted by air carrier operators were locating the detectors, the sensitivity of the detectors, and the reduction of the false alarm rate to one that would be acceptable to an operator.

However, since the pdblic hearing, two U.S. air carriers have voluntarily installed smoke detectors in the lavatories of their airplanes. To date, these carriers have indicated that they have not experienced false alarm problems with the installations. One of these carriers, Pan American World Airways, installed residential type, battery operated ionization detectors on the ceilings of the lavatories of all the airplanes in their fleet. Since January 1, 1984, they have had 35 to 40 smoke detector alarms. Two of these alarms were caused oy actual lavatory trash bin fires. The fires were caused by cigarette ignition of waste paper in the bin. In these two incidents the smoke detector ectivated before the automatic Halon suppression system in the trash container activated. The majority of the other incidents were the result of passengers smoking in the lavatories and air contarnination of the cabin environment from some external source such as the airplane engines.

1.17.4 Examination of Other DC-9 Airplanes

During the investigation, the Safety Board examined the circumstances surrounding a report of heavy smoke which originated in the aft lavatory on board a chartered DC-9. The examination disciosed that the aft lavatory flush motor had overheated and had emitted smoke; however, there was no fire. During the examination of the vanity area, which was identical to that in the Air Canada DC-9, paper debris and a bottle top were found beneath the trash container and to one side of the trash container. Toilet paper was found on the lower shelf of the amenities section and the lightening hole containing tne flush motor power harness was stuffed with wadded toilet gaper.

1.17.5 Air Traffic Control Procedures

The indianapolis ARTCC and Cincinnati TRACON controllers provided ATC assistance to Flight 797 at the onset of the emergency, during the emergency descent, and during the subsequent landing. Indianapciis Center was equipped with a National Airspace System Stage A (NAS Stage-A) computer; the Cincinnati TRACON was equipped with an Automated Radar Terminal System III (ARTS III) computer. The NAS Stage-A computer can track, display, and attach a data block to a nonbeacon or primary target; the data block displays the airplane's call sign, ground speed, and last assigned altitude. The ARTS III computer in service at the Cincinnati TRACON could not track, display, or attach a daia block to a primary target; however, the airport surveillance radar was capable of displaying an airplane's primary target. Since Flight 797's transponder was inoperative, an automated handoff of the flight from Indianapolis Center to the Cincinnati TRACON was not possible. Therefore, the controllers used the interfacility landline to hand off the flight manually.

FAA Order 7110.65C, "Air Traffic Control,'! January 21, 1983, contains the recommended procedures for transferring radar identification of an airplane from one controller to another or from one facility to another. Controllers are required to be "familiar with the provisions that pertain to their operational responsibilities and to exercise their best judgment if they encounter situations that are not covered by it (the Order).':

The procedures require the controller initiating a manual handoff *to* convey to the receiving controller that he has a "handoff." Thereafter, he shall provide the receiving controller with the position of tine target relative to a **fix,** a ma:, symbol, or a known radar target which is displayed on the screens of both the receiving controller and the transferring controller. The controller initiating the handoff should provide the airplane identification, its assigned altitude, any restrictions, and if applicable, whether the airplane is climbing or descending. He should also advise the receiving controller of pertinent information not contained in the data block or flight progress strip. Pertinent information includes assigned heading, airspeed and aititude restrictions, observed track, and beacon code if different from that normally used or previously coordinated. The receiving eontroller shall, in turn, insure that the target's position corresponds with that given by the transferring controller or that there is **en** appropriate association between an automated data block and the target being irsnsferred before accepting a handoff.

Paragraph 661b of the Order states, "If identification is questionable for any reason, take immediate action to reidentify the aircraft or terminate radar service." With regard to identifying a primary target, parsgraph 254 states, in part, that a primary target can be identified ***by*** observing a target make[ing] an ideniifying turn or turns of 30 degrees or more, provided. . .only one aircraft is observed making these turns."

Three methods of identifying beacon targets are provided in paragraph 655. The controller can either request the airplane to activate the identification (ident) function of the transponder and then observe the identification display; request the airplane to change to a specific discrete or nondiscrete transponder code and then observe the display change; or request the airplane to change its transponder to "standby" and observe the loss of the beacon target, then request the airplane to return the transponder to normal, and observe the reappearance of the beacon target.

The Louisville high controller said tnat the handoff of Flight 797 to the Cincinnati TRACON was a "team effort," between him and the LEX-D controller. The LEX-D controller's positicn, which was located across the aisle from the Louisville high controller's position, is a nonradar position and is responsible for coordination between sectors, flight pian updating, and computer inputs. The LEX-D controller, who was radar-rated, had not been in direct communication with the Louisville high controller; however, he had overheard him discuss the emergency with Flight 797. The LEX-D controller did not cross the aisle either to observe the Louisville high controller's radarscope or to talk with him. He said that he tried to configure the radarscope next to his position to obtain a transponder code and data block on Flight 797, but his initial attempts failed. He knew the flight was being vectored to land at Cincinnati; therefore, at 1909:17, he called the Cincinnati TRACON on the landline to alert the Cincinnati approach controller of an impending handoff in his southwest sector. He also asked his radar controller seated at the radarscope next to his position to program the computer to display Flight 797's data block so that he could get its transponder code for the handoff.

The LEX-D controller stated that he also had overheard Flight 797 receive clearance to descend to 5,000 feet and to turn to 060°. He knew the airplane had an onbcard fire, but he was not aware of its electrical problems. According to the Center's standard operating procedures, Flight 797 should have been handed from Louisville High Radar Sector to the Evansville/Nabb Low Radar Sector and then to Cincinnati approach control. The LEX-D controller said that he independently made the decision to effect a direct handoff of Flight 797 from the Louisville high controller to the Cincinnati approach controller.

The LEX-D controller said that, when the approach controller accepted the handoff, he did not hear the approach controller say the 0662 transponder code; he only heard him say the altitude. He said that, at that moment, he was talking directly to his radar controller seated beside him and he believed that the "yeah" in his response was directed to his radar controller. He was not aware thet he had also trsnsmitted the word "yeah'! to the Cincinnati approach controller when he called later to correct the altitude.

According to the LEX-D controller, by 1909:25, Flight 797's primary target symbol and data block were being displayed on the adjacent radarscope. However, he did not tell the approach controller that Flight 797's transponder was inoperative because he was not sure that it was, in fact, inoperztive. He stated that a beacon can be missed for several sweeps of the radar antenne, and in the interim, until it is reacquired, the computer will display a primary target symbol on the radarscope.

The LEX-D controller stated that there were no beacon targets near Flight 797 during the handoff. He believed that he hed pointed out the correct target and that. the Cincinnati approach controller had accepted the target he had pointed out. Thereafter, at 1910:01, the LEX-D controller called the approach controlier on the landline and told him that Fiight 797 had been assigned a 060° heading and that the approach controller repeated the heading and signed off with his operating initials. At 1910:08, the LEX-D controller told the approach controller that the flight was descending to 5,000 feet.

When the Cincinnati approach controller was alerted to the impending handoff, he saw a westbound beacon target in the southwest sector of his radarscope. The target was above the 12,000-ioot upper altitude filter limit of his scope and was displayed as an asterisk with no data block. As a result of the 1909:23 and 1909:25 transmissions from the LEX-D controller. he knew he was accepting an emergency but he elso expected to receive a transponder coaed handoff. He used his computer trackball 12/ siewed to the target he had observed earlier, entered the position into his computer, and received a partial data block containing a 0652 transponder code and the airplane's sitirude -- FL 350. (Under these conditions, the partial. data block would only be displayed for about three sweeps of the redar antenna.) He advised the LEX-D controller of the code. the altitude he had observed, and when LEX-D answered "Yeah, thirty-three now. tie's twenty-five southwest." it confirmed his belief that he had identified and accepted Flight 797.

The approach controller said that there were no other beacon targets or primary targets near the 0662 code. He said he was aware of the altitude difference, but he also was aware that Flight 797 had declared an emergency and was probably descending. Therefore, the mode C altitude data might be lagging. At the time of the handoff, he had not been told the flight's assigned heading. Believing he had identified the correct airplane, he assigned a radio frequency and waited for Flight 797 to contact him.

The approach controller stated that after he had requested the 090° turn and saw no response from the target he had been observing, he observed a partial data. block containing an Air Canada 797 identification tag in the vicinity of the secondary target he had initially identified as Flight 797; the TRACON supervisor also stated that he had seen this data block. About 1911, the Evansville/Nabb D controller had "forced" an amended flight plan for Flight 797 into the Cincinnati ARTS III equipment. The flight plan, as amended, contained Flight 797's assigned transponder code, changed its destinstion to Cincinnati, and stated that the flight was descending to 10,000 feet. Had Flight 797's transponder been operating, the "force" would have configured the Cincinnati ARTS III computer to accept an automated handoff at the geographic point where the computer was programmed to accept handoffs from the Evansville/Nabb sector. However, since Flight 797's transponder was inoperative, the ARTS III computer could not locate a beacon target to associate with the "forced" data block and the "force" merely placed the data block on the approach controller's radarscope. The data block, because it did not match a properly coded beacon target, was displayed only for about three radar sweeps.

The approach controller was asked, based on his emergency procedures training, how far from the threshold of runway 36 he would have had to have placed Flight 797 in order for it land on that runway. He testified that it would depend on the weather. If the descent was conducted in visual flight conditions, he thought that "the pilot might be able to descend from five or six thousand feet from a point ten miles south of the airport at a slower speed and complete a landing. If it were an IFR (instrument flight rules) approach, he'd want to be level at twenty-five hundred feet or three thousand feet maybe seven or eight or ten miles from the airport. In this situation, it was difficult for me to judge how quickly the aircraft could descend (and) how tightly he could turn." The controller testified that he wanted to avoid vectoring Flight 797 to runway 36, have it arrive too high and too close to the runway threshold to complete the landing, and then have to circle the airport in order to land on another runway.

The controller was not familiar with nor was he required to be familiar with either the indicated airspeeds or the descent rate capabilities of a DC-9-30 airplane during an emergency descent. He also said that even if he had identified Flight 797's primary target earlier he would not have turned the flight away from the airport and toward the south in order to space it to land on runway 36. He would have "kept him going for the airport at all times."

1.17.6 ATC Radar Data

Data Analysis Reduction Tool (DART) radar data information was obtained from the Indianapolis ARTCC. The data included airplane position information and available mode C altitude information for Flight 797 and for Continental Airlines Flight 383, which was transmitting on code 0662. The Safety Board's laboratory reconstructed the ground radar tracks of both Flights 797 and 383. Runways 9R-27L and

12/ A movable position identification device available to the controller to identify radar targets on his radarscope.

18-36 of the Greater Cincinnati Airport were digitized and plotted with the ground tracks. Times of key transmissions and selected key events were included along Flight 797's radar ground track. The last radar fix retrieved from the DART's data occurred at 1914:15, and the last transponder information from Flight 797 was received at 1906:12. (See figure 13.)

1.17.7 DC-9-32 Descent Performance

According to the manufacturer, assuming a descent at flight idle **thrust,** landing gear retracted, flaps/slats retracted, speed brakes extended, at a temperature 3° C warmer than international standard atmosphere temperature **(ISA +3° C),** a final descent weight at 3,000 feet of 61,600 pounds, and at airspeeds of .78 Mach and 310 **KIAS,** Flight 797 was capable of achieving the following descent rates:

at 30,000 feet	7,800 fpm
at 20,000 feet	5,700 fpm
at 5,000 feet	5,100 fpm

The time required to descend from 33,000 feet to 3,000 feet was **5** minutes **11** seconds and the still air distance was 34 nmi.

Since the touchdown zone elevation of runway 27L at the Greater Cincinnati International Airport was 875 feet, additional time would be required to complete the descent from 3,000 feet, decelerate from descent speed, configure the airplane for landing, and fly the final approach. The Safety Board constructed a descent model containing the time required to complete these phases of the descent and landing. The model is based on the following assumptions:

Phase of Flight	Time
1. Descend from 3,000 feet to 2,000 feet at 500 fpm and decelerate from 310 KIAS to 200 KIAS.	2 minutes
2. Extend the landing gear, and extend the flaps incrementally; stabilize the airspeed at each flap increment.	1 minute
3. Final approach-descend from 2,000 feet to *675* feet at 750 fpm.	1 minute 30 seconds

Based on the times contained in this model and the manufacturer's performance data, the total time required to descend from 33,000 feet **and** land on runway 27L was **9** minutes 41 seconds.

The field elevation at Standiford Field, Louisville, Kentucky, is 497 feet. The Safety Board estimated that 10 minutes **11** seconds would have been required to descend from 33.000 feet and land at Standiford Field.

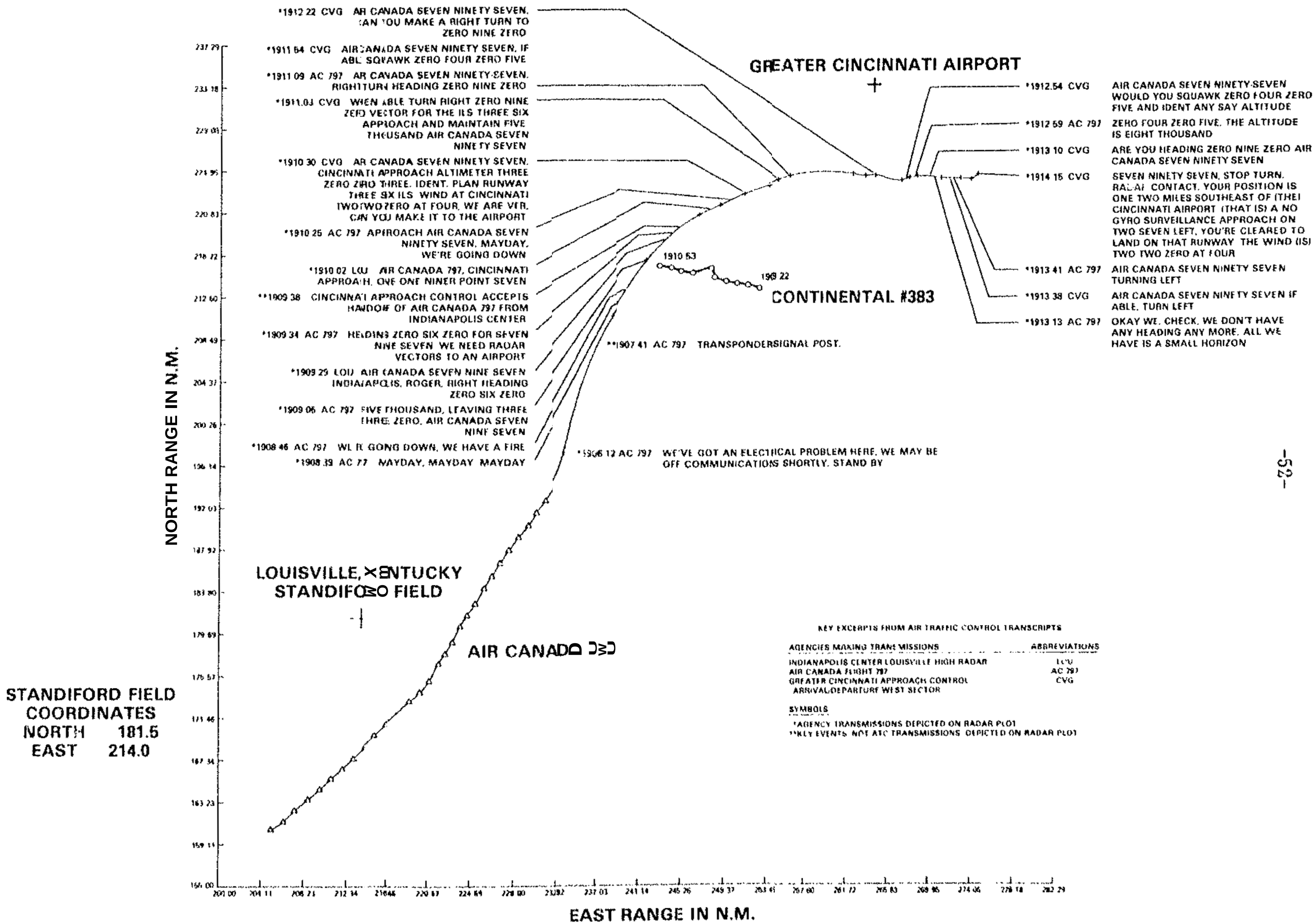

Figure 13.—Ground radar tracks for Flights 797 and 383.

As stated earlier, the captain had inadvertently extended the speed brakes to the ground position. According to the manufacturer, during the emergency descent at .78 Mach and then at 310 KIAS, the airflow over the wings would blow the speed brake panels down to the position they would have assumed had he extended them tc the position prescribed in the flight manual. Thus, despite the mispositioning of the speed brake control lever, the airplane's descent rates during the emergency descent would have been essentially the same as those cited above.

A? 1909:05, Flight 797 reported that it was leaving FL 330. Thereafter, it reported it was at 8,000 feet at 1912:59; at 2.500 feet at 1915:11; and, at 2,000 feet at 1916:07. Based on these altitude callouts, tine average rates of descent obtained during the emergency descent were as follows: between 1909:05 and 1912:59, 6,410 feet per minute (fpm); between 1912:59 and 1915:11, 2,500 fpm; and between 1915:11 and 1916:07, 536 fpm.

2. ANALYSIS

2.1 General

The airplane was certificated, equipped, and maintained in accordance with Transport Canede and U.S. FAA regulations and company policies and procedures. The flightcrew was qualified and certificated properly and the flight attendants were qualified for the flight. Each flight and cabin crewmember had received the training and off-duty tine prescribed by Canadian regulations. There was no evidence of any preexisting medical or psychological conditions that might have affected the performance of the flight and cabin crews. involved air traffic controllers were certificated properly, and each controller had received the training and off-dutp time prescribed by FAA regulations. Accordingly, the Safety Board directed its investigation to the ignition and propagation of the fire; to ATC procedures; to the performance of the pilots and flight attendants after the fire was discovered; and to factors which affected the survivability of the passengers and crewmembers.

2.2 Fire

Ignition.—The evidence substantiates a conclusion that when the smoke was detected by the flight attendants, there was a fire located within the vanity and/or the toilet shroud in the aft lavatory. Therefore, the Safety Board tried to identify all possible ignition sources in this area. Given the location of the fire at the time the smoke was discovered. the Safety Board identified five possible ignition sources: an incendiary or explosive device; deliberate ignition; a burning cigarette; the toilet flush motor: or the flush motor electrical harness. In addition to these five, the arcing damage found on the ieedcr cables of the left and right a.c. generators and the maintenance history of the airplane a.c. generating system led the Safety Board to investigate a sixth possible source of ignition—the generator feeder cables which were routed beneath the floor of the aft lavatory.

Based on the examination of the physical evidence and the results of the FBI laboratory analysis, the Safety Board concluded that neither an explosive nor incendiary device was involved. Also, there was no evidence that the fire was deliberately set.

Since the tests of tine materials used in the aft lavatory showed that they met the fire resistance criteria contained in **14** CFR 25, it would have been virtually impossible for either a lighted cigarette or sparks produced by electrical arcing to ignite the materials used in the construction of the lavatory. In order to ignite the lavatory partitions and walls, some combustible material capable of sustaining high temperature combustion for the amount lime necessary to ignite the lavatory walls had to have burned. Therefore, in investigating the possibility that the fire was ignited by a burning cigarette, the Safety Board focused on two areas below the vanity which could have contained combustible materials and into which a cigarette might have fallen—the *sink* area containing the trash chute and receptacle and the adjoining amenities section. Since the iavatory trash receptacle was ?he most logical place for combustible material to collect and since a burning cigarette could fall down the trash chute into the receptacle, the damage in this area was evaluated. Had a cigarette started a fire in the receptacle, the only propagation path out of the receptacle would have been the trash chute. In order for the fire to reach and short circuit the wires in the flush motor harness, it would have had to have burned from the top ***of*** the trash chute to the lightening hole containing the harness. The lightening hole where the flush motor harness wires had short circuited was several feet outboard and well below the top of the chute and the fire damage was not continuous from the top of the trash chute to the area of the lightening hole. Xoreover, it was unlikely that a fire could have spread from the top ***of*** the chute, which had burned away where it attached to the sink shroud, down to the flush motor harness, shorted the wires, and then remained undetected for 11 minutes.

Although there was some evidence of flame damage both in the area of the trash chute and the receptacle, the automatic Halon fire extinguisher had discharged only into the chute. The evidence showed that as the trash receptacle was being heated by the fire, warm air within the receptacle rose into the trash chute, and was trapped in the area where the heat-activated discharge nozzle was located. Based on the damage in this area, the Safety Board concludes that the air reached the melting point of the nozzle before the temperature below tne sink could attain that level and the entire Halon supply was discharged into the trash chute. In addition, since there was no evidence ***of*** a continuous flame path from the top of the trash chute down to the area of intense fire damage under the vanity, the Safety Board further concludes that the fire did not originaie within the trash chute. Also the presence of unburned trash within the trash receptacle further corroborates this conclusion.

The amenities section of the vanity was almost completely destroyed by fire. The flame patterns showed that the area of most intense burning was in the lower aft outboard corner ***of*** the void space located in the lowest level of the amenities section and almost directly below the failed cold air supply line. The fire was so intense that it melted a part of the aluminum bottom sheif in this area, while the rfmainder of the shelf remained intact. Since the cold air supply line outlet was closed, there was no airflow through this pipe initially. However, once the line melted through, airflow began which supplied air to the fire and caused it *to* intensify. The coid air supply line break coincided almost exactly with she most intensely burned area on the aft bulkhead. Given Chis evidence of fire damage and given the fact that the amenities section adjoins the sink area containing the trash chute ·nd receptecle, the Safety Board attempted to determine whether a lighted cigarette could have penetrated the void spncc of the amenities section.

An aluminum partition separated the sink section containing the trash chute and receptacle from the open space below the amenities section. However, about **4** inches above the floor there is a 4-inch-square hole in the partition through which loose material can pass into tine open space beneath the amenities section from the area beneath the sink. Thus, if the fit between the trash chute and waste disposal door or between the chute and trash receptacle had not been secure, it is possible that a lighted cigarette placed in the chute partition could have fallen from the chute and thereafter rolled or made its way through the hole into the open area below the amenities section. The fact that debris can enter this area was illustrated by the discovery of the vial and maintenance tag below Flight 797's vanity, and the waste materials found in this area on another air carrier's DC-9. The Safety Board concludes that the possibility thet this occurred cannot be ruled out.

To investigate the possibility that the fire was ignited as a result of an overheated flush motor, the Safety Board conducted two tests. The highest temperature achieved during the tests was 803° F, which was not high enough to ignite lavatory components in the vicinity of the flush motor. In addition, the motors used in the tests were damaged internally by heat. The flush motor involved in the accident did not show any evidence of internal heat damage or internal failure.

In order for the flush motor to overheat in service, three malfunctions must take place: the motor must seize; the flush button must be held in or fail in the depressed, or power on, position; and finally, the timer must either be defective or fail. (A properly functioning timer will limit the flush motor to a LO-second cycle even if the flush button is held in the depressed position. Once the timer cycles the motor off, the flush button must be released and then depressed again to restart tne motor.) The recovered components of the timer circuitry were tested functionally after the accident and were found to be operational.

The last known person to use the lavatory did so about 35 to 40 minutes before the fire was detected. She stated that the flush motor worked properly at that time. She also stated that another passenger was waiting to enter the lavatory when she left; therefore, the Safety Board conciudes that the flush motor was operating normally within 35 to 40 minutes before the fire was discovered. Given the facts that (1) the test demonstrated that an overheated flush motor would not produce temperstures high enough to ignite edjacen: lavatory materials; (2) evidence showed that the flush motor had not failed internally and was not damaged internally by heat: (3) there was no evidence to indicate that the flush motor timer had failed; and (4) the flush motor was most probably operating normally before the fire was discovered, the Safety Board concludes it unlikely that the flush motor was the source of ignition of the fire.

Another possible source of ignition near the area where the fire was discovered was the flush motor wiring harness. The tripping of the three circuit breakers accompanied by the arcing sounds recorded by the CVR occurred at 1851:14. The three circuit breakers tripped almost simultaneously indicating that the circuitry of all three phases shorted at the same time. The only evidence of wiring damage was found where the flush motor wiring harness passed through the lightening hole in the partition between the amenities section and the toilet section of the lavatory. The damage noted in the wiring harness et this location could only have been the result of fire and heat, and the Safety Board concludes :hat the damage to the wiring which caused the three flush motor circuit breakers to trip was caused by heat and fire.

Beginning 3 minutes 2 seconds before the 'hree circuit breakers tripped, numerous arcing sounds were recorded on the CVR. These sounds were accompanied by voltage fluctuations and the electrical components which showed these fluctuations, as well as the flush motor, were ell powered by the right a.c. bus. Because of the extensive fire damage in the area, it could not be determined whether the flush motor electrical harness had been properlv suspended in the lightening hole, or whether the protective grommet had been installed around the rim of the lightening hole. Based on the available evidence, a hypothesis that the grommet was missing and that the wires were not suspended properly before the fire cannot be supported readily by tangible evidence. However, assuming that this may have occurred, tests were conducted after the accident which showed that, although considerable force and effort were required to expose the conductors, the harness could chafe against the exposed edge of the lightening hole. The tests showed that the chafed wire could arc egainst the edge of the hole without causing the circuit breaker to trip. Such an occurrence could account for the unexplained arcing signals noted on the CVR. A trash fire ignited by this initial arcing could explain how an external heat source was generated which melted through the insuiation of the remaining wires and caused the circuit breakers to trip simultaneousiy. Also, tests demonstrated the simultaneous tripping of the three circuit breakers after a 4-minute exposure of the harness to a 4.4-BTU/ft^2-sec exrernal flame. Since the flammable source which fueled the fire initially could not be identified, the flame used in the test might not have been representative of the heat level of the initial fire aboard Flight 797. Although the Safety Board cannot eliminate the flush motor electrical harness as a possible ignition source, given the facts that (1) the tests demonstrated that a great amount of effort end force was required to chafe away the flush motor harness and ?he insulation of the wires in the harness; and (2) the fsct that the harness would not have been subjected to the abuse during actual operating conditions that it was subjected to during the tests, the Safety Board concludes it unlikely that the chafing of the harness wires against the lightening holes was the source *of* ignition for a fire in the amenities section of the aft lavatory.

The sixth possibility of an ignition source — a high resistance short circuit on a generator feeder cable where it passed through ihe lightening hole in the floor beam below the lavatory floor at FS 980 — was considered primarily because of clear indications of arcing between the left and right engine generator feeder cables and the floor beam. These indications consisted of a notch burned into the floor beam ai FS 980, chafed areas on both engine generator feeder cables which exposed the bare conductors at FS 980, and the physical indications of short circuiting on the exposed conductors of both feeder cables. Further, this potential ignition source was in proximity to the floor of the af? lavatory. In addition, this ignition source was gven consideration due to repeated electrical problems with this aircraft prior *to* the fire and the "electrical arcing" sounds recorded on the CVR. This arcing was recorded **3** minutes prior to the ?ripping of the three circuit breakers on the lavatory flush motor. **A** decrease in the right a.c. bus voltage occurred simultaneously as recorded on the DFDR.

For ignition from this source to occur, the cable must have contacted the aluminum frame at FS 980. This would assume that the conduit was either missing and/or broken, that the cables were not supported properly at FS 980, and that the differential current fault would have been of a low order which would elude the protective circuits designed to trip the generators. Given these conditions, it appears possible that sufficient electrical energy could be transferred from the cable to heat and eventually ignite the nylon conduit and propagate a fire to other combustible materials, probably the epoxy behind the aft and side walls of the lavatory.

The damage and destruction which occurred beneath the lavatory floor in the vicinity of FS 980 precluded a determination of whether the generator feeder cables were properly suspended within the lightening holes at that location; however, the evidence of chafing in the Pibergiass insulation of the generator feeder cables where they passed through the lightening hole at FS 980 indicates that the cables may not have been properly supported, and that they could have sagged and chafed against the floor beam. Further, although the fault protection circuitry had actuated and had tripped the generators off the Line, this occurred about 14 and 15 minutes after fire damage had caused the three circuit breakers of tine flush motor harness to trip. Since the protective circuit?? only operates when the current differential between the generator and the bus exceeds about 20 to 40 amperes, it appears that a transfer of up to 40 amperes through the abraded cable insulation could have provided sufficient heat to have ignited the nylon conduit.

In an effort to examine the possibility of the generator feeder cables as an ignition source, the electrical system discrepancy reports were reviewed to determine whether any might have indicated an intermittent electrical short circuit in the generator feeder cables. The analysis failed to disclose a problem that could be related to such a condition in the feeder cables, even though the electrical problems continued up to the time of the accident flight.

Because of the extensive damage at FS 980, it was not possible to determine if the electrical wiring was properly secured and protected, nor was it possible to positively establish a fire pattern which would permit a conclusive determination that the fire started as a result of a generator feeder cable fault. However, this possibility could not be dismissed.

Propagation.—Regardless of the ignition source, the physical evidence showed that there was an area of intense burning in the lower aft outboard corner of the lowest section of the amenities section, and it also showed that the fire propagated forward from that point. As the fire moved forward from the amenities section, it also burned through the lavatory walls allowing the smoke, hot gases, an6 fumes to rise in the air space between the lavetory shell and the airplane's outer skin and between the aft pressure bulkhead and the lavatory's liner walk The seams connecting the lavatory side walls and ceiling walls are not sealed: thus as the smoke rose, it began to enter the lavatory through the sidewall and ceiling seams, while the fire remained concealed behind the amenities section and below the toilet shroud.

As the fire moved forward into the area between the toilet shroud and the top of the waste tank, the hot gases, smoke, and melted plastic were still being vented overboard through the lavatory vent line. The vent line exits the lavatory and enters the tunnel in ?he aft cargo compartment aft of FS 980. It is then routed forward below the generator feeder cable bundles to a point just forward of FS 965 where it exits the airpiane through a venturi in the lavatory access panel. The hot gases caused the aluminum vent tube io melt away, thus permitting the entry of superho? gases into the floor beam area below the lavatory floor and ?heir impingement on the generator feeder cable bundles where they passed through the lightening holes in the floor beam located at FS 980. As a result of the heat, faults developed on the left and right generetor feeder cables, and between 1905:35 and 1907:41, the protective circuits tripped them off the Line.

The flexible connection for the waste tank flush and fill pipe and its check valve assembly was located close to the inlet of the lavatory vent line. When the flexible connection and the plastic ball in the check valve failed, this stainless steel flush and fill pipe also became an overboard vent. The denosits of soot and tar on the access door to the lavatory service panel and the melted rivets in the pipe connector at the service panel confirm that the pipe aid become an overboard vent.

The path of almost all fires is upward and in the direction of the airflow. Except for the damaged area below the lavatory floor, the fire damage noted on the airplane was above the airplane's floor line. The lowest and aftmost point of fire damage was within the amenities section at the outboard part of the lavatory and the forward wall of the aft pressure bulkhead, respectively. From this location, based on the damage pattern, the path of the fire was upward and forward. The direction of airflow within the amenities section and the toilet shroud was aiso forward.

The damage below the lavatory was in the tunnel below its floor. While there was some evidence of fire damage, the damage in this area was for the most part heat damage, and the lavatory floor had not burned through. The most severe damage in this area was located above the failed lavatory vent tube between FS 965 and FS 980. In this area, the suspension and insulation of the generator feeder cables had melted away and arcing had occurred. Given the proximity of the failed lavatory vent tube to these cables and the type damage noted on the cables and structure in this area, the weight of the evidence indicates that the damage in this area was caused by the hot gases from an existing fire in the lavatory being vented through the tube. This evidence tends to further corroborate the hypothesis that the arcing of the generator cables was the result of the fire and not the source of its ignition.

The momentary smoke abatement noted by the firs? officer and flight attendant in charge between 1904:16 and 1904:23 was probably attributable to the dilution effect of opening the lavatory door and discharging the CO_2 into the aren. reclosing the lavatory door, and the almost simultaneous failure of the 'lavatory vent line and the flush and fill pipe connections and check valve, all of which increased the ventilation rate beneath the toilet shroud and accelerated the flow of smoke and gases to the area below the lavatory floor and overboard.

The rectangular scorched area on the airplane's outer skin above the left engine and coinciding with the aft lavatory's frame channels snowed that as the fire consumed the lavatory structure it used the airspace between the lavatory outboard wail and the airplane's outer skin as a flue. The superheated gases progressed up these channels and forward along the space between ceiling liner and the airplane's outerskin, and Segan to preheat the ceiling panels. Smoke and fumes generated by the fire Segan to collect in the ceiling space. The smoke, fumes, and hot gases then entered the cabin through the ceiling and sidewall liners end Segan to collect in ?he upper portions of the cabin.

After the captain stopped Flight 797 on the runway. both forward exit doors and three overwing emergency exit windows were opened and an unlimited supply of fresh oxygen became available to the fire. With this availability of oxygen. the preheating of the ceiling panels, and the large quantities of unburned gases in the upper cabin, a back draft and flashfire occurred, and the fire progressed rapidly through the entire cabin. Tne evidence showed that the carpets, the lower portions of the sidewall panels, and combustible portions of the lower seat structure, including armrests, did not ignite and burn, whereas almost all combustible materials above the windowline were destroyed or heavily damaged by fire including large portions of the airplane structure and skin. The physical evidence indicated that the fire in the cabin ignited initially near the ceiling and thereafter the seat surfaces were ignited by the heat radiated from the fire ai the ceiling and luggage rack level. Therefore, the Safety Board concludes that flashfire. rather than flashover occurred.

Based on estimates by firemen and passengers, the flashfire probably occurred within 60 to 90 seconds after the doors and overwing exits were opened. The upper fuselage skin, after the cabin ceiling's insulation blanket was consumed by fire and the cooling effects of the airflow of flight ended, failed rapidly. The absence of significant smoke stains on the outside of the open exits supports this view, since following the failure of the upper fuselage skin, the airflow would reverse and go in the windows and doors and out the ruptured fuselage skin at the top of the airplane.

In summery, although no positive conclusion can be drawn as to the precise point of origination of the fire, the evidence indicates that the fire propagated through the lower part of the amenities section of the lavatory vanity. Because of the direction of the airflow from the areas below the vanity and above the toilet waste tank, the smoke, fumes, and hot gases were vented overboard and pulled away from the passenger cabin and the open area of the lavatory, allowing the fire to burn undetected for almost 15 minutes. The first noticeable evidence of smoke within the open area of the lavatory was observed after the fire penetrated the lavatory liner and began to rise behind and outboard of the liner. Smoke then began to penetrate the sidewall and ceiling seams of the lavatory Lining as described by the two flight attendanrs.

2.3 Operational and Survival Factors

The captain and first officer testified that they did not hear the arcing sounds recorded by the CVR. The DFDR showed that the arcing sounds were accompanied by voltage excursions on the right a.c. bus. The airplane's wiring diagrams showed that the DFDR and CVR wiring was routed near the generator cable feeder bundles. Spectrum analysis of the arcing sounds showed that they contained harmonics that were above the frequency range that would normally be detected by the microphone and preamplifier in the cockpit area microphone (CAM) channel. Given the proximity of the CVR wiring to the generator cable bundles, the Safety Board concludes that the arcing signal was electromagnetically induced into the CAM's circuitry and, therefore, not audible to the flightcrew. Since the ercing sounds which were recorded by the CVR were not heard by the flightcrew. the tripping of the flush motor's three circuit breakers at 1851:14 was the first abnormal occurrence they noted.

At 1851:27, the captain tried unsuccessfully to reset the circuit breakers. At 1859:58, he again tried unsuccessfully to reset the three circuit breakers. Air Canada flightcrews are taught to meke one attempt to reset a tripped circuit breaker. They are taught that it may be necessary to allow a 3-minute cooling time before a circuit breaker will accept a reset and that circuit breakers protecting a single phase are trip free: therefore, a circuit cannot be completed by holding in an unlatched single-phase circuit breaker. Most important, they are taught that a tripped circuit breaker denotes that the circuit protected by the circuit breaker is no longer powered. The flightcrew and other Air Canada flight personnel stated that circuit breaker trips during flight are not an uncommon occurrence, and the procedure contained in Air Canada's DC-9/AOM allows personnel to cope adequately with such occurrences.

In this case, the captain sttempted to reset each of the tripped circuit breakers twice; the first attempt occurred almost immediately after they had tripped and was unsuccessful. He testified that he "thought at the time that the unit (flush motor) might be overheated so I just continued the routine of the flight.. .and after a certain time had passed. . .I attempted to reset the circuit breakers again to make sure. . . . The circuit breakers would not move." Although the captain was unable to detect any movement of the circuit breakers, the CVR showed that arcing sounds. which were not audible to either the captain or first officer, accompanied each attempt to reset each circuit breaker indicating that the circuit breaker had moved and momentary electrical contact had been made. However, once the contact was made, the protective circuitry caused the breaker to trip again. Since the fire was already well established, the attempts to reset the circuit breakers had no effect on the sequence of events. About 1902:40, 11 minutes 26 seconds after the initial trip of the three flush motor circuit breakers, the No. 2 flight attendant informed the flightcrew that there was *e* "!fire."

When the circuit breakers tripped, there was no resson. based on their training, for either pilot to surmise that an emergency capable of compromising the **safety** of the airplane existed. Aithough in this instance the **failed** component could be checked visually, the abnormal procedures checklist made no distinction between faiied components which are visually accessible to crewmembers and those which are not. The pilots are required only to allow the circuit time to cool, and thereafter, limit themselves to one reset attempt. If the circuit breaker cannot be reset, they can assume that the component is shut down and, if required, perform the action set forth in an applicable checklist. While it can be argued that the captain, from the standpoint of passenger comfort, should have requested a fiight attendent to inspect the lavatory and ascertain :he reason, if possibie, for the failure of the flush motor circuit, it was a matter of Judgment on his part as to whether he should require this to be doze. In retrospect, his decision not to do so may have forestalled an early opportunizy to discover the fire.

Initial actions taken by the cabin crew when the smoke was discovered weie inadequate to assess quickly the origin and scope of the fire. When the flight attendent in charge opened the lavatory door, he was able to see into the Lavatory and observe that the smoke was emerging through the seams of the aft wall of the lavatory. Even though he stated that he knew the fire was not in the trash container, he never did open the door of the sink compartment to inspect visually the trash chute and container. The dispersal of the CO_2 into the lavatory had little or no effect on the fire. In order for the extinguishing agent to be effective, it must be applied to the base of the flames.

According to Air Canada procedures, the fire axe should be used, "if necessary,!' to remove paneling to obtain access io the fire. After assessing ?he situation in the lavatory, the flight attendant in charge did not request that the exe **be** brought to him from the cockpit because he did not believe he could use it. He testified that *he* did not consider using the axe to remove the paneling because, "I would have to destroy half rhe aircraft to get to it." The flight attendant in charge's testimony *also* showed that, while he knew the company procedure, since he had nst been shown which paneling could be removed with the fire axe without endangering critical airplane components, he was reluctant *to* use the axe. Xoreover, he was afraid that this action migh: provide a draft to the fire and accelerate combustion.

Based on the conditions in the lavatory, the Safety Board cannot determine whether removing the lavatory paneling would have enabled the flight attendant in charge to expose and attack the fire successfully or whether the remove: of the paneling would have acceicrateci the propagation of the fire. Further, given the situation inside the lavatory, even had the fire axe been brought to the lavatory, the Safety Board is **not** convinced that the flight attendant in charge could have carried out the firefighting activities contained in the **Air** Canada manual effectiveiy without a full face smoke mask with self-contained breathing apparatus.

After he had dispersed the CO_2 into the lavatory and ciosed the lavatory door, the flight attendant in charge briefed the first officer on what he had done. **Also,** he told the first officer that he did not believe the fire was in the trash container but was located elsewhere. Neither he nor the first officer told the captain that they had not seen the fire and that they did not know exactly where it was or how intensely it was burning. On the other hand, the captain did not question either man about the Iocation or severity of the fire.

The only crewmembers to observe the conditions in the lavatory were two flight attendants. The first officer made two trips aft, but did not enter the lavatory. He retreated the first time because he did not have smoke goggles with him: the second time, based on the heat he felt on the lavatory door, he decided that it was not advisable to open the door. Since the flight attendant in charge and the first officer were not able to determine the location of the fire, they were not able to assess the severity *of* the fire. Consequently, based merely on their assessment of the course of the smoke drifting into the lavatory though the seams of the lavatory walls, they provided the captain with an inadequate assessment of the fire's severity.

The fire was reported to the captsin at 1902:40 and he directed the first officer *to* go aft and assess the situation. About 1904:07, the first officer returned to the cockpit and he told the captain, "I think we had Setter go down;" however, he later testified that at that time he was not thinking of an emergency descent. Almost simultaneously, the captain received a series of optimistic reports from both the fiight attendant in charge and rhe first officer concerning the smoke conditions in the aft cabin area, and at 1904:46, the captain directed the first officer to go aft a second time to reassess the conditions in the aft cabin area. As a result, about 5 minutes 30 secoxds elapsed between the time that the No. 2 flight attendant told the captain there was e fire in the aft iavatory and his decision to begin the emergency descent. While an actual in-flight fire is an extremely rare occurrence, ail reports of smoke in the cabin must be regarded as potentially serious. However, such reports often turn out to be smoke from an overheated flushing motor or waste ignited by a discarded cigarette in a trash receptecle designed to contain a fire, conditions which are normally identified and corrected by flight attendants without further consequences. Therefore, the Safety Board realizes that there is a need to evaluate the situation before deciding on the emergency action required. However, in this case, the time to make the decision appears excessive given the circumstances. Most significantly, neither the flight attendant in charge nor the first officer was able to **fix** precisely the source of the fire or to assure the captain that it had been extinguished. The Safety Board believes that a precautionary emergency descent should have been initiated as soon as it became evident that the fire had not been visually located and could be attacked directly with extinguishant. This became known at 1904:07 when ***the*** first officer came forward from his first inspection of the aft cabin area, about 3 minutes before the decision to begin an emergency descent.

At 1904:07, after the first officer returned from his first trip aft, Flight 797 was about 14 nmi northeast of Standiford Field, Louisville. Kentucky, at FL **330.** Had the emergency been declared at this time and the descent started, performance data indicate that Flight 797 could have landed at Standiford about 1914:18, or about 5 minutes 51 seconds earlier than it landed at Cincinnati. However, given the actual conditions in the airplane Juring the descent, it is not realistic to expect the captain to have duplicated the times and optimum rates contained in the descent performance profile. For example, the evidence showed that during the actual descent, the total time required to descend from 33,000 feet to 3,000 feet was about 1 minute longer than that required in the descent profile. The Safety Board believes thet ?he evidence indicates that it would be reasonable to assume that, given the conditions in the cockpit, the descent and landing wouid require 1 to 2 minutes longer than the elapsed time shown in rhe descent profile. Therefore, the Safety Board believes that, had Flighr 797 landed at Standiford Field, the flight most probably would have landed about 3 to 5 minutes earlier than it did et Cincinnati.

While the research data does not permit the Safety Board to conclude whether the shortened flight time would have delayed or prevented the flashfire, there can be no doubt that the decreased exposure time of the passengers to the toxic environment in the cabin would have enhanced their physical and psychological capability to escape after the cabin doors and overwing exit windows were opened. Consequently, the Sefety Board conciudes that the delayed decision to descend contributed to the severity of the accident.

At 1908:12, when the captain did declare en emergency, Flight 797 was closer to Cincinnati than Louisville; therefore, the Louisville high controller vectored it toward the Greeter Cincinnati Airport and cleared it to descend. At 1909:05, the flight departed FL 330 and it landed at Cincinnati at 1920:09. in the process, however, there was a faulty ATC handoff which occurred at 1909:38.

The Safety Board concludes that the faulty interfacility handoff leading to the misidentification of Flight 797 resulted from the attempt on the part of :he controllers at the Indianapolis Center to expedite the handling of an aircraft experiencing a dangerous in-flight emergency. The Safety Board believes that the LEX-D controller's decision to hand off Flight 797 directly tc Cincinnati approach control wes a valid exercise of the controller's discretionary authority and if handled properly wouid have eliminated additional radio frequency changes and decreased flightcrew and controller workloads. The Safety Board also concludes that by beginning tine handoff without direct communica-lion with the Louisville high sector controller who was handling Flight 797 end by not including him directly in the handoff procedure, the timely transfer of vital information between the two facilities was either compromised or never accomplished. The most important omission was the LEX-D controller's failure to tell the Cincinnati approach controller thai he was being handed off an airplane with an inoperative transpcnder.

The Cincinnati approach controller also contributed, though to a lesser degree, to the faulty handoff. Instead of waiting for the initiating controller to apprise him of the identification, transponder code, heading, and altitude of the target to be transferred. he trackballed out to the target he assumed was the subject of the alerting call he had received from Indianapolis Center at 1909:17. Thus at 1909:23, when :he LEX-D controller told him, "I got a code for you," instead of waiting for the remainder of the information, he supplied the transponder code to the initiating controller and thereby ccntributed to the ensuing communications breakdown. The primary question presented by the faulty handoff was whether it delayed the landing of Flight 797. At 1909:05, when Flight 797 began the emergency descent, the DARTS data showed that it was about 27 nmi southwest of, and turning toward, the Greater Cincinnati Airport. According to the optimum performance data, it would require 34 nmi to descend from 33,000 feet to 3,000 feet. In addition, the winds aloft data showed that the winds during the flight's descent were from the west at speeds ranging from, about 85 knots at FL 330 to about 8 knots at 3,000 feet; thus it would require more than 33 nmi lo descend to 3,000 feet. The evidence was conclusive that regardless of which runway the controller elected to use for landing, he would have to vector Flight 797 through some type of traffic pattern in order to land it at Greater Cincinnati Airport. In this case, he elected to vector it to land on runway 27L.

According to optimum descent performance data, it would require 9 minutes 41 secocds to descend and land at the Greater Cincinnati Airport. Since the descent began at 1909:05, the earliest possible landing time was 1918:46, or 1 minute 23 seconds earlier than the flight had actually landed. However, since it is unrealistic to expect the captain to have duplicated the optimum descent data during the approach, and given the small difference between the calculated landing time and the actual landing time, the Safety Board concludes that the faulty handoff did not delay the landing of Flight 797 appreciably. Since the descent and landing at Greater Cincinnati Airport was accomplished expeditiously and since ATC procedures did not delay the landing, the Safety Board concludes that the only factor which significantly delayed Flight 797's landing was the flightcrew's delayed decision to descend.

During the descent. the smoke in the passenger cabin continued to accumulate; it was heaviest at the ceiling and became ircreasingly thick from the ceiling down to the floor. As the airplane descended, the smoke moved forward in the cabin. In addition, with tile loss of electrical pcwer, the augmentation valve in the pressurization system closed, and high pressure bleed air was not available. Therefore, when the engines were retarded to flight idle for the descent, little or no fresh ai? was being introduced into the cabin. Some of the passengers noted that air stopped flowing out of the eyebrow vents during the descent, confirming that the augmentation valves had closed. However. when the airplane was leveled off after the descent and engine thrust applied, the exchange of air would have been restored, provided the: the air conditioning and pressurization packs had not Seen turned off.

The captain's difficulties during. the descent were compounded by the condition of his flight instruments. About 8,000 fee: during the descent. the emergency inverter was lost. The Safety Board could not determine the cause of the failure: however. with the loss of the inverter. the emergency a.c. bus was lost. The airplane's ADI's, horizontal situation indicators, and radio magnetic indicators became inoperative, an6 the only attitude indicating instrument available was the small emergency standby ADI. The captain flew the latter part of the descent, tne treffic pattern, and the landing using the standby ADI and his airspeed indicator. In addition, with smoke entering the cockpit, he had difficulty seeing the instruments.

The damaged cockpit door was not closed sfter the first officer reentered the cockpit. The captain had not ordered the door io be left open and was, in fact, not aware that it was open. The first officer had decided to leave the door open because it facilitated communication with the cabin crew. As a result, the smoke entered unimpeded into the cockpit. Since the louver panel was missing from the cockpit door, closing the door would not have blocked totally the entry of the smoke. However, even with the panei missing, a closed door would have delayed the accumulation of smoke within the cockpit.

The smoke in the cabin increased rapidly during !he emergency descent: however, the flightcrew did not try to use the cabin smoke elimination procedure -- depressurize the airplane after it descended below 10,000 feet. open the aft pressure bulkhead door, and open slightly the righ! forward cabin door. The captain testified that he did not order the procedure to be used because the fire was not out and because he needed the first officer'.; assistance in the cockpit in order to fly the airplane safely. Had this procedure been tried, the airflow through the cabin wouid have been directed forward and nut the right forward cabin door. Though ideally the procedure would be used when a fire has been extinguished, according to the airplane manufacturer, the procedure can be used when a fire is still burning. According io the manufacturer. the flightcrew must judge whether survival depends on the elimination of the entrapped smoke regardless of the effect that a draft of air might have on the fire. However, the fire protection engineer who investigated the airplane fire damage believed that opening the doors would have created "a very strong potential" that the fire would have been drawn from the lavatory into the cabin; that the smoke would have been moved forward faster; and that the use of the procedure would have endangered the passengers and the safety of the airplane. The evidence concerning what would have happened had the procedure been used was highly conflicting, and therefore, the Safety Board will not speculate as to what might have occurred had the procedure been used.

After descending through 3,900 feet, the captain ordered the first officer to depressurize the airplane in order to prepare it for landing and to insure that the flight attendants and passengers would be able to open the doors and overwing exits. The first officer depressurized the airplane and then, although the procedures do not require this to be done, turned the air conditioning pack switches off which still would have been operating because they are powered by the emergency d.c. bus. The evidence showed that the captain did not order the first officer to shut off the air conditioning packs, nor did he know that they were shut off. The first officer testified that after the airplane had been depressurized he decided to turn the packs off because the smoke was getting bad; he thought he had to do something, and he thought that "those packs, they are just feeding the fire."

The statement and testimony concerning when the air conditioning packs were shut off is slightly conflicting. However, the consensus of all the testimony and statements indicated that they were almost certainly turned off by the time the airplane reached 2,000 feet. The ATC transcripts showed that Flight 797 reported "at two thousand five hundred (feet)" and "we're VFR now," at 1915:11 and 1915:27, respectively. The flight landed at 1920:09. Based on the flightcrew's testimony and statements and the times in the ATC transcript, the Safety Board concludes that the air conditioning packs were turned off at least 4 minutes before the airplane landed in which almost two complete changes of cabin and cockpit air otherwise would have occurred.

During the descent, the augmentation valves in the air conditioning and pressurization packs had failed to the closed position; therefore, the smoke in the cabin and cockpit was not being purged overboard as rapidly as it would have been had these valves remained operational. Consequently, the rate at which the smoke was filling the cabin and cockpit increased which may have led to the first officer's belief that the air conditioning and pressurization packs were supplying air flow to the fire. Given the conditions that existed in the cabin during the descent, the first officer's action was understandable; however, when the packs were shut off, the best available means of eliminating smoke from both the cockpit and the cabin was inoperative. Since the ram air valve never was opened and the pressurization system had been shut off, there was virtually no fresh air supply to the cockpit and cabin. With no exchange of air in the aircraft, smoke and heat continued to accumulate at the ceiling and to build down toward the floor and the toxicity of the air in the cabin began increasing at an accelerated rate. Moreover, with no airflow available to reduce the buildup of heat and combustible gases at the upper levels of the cabin, the onset of factors conducive to flashover or flashfire was accelerated.

In conclusion, once the decision to descend was made the flightcrew executed an emergency descent and then, in coordination with the approach controller, flew a descending traffic pattern to the landing runway using only rudimentary airplane instrumentation. The captain, though confronted with a hostile cockpit environment, loss of engine and flight instruments, and an inoperative horizontal stabilizer trim system was able to maintain his concentration, end with the assistance of his first officer, configure the airplane for landing, slow it to the desired indicated airspeeds, and despite the unfamilar longitudinal control forces resulting from the inoperative horizontal stabilizer, land the airplane safely. Cc idering the conditions which confronted the captain during the descent and landing, the Safety Board concludes that the captain exhibited outstanding airmanship without which the airplane and everyone on board would certainly have perished.

Evacuation of the Airplane

Although fataiities occurred, this accident must be considered survivable because none of the survivability factors were violated. By definition, a survivable accident is one in which the forces transmitted to the occupants **do** not exceed the limits of human tolerance to abrupt acceleration, either positive or negative, and in which the structure in the occupant's immediate environment remains structurally intact to the extent that an occupiable volume is provided for the occupants throughout the crash sequence. 13/ In this accident, the fuselage integrity was not breached during the landing and none of the occupsnis were exposed to decelerative forces beyond the limits of human tolerances.

According to the passengers and flight attendants. when the airpiene landed the visibility in the cabin was virtually nonexistent at heights higher than 1 foot above the cabin floor. In addition, during the descent and landing, the passengers and crew were exposed to constantly increasing quantities of smoke and toxic gases, and these factors combine? to make the evacuation procedures more difficult to execute and complete.

The flight attendants' efforts to move the passengers forward of row 12 2nd away from the source of the smoke and heat (except for two passengers in seats 12D ani 12E who had refused to move because their seats were next to the right forward emergency exit window) *and* their selection and briefing of able-bodied male passengers to open the four overwing exit windows, apparently were successful since three of these four exits had been opened and were used by surviving passenge-s. Additionally, the flight attendants attempted to brief passengers on how io assume the brace position and other items relevant to the emergency situation. However. because of the smoke an6 toxic gases in the cabin, they had great difficulty communicating, and in some cases, passengers did not hear all these instructions. Virtually ail the survivors stated that they had covered rheir mouths and noses with towels, articles oi clothing, or other like items, as instructed by flight attendants. Wet towels will filter out smoke particles, acid gases such *es* hydrogen chloride and hydrogen fluoride, and hydrogen cyanide. While breathing through items of clothing will elso filter out smoke particles, the clothing would probably be less effective in filtering out the acid gases and hydrogen cyanide. Neither filter system will reduce the carbon monoxide concentration. Therefore, although this procedure was not contained in the company manual, the initiative on the part of the flight attendants to distribute wet towels and instruct the passengers to breathe through the towels or other items of clothing may heve aided the survival of the passengers.

13/ Aircraft Survival Design Guide, Volume 1: "Design Criteria and Checklists," U.S. Army Research Technical Laboratory, Technical Report 79-22A, December 1980.

In spite of these efforts, several factors limited the success of rhe evacuation of the passengers. The flight attendants at the forward doors were not able to make themselves heard inside the cabin. The location of the fatalities in the cabin tends to confirm that those who succumbed either made no attempt to move toward an exit o? started too late and were overcome as they attempted to move toward an exit. Studies indicate that in the absence of ccmmands, some passengers will remain seated and await orders, a phenomenom known as "behaviorial inaction." 14/ It is also possible that some of ?he passengers were incapacitrted because of exposure to toxic gases and smoke during the descent and landing.

The statements and testimony of the survivors who exited tine airplane through tine overwing exit windows indicated that the visibility in this area of the cabin was probably worse than that in the forward cabin. The survivors who had moved aft to reach ?he overwing exits found them because they had memorized i'ne number of rows between their seats and the exits and thereafter counted the rows by feeling tine seatbacks as they moved aft; because they 'were able to see a dim glow of light when they reached the exit area; or as in one case, the survivor felt *a* slight breeze across the back of her legs when she reached the arta of an open exit,

The evidence showed that the cabin environment deteriorated rapidly after the doors and overwing exit windows were opened. Although all of the passengers had Seen seated forward **of** row **13** when the airplane stopped, two of the fatalities were found in the cabin aisle at rows 14 and 16. It is likely that these passengers hac made their way aft trying to locate the overwing exits; however, the visibility had deteriorated so badly that they were not abie to locate them. Based on this evidence and the difficulties experienced by the survivors who were able to locate the overwing exit windows, the Safety Board believes rhet had floor levei, or near floor level, emergency lighting denoted the location of the overwing emergency exit windows, not only might these two passengers have been able to find them, the task of the other survivors would have been made easier. Many of the survivors stated that they were able to see better either by bending forward or by crawling. The survivors?experiences appeared to follow closely the results of reseerch contained in the AGARD report concerning the stratification of toxic gas concentrations within *a* cabin and its effect on survival times. Based on the results of the FAA's cabin environment research studies, the Safety Board concludes that the cabin environment became nonsurvivable within 20 to **30** seconds eftnr the flashfire.

The evidence also indicated that there were instances in which the flight attendants had not complied completely with the Air Canada evacuation procedures. In the event of failure of the PA system, Air Canada procedures direct the use of a mega- phone to make required announcements before the airplane door and exit windows are opened. Even though the flight attendant in charge knew that the airplane PA system was inoperative, he did not remove ?he megaphone to make the announcements prescribed in the company briefing format. Although he was busy attending to a sick passenger-, :?e could heve required one of the other attendants either to take care of the passenger or to take the megaphone and make the announcements to augment the individual briefings given to the passengers by the Nos. 2 and **3** flight attendants. The Safety Board concludes that had this been done, the emergency briefings probably would have been heard, by more, if not all, of the passengers, and in any event in greater detail. However, even had all the passengers heard the briefings, the Safety Board cannot conclude that this would have aitered appreciably the sequence of events which occurred after the doors and exit windows were opened. One of the required announcements contained in the briefing

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14/ Daniel Johnson, "Behavioral inaction Under Stress Conditions Similar to the Survivable Aircraft Accident," Safety Journal, 1972, First Quarter.

format would have directed the passengers to remain seated while the flight attendants completed opening the doors and exit windows and until the attendants directed them to get up and move toward the doors and exits. The evidence showed that a passenger seated in row 2 had, in fact, been briefed to restrain the other passengers from moving toward the forward doors until he received the evacuation command from the flight attendant in charge. This procedure is designed to prevent congestion at the doors and exits so that the attendants can operate them without interference. In a smoke-free environment this is an excellent procedure; however, on Flight 797 the procedure would have operated to the detriment of the passengers. The poor visibility made it impossible for the passengers to see either the opened doors, the opened exit windows, or the flight attendants. Given these conditions and given the contents of the briefing announcement, the Safety Board believes it highly unlikely that the use of the megaphone during the descent would have provided a better briefing to the passengers who did not move after the airplane stopped and the doors and exits were opened.

Since neither the No. 2 or No. 3 flight attendant was able to reach and occupy her designated emergency landing position, no direct supervision of the emergency evacuation through the overwing exit windows was provided by a flight attendant. Both of these attendants were in the cabin aisle either briefing or attending passengers when they were directed to sit down by the first officer. Despite that, they continued to move along the aisle checking seatbelts and briefing and comforting passengers. Since the conditions in the cabin made it impossible for them to look outside and estimate how soon the airplane would land, it was incumbent upon the flight attendants to seat themselves as soon as possible after receiving the first officer's command. The No. 2 and No. 3 flight attendants were seated in seat 3C and in an aisle seat in rows 7 or 8, respectively, when the airplane stopped.

Neither flight attendant tried to reach her designated supervisory position at the overwing exit windows. In order to do so, the No. 2 attendant would have had to have moved aft against the flow of passengers moving toward the forward doors. The No. 3 flight attendant was closer to the overwing area. However, had she tried to go aft, it is doubtful if her presence would have altered the evacuation sequence at these exits. She probably could not have reached the exits before the passengers seated at rows 10 through 12 reached them, opened them, and left the airplane. The survivors who exited the airplane through the overwing exit windows stated that they barely had the strength and presence of mind to negotiate the exits and that they were 3 to 5 rows closer to the exit than the flight attendant. Even assuming that the No. 3 flight attendant had reached the area of the exits, her ability to exercise supervisory functions at the four exit windows would have been diminished severely, if not totally.

In summary, the evidence showed that two flight attendants had opened the two forward doors, deployed and inflated the slides, and attempted to call out required commands and directions to the passengers. They remained at their posts at those doors until they were either driven out by the heat or until they believed that no more passengers were moving toward the doors. They had briefed passengers on the location and operation of the overwing emergency exit windows. Though not required by company procedures, they had, until directed by the first officer to "sit down," passed out wet towels and directed the recipients to breathe through them and otherwise attended to the passengers. The Air Canada procedures require their flight attendants to "do all possible to evacuate everyone, but they are not obliged to risk their own lives." Given the location of the flight attendants when the airplane stopped on the runway and given the conditions within the cabin at that time, the Safety Board can only conclude that any attempt by the flight attendants to move farther aft into the cabin and to remain within the cabin for any appreciable length of time could not have been made without placing their survival in dire jeopardy and that it is doubtful that additional lives would have been saved thereby.

2.4 Firefighting

The response of the crash-fire-rescue units and the methods used by the firefighters to extinguish the fire on board Flight 797 were consistent with those used to fight typical airplane fires, primarily fuel spills and interior fires. The tactics used by crash-fire-rescue units in response to these types of fires are designed to protect the passengers leaving the airplane and to assist them in moving from the endangered area. Thereafter, rhe attempt can be directed to save the airplane. The effcrts of the firefighters in this case were complicated by the fact that they did not know how many passengers and crewmembers were on board and they did not know how much fuel was on board. However, they did know that smoke had been reported coming from the airplane's aft lavatory and that there was smoke or fire in the rear of the airplane.

In evaluating the attempts to attack or contain the fire, the question arises as to whether an entry at the left forward door with a handline would have been possible and more logical. From this location, the fire might have been pushed back and several passengers possibly rescued from the interior. When the firefighters arrived at the airplane and began applying foam on the top of the fuselage and on the runway directiy underneath the airplane, flames were not visible. The fire did not become visible untii after the last survivor had left the airplane. The on scene commander testified that when his personnel began the attack, passengers were still exiting through the left forward door, and he believed that an attempt to enter the airplane at that door at that moment would have impeded passenger egress. He also believed that the deployed escape chute would have impeded and slowed the entry of his personnel into the airplane. In addition, the firefighters did not know the seat location of the passengers. Therefore, the first interior attack was mounted at tine left overwing exit and was designed not only to assist the passengers in this area, but also to insert firefighters between the fire and the remainder of the passengers still on board. The decision to mount the initial interior attack through the left overwing exit was an operational decision made by the on scene commander, and was based upon his assessment of the situation. Based upon the evidence, the Safety Board concludes that his decision was reasonable and that the ensuing flashfire could not have been averted by other tactics.

The evidence also showed that the firefighters involved in the three interior attacks were not abie to don their protective hoods over their self-contained breathing apparatus. The lack of protective hoods impeder: the interior attacks. Testimony of the FAA's airport safety specialist indicated that the requirements for protective equipment for airport firefighters are ambiguous or nonexistent, and tnat the provisions of 14 CFX 139 do not specify the need fc: training in interior firefighting tactics. The deficiencies of 14 CFR 139 in addressing crash-fire-rescue training and protective equipment have been addressed in some detail in the National Transportation Safety Board's recent Airport Safety Study. 15/

2.5 In-flight Fire Prevention/Detection

During this investigation, the Safety Board identified the continued presence of causa! factors similar to those identified in previous Safety Board investigations of

15/ Safety Study: "Airport Certifications and Operations." (NTSB/SS-84/2).

airplane lavatory and cabin fires. As a result of these earlier investigations, the Safety Board had made recommendations to the FAA designed either io preclude the recurfence of similar occurrences or to minimize their severity should they recur. Had comprehensive action been taken in response to some of these recommendations, the Safety Board believes that the severity of this accident would have been lessened. On September 5, 1973, the Safety Board issued the following Safety Recommendations to the FAA:

> Require a means €or early detection of lavatory fires on all turbine-powered, transport-category aircraft operated under Part 121 of the Federal Aviation Regulations, such as smoke detectors or operating procedures for the frequent inspections of lavatories by cabin attendants. (Safety Recommendation *A-73-61)*

> Require emergency oxygen bottles with full face masks for each cabin attendant on turbine-powered transport aircraft in order to permit the attendants to combat lavatory and cabin fires. (Safety Recornmendation A-73-68)

While the **FAX** has required more frequent inspections by flight attendants, neither smoke detectors nor full-face smoke masks are required by regulation to be placed on board transport category aircraft. Given the conditions inside the lavatory on Flight 797 when the flight attendants first opened the door, the Safety Board believes that an operable smoke detector would have alerted tine crew to the existence of the smoke before it was actually discovered.

The flight attendant in charge was able to see tine aft wall and that smoke was emerging from the seams in the lavatory walls when he entered the lavatory. The Safety Board believes that had an oxygen bottle with a full-face smoke mask been available and used, it might have encouraged and enabled the first attendant to take immediate and aggressive actions to locate the source of the smoke and to fight the fire, as set forth in the company manual. The Safety Board believes that had either the smoke detector or the full-face smoke mask, or both, been available and used on Flight 797, the ccnsequences would have been less severe. There can be little doubt that, at the very least, earlier detection of the smoke would have produced a more prompt assessment of the severity of the conditions in the lavatory, and consequently an earlier decision to descend and land.

3. CONCLUSIONS

3.I Findings

1. The airplane was registered, equipped, acd maintained in accordance with Canadian regulations, and it was operated within the United States in accordance with applicable Federal Aviation Regulations.

2. The flightcrew and the cabin crew were qualified and trained in accordance with Canadian regulations and Air Canada requirements. Each crewmember had received the off-duty times prescribed by Canadian regulations.

3. A fire propagated through the amenities section of the aft lavatory and had burned undetected for almost 15 minutes before the smoke was first noticed.

4. The fire was not set deliberately nor was it the result of an explosive or incendiary device.

5. The Safety Board could not identify the origin of the fire.

6. The first malfunction to evidence itself to ?he flightcrew was the simultaneous tripping of the three flush motor circuit breakers, about 11 minutes before the smoke was discovered. Tne flightcrew did not consider this to be a serious problem.

7. The smoke in the aft lavatory was discovered by a flight attendant. The smoke was reported to the captain as a fire.

8. The source of the smoke was never identified either by the flight attendants or the first officer. The captain was never told nor did he inquire as to the precise location and extent of the "fire," which had been reported to him. Thereafter, he misconstrued reports tnat the fire was abating and he delayed his decision to declare an emergency and descend.

9. Because of the delayed decision to descend, the airplane lost the opportunity to be landed at Louisville. Had the airplane been landed at Louisville, it could have been landed 3 to 5 minutes earlier than it actually did land at Cincinnati. The delayed decision to descend and lend contributed *to* the severity of the accident.

10. A fauity ATC handoff did not delay significantly Flight 797's landing at Greater Cincinnati Airport.

11. The fire consumed the lavatory walk, propagated into the ceiling, and then began to move forward. Smoke, toxic fumes, and heated gases began to enter the cabin, spread forward, and collect along the ceiling of the cabin.

12. The flight attendants' passing out wet **towels** to the passengers and instructing them to breathe through the towels or through articles of clothing aided in the survival of some of the passengers.

13. The first officer turned off the air conditioning and pressurization packs in the belief that the airflow was feeding the fire. The resulting loss of circulation accelerated the accumulation of smoke, heat, and toxic gases in the cabin and likely decresst the time available for evacuation.

14. Three of the four overwing exit windows were opened by designated passengers who had been selected and briefed to open them by the flight attendants.

15. When ***the*** airplane stopped, smoke had filled the cabin and visibility within the cabin was almost nonexistent 2 to 3 feet above the cabin floor.

16. A flashfire occurred within the cabin within 60 to 90 seconds after the doors and overwing window exits were opened. Flames from this fire were not evident untii after the survivors had left the airplane. Flames from the original fire never were evident within the airplane or to persons on the ground.

17. This was a survivable accident.

32 Probable Cause

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 conflicting fire progress information provided to the captain.

Contributing to the severity of the accident was the flightcrew's delayed decision to institute an emergency descent.

4. RECOMMENDATIONS

On July 11, 1973, the Safety Board participated in the investigation of the Varig Airlines, Boeing 707 accident near Paris, France, in which 124 persons died after a fire erupted in the rear lavatory. As a result of that accident, the Safety Board, on September 5, 1973, issued the following Safety Recommendations to the Federal Aviation Administration (FAX):

> Require a means for early detection of lavatory fires on all turbine-powered, transport-category aircraft operated under Part 121 of the Federal Aviation Regulations, such as smoke detectors or operating procedures for the frequent inspections of lavatories by cabin attendants. (Safety Recornmendation X-73-67)
>
> Require emergency oxygen bottles with full-face smoke masks for each cabin attendant on turbine-powered transport aircraft in order to permit the attendants to combat lavatory and cabin fires. (Safety Recommendation A-73-68)
>
> Organize a government/industry task force on aircraft fire prevention to review design criteria and formulate specific modifications for improvements with respect to the fire potential of such enclosed areas as lavatories in turbine-powered aircraft operating under the provisions of Part 121 of the Federai Aviation Regulations. (Safety Recornmendation A-73-70)

Following the investigation of the Pan American World Airways, Inc., Boeing 707 accident that occurred on November 3, 1973, while the flightcrew was attempting to land at Boston, Massachusetts, after the detection of a fire in the cargo compartment, the Safety Board issued these additional Safety Recommendations to the FAA:

> Provide operators of the subject aircraft with data to enable flightcrews to identify smoke sources, and require operators to establish procedures in their operating manuals to control and evscuate smoke effectively during the specific flight regimes. (Safety Recommendation A-73-121 issued January 10, 1974)

> Require that transport category airplanes certificated under Part 4B of the Civil Air Regulations prior to the effective date of amendment 4B-8 comply with Far? 25.1439 of the Federal Aviation Regulations. (Safety Recommendation A-74-5, issued February 6, 1974)

> Require that a one-time inspection be made of all smoke goggles provided for the flightcrew of all transport category airplanes to assure that these goggles conform to the provisions of Part 25.1439 of the Federal Aviation Reguletions. (Sefety Recommendation A-74-6, issued February 6, 1974)

As a result of two other lavatory fires, one aboard a Boeing 747 airplane on July 17, 1974, and the other aboard a Boeing 727 airplane on August 9. 1974, the Safety Board recommended that the FAA:

> Require that automatic-discharge fire extinguishers be installed in lavatory waste paper containers on all transport aircraft. (Safety Recommendation A-74-98, issued December 5, 1974)

In response to Sefety Xecommendation A-73-67, the FAA issued en Air Carrier operations Bulletin (No. 1-76-17, "In Flight Lavatory Fires") instructing Principal Operations Inspectors to encourage air carriers to prohibit smoking in the lavatories and to institute routine flight attendant inspections of lavatories before takeoff and periodically during flight. This action was followed by an Airworthiness Directive which required the installation of "No Smoking" and "No Cigarette Disposal" signs in the iavatories of transport category airplanes.

Although these actions fell short of the Safety Board's intention to promote the installation of smoke detectors such as those using ionization and photo-electric technology to trigger an alarm signal, the Safety Board, in May 1979, closed Safety Recommendation A-73-67 and assessed the FAA's action as acceptable. While the Safety Board at that time was sympathetic to the industry's position that the lack of demonstrated reliability and the potential for false alarm problems associated with such smoke detectors would degrade their effectiveness, it now is convinced that the technology exists to provide an effective and reliable early warning fire detection system in the lavatories of transport category airplanes. Further, the Safely Board notes that the FAA report "Feasibility and Tradeoffs of a Transport Fuselage Fire Management System," (FAA RD 76-54, dated June 1976) concludes that such systems ere feasible with current technology.

Safety Recommendations A-73-68 and A-74-5 both addressed the need for standards and requirements for protective breathing equipment to provide flightcrew members with a supply of oxygen and a mask of eye protection so that they could continue to perform necessary airplene control functions and cabin duties, as well as firefighting functions in the event of an in-flight fire.

In response to Safety Recommendation A-73-68, the FAA issued a revision to the Federal Aviation Regulations effective February 1, 1977, which required the installation of protective breathing equipment in each isolated separate compartment of the airplane in which crewmember occupancy is permitted during flight. This revision was not responsive to the recommendation since it did not provide for portable protective breathing equipment For use in passenger compartments. Also, the FA?, issued an NPRM in 1975 proposing to amend **14** CFR 25.1439 to include new standards for oxygen masks and eye coverings. However, the proposal was later withdrawn with the reasoning that further testicg was needed to establish the standards, The FAA's response regarding Safety Recommendation A-73-68 and A-74-5, in August 1981, advised the Safety **Board** that an updated Technicai Standard Order (TSO) would be prepared to prescribe minimum standards for emergency equipment to provide flightdeck and cabin crewmembers with eye and respiratory protection from toxic atmospheres during in-flight emergencies. The FAA has stated that it intends to issue an Advisory Circular after it adopts the TSO to recommend that operators upgrade the protective breathing equipment aboard their airplanes to meet the new TSO standards. The FAA has stated that the Advisory Circular wouid also recommend that operators provide equipment beyond regulatory requirements for cabin attendants. The Safety **Board** assumes that the issuance of TSO-C99, "Protective Breathing Equipment,': on June 27, 1983, completed the first phase of **FAA's** intended action. An FAA witness from the Civil Aeromedical Institute testified at the Safety Board's public hearing in the Air Canada case that much of the equipment in current use fails to comply with the newly established minimum standards. He descriiied serious shortcomings particularly in the effectiveness and fit of smoke goggles. Another FAA witness from Aviation Standards Office of Airworthiness slated that he was not aware of any FAA plans for regulatory action to require that the protective breaching equipment currently installed on transport category airplanes in accordance with the provisions of 14 CFR 2? 1439 and 14 CFR i21.337 meet the minimum standards prescribed in TSO-C99. Furthermore, the FAA has not indicated that it intends to require by regulation the installation of portable breathing equipment which would be available immediately in passenger compartments for use by cabin attendants in combating cabin fires. The Safety Board believes that regulatory action is required and that the contemplated Advisory Circular recommending voluntary action by operators is not adequate to assure passenger safety.

In evaluating the FAA's aciions regarding Safety Recommendation 8-73-70, the Safety Board acknowledged that the establishment of the Special Aviation Fire and Explosion Reduction (SAFER) Advisory Committee in May 1978 would be responsive to the recommendation. The mandate of this committee, which was composed of government and industry representatives, went beyond the specific scope of the Safety Recommendation and considered the broader aspect of the airplane fire problem by addressing the postcrash scenario- The SAFER committee's short-term recommendations were directed primarily toward actions to inhibit the ignition and rapid propagation of a postcrash fuel-fed fire. ?he committee determined that there was a need for continued research in interior cabin materials before new testing procedures and standards could be established regarding the flammability, smoke, and toxic emission characteristic of cabin materials.

Although the FAA's action to convene the SAFER committee was viewed as responsive to Safety Recommendation A-73-70, the Safety Board maintained the recommendation in an open status pending further progress toward the mandating of safety enhancing improvements to airplane cabin interiors. ?he Safety Board has received no further response *from* the FAA regarding this recommendation since March 14, 1979. However, the Safety Board has followed end has encouraged the continuing research being conducted at the FAA's Technical Center at Atlantic City, New Jersey. The Safety Board believes that this research has identified several potential cabin improvements which could be implemented now. 'The Administrator announced on October 11, 1983, **FAA's** intention to issue **two** Notices of Proposed Rulemaking (NPRM) proposing new performance standards for the use of fire-blocking materials on passenger seats to inhibit the propagation of cabin fires end new standerds for emergency lighting thst would **be** more effective for passengers evacuating smoke-filled cabins. One of the parties to the Air Canada accident investigation has recommended that, in addition to relocating the cabin emergency lights, tactile aisle markers like those on the overhead stowage bins on many airplanes be installed near to the floor to guide persons to emergency exits in the smoke-filled environment. The Safety Board agrees with this recommendation. **Further,** in addition to the proposed improvements already announced by the Administrator, the FAA tests conducted *at* the Technicai Center have identified other needed upgrading of equipment. These tests have demonstrated vividly that the performance of hand fire extinguishers with the Halon extinguishing agent is significantly superior to **the** performance of the carbon dioxide, dry chemical, or water-type hand extinguishers and that safety will be enhanced by replacing the latter types of extinguishers with the Halon type. The Safety Board strongly encourages the FAA to expedite the rulemaking actions to make fire-blocking seat materials, improved emergency lighting, tactile emergency exit indicators, **and** hand fire extinguishers using advanced technology extinguishing agents mandatory in the transport airplane Ceet as early as practicable.

The **FAA** acted promptly in response to Safety Recommendation A-73-121 to assess the adequacy of the smoke removal procedures on the Boeing 707 airplane. As a result of the FAA's assessment **and** tests, the relevant section of the airplane's Flight Manual was revised to include improved and clearer smoke removal procedures. Both the recommendation and the FAA's actions were specifically directed to the Boeing 707 airplane. On that basis, Safety Recommendation **A-73-121** was closed an? **FAA's** response was deemed acceptable. However, the circumstances of the Air Canada accident indicate that the flightcrew encountered difficult? in controlling smoke in the cockpit of the McDonnell Douglas DC-9 airplane. The Safety Boerd questions the applicability of the prescribed procedures when a cabin fire continues to generate smoke and toxic gases. Further, testimony at the public hearing disclosed uncertainties among both flightcrew and expert witnesses regarding optimal smoke control procedures, such as the best use of cabin air conditioning systems. The Safety Board, consequently, believes that smoke removal procedures in all types *of air* carrier airplanes should be reassessed.

The FAA dia not concur in the Safety Board's recommendation to require that automatic-discharge fire extinguishers be instailed in lavatory waste receptacles on all transport airplanes (Safety Kecommmdation **A-74-98).** The FAA reasoned that the combined actions of installing fully sealed waste receptacles to assure fire containment and extinguishment, as required by Airworthiness Directives for transport category airplanes, and the prohibition of smoking in airplane lavatories eliminated the need for mandatory installation of automatic-discharge fire extinguishers. Although automatic-discharge fire extinguishers have been installed in the lavatory waste receptacles of some airplanes, including the Air Canada DC-9, they have not been required and are not generalip installed. The Safety Board closed Safety Recommendation **74-98** after assessing **FAA's** action as unacceptable.

Moreover, the Safety Board is concerned that the FAA's actions to assure a sealed design of the lavatory waste receptacle have not been adequate. On June **25,** 1983, a flight attendant aboard en Eastern Air Lines McDonnell Douglas DC-9 airplane noticed smoke coming from the right rear lavatory as the airplane **was** being taxied lo the gate after landing. It was determined that the fire had started within the lavatory waste receptscle and propagated behind the vanity io the lavatory aft wall before it **wss** extinguished **by** the airport iiie department. The inspection of the undamaged left rear lavatory in **tile** airplane revealed that the upper area of the waste chute behind the disposal door was not sealed to contain a fire, and there was no fire extinguisher in the receptacle. Further, it was evident that waste could accumulate in the enclosed area of the vanity adjacent to the waste receptacle. Following this incident, the Safety Board's personnel have observed similar discrepancies aboard other airplanes. As a result, the Safety Board on July 1, 1983, issued the following Safety Recommendation:

> Issue a Telert maintenance bulletin to all principal airworthiness inspectors to inspect immediately all lavatory paper and linen waste receptacle enclosure access doors and disposal doors on the applicable aircraft for proper operation, fit, sealing, and latching for the containment of possible trash fires, in accordance with the requirements of AD 74-08-09. (Safety Recommendation A-83-46)

On the same day that the recommenda.ion was issued, the FAA issued a telegraphic General Notice (GENOT), No. 8320.283, describing discrepancies in airplane lavatories observed by FAA inspectors and emphasizing the need for an aircraft lavatory maintenance and inspection program designed to correct these discrepancies. The Safety Board believes that this immediate action was appropriate; however, it appears that the continued fire containment integrity of lavatory waste receptacles cannot be assured even with periodic inspection. Thus, the Safety Board will continue to advocate that more positive protection against fires in and adjacent to waste receptacles be provided by an automatic-discharge fire extinguisher.

Until recently, Safety Board recommendations and related FAA actions to minimize the lavatory fire hazard have focused on the waste receptacle as the most common fire origin. However, since the Air Canada accident, the Safety Board has examined the potential hazard of overheated electrical components associated with the lavatory flush pump motor circuits. Concern regarding this safety hazard was expressed in Safety Recommendations A-83-47 through X-83-49 which were issued on July 19, 1983, after the Safety Board's investigation of an incident which occurred on July 12, 1983, involving an American International Airways DC-9 on the ground st Charlctte, North Caroiina, in which smoke was observed coming from the airplane's right rear lavatory while it was being serviced. Shortly thereafter, maintenance personnel observed that several circuit breakers had tripped, including the 5-ampere breakers for the 3-phase electric flushing motor. Examination of the components disclosed that the flushing motor had overheated, that a phase-to-phase short had taken place in the motor, and that the flushing circuit timer had been damaged by overvoltage. As a result, the Safety Board recommended on July 19, 1983, that the FAA:

> Issue an Airworthiness Directive (1) to require an immediate inspection of the lavatory flushing pump motor and the associated wiring harnesses between the timing components and the motor in the lsvatorics of transport category airplanes for evidence of moisture-induced corrosion or deteriorated insulation and to require that flushing pump motors or wiring harnesses which exhibit such conditions be replaced, and (2) to establish appropriate periodic intervals for repetition of these inspections. (Safety Recommendation A-83-17)

> Establish, in conjunction with the flush pump motor, timer, an6 airframe manufacturers, a procedure which airline maintenance personnel could employ to verify that the electrical circuitry of lavatory flushing pump motors has not been damaged by corrosion or other causes so as to produce excessive heat during motor operation. (Safely Recommendation A-83-48)

> Issue a Maintenance Alert Bulletin to require Principal Maintenance Inspectors to assure that airlines have an acceptable program (1) for the frequent removal of waste from all areas of the lavatory with particular attention to those enclose5 areas in and around the waste receptacles, and (2) which gives sufficient emphasis to areas susceptible to the accumulation of fluids in the vicinity of wire harnesses and other electrical components which can cause corrosion. (Safety Recommendation A-83-49)

The Safety Board notes that the FAA has, in response to several of the Board's Safety Recommendations, issued Notices of Proposed Rule Making (NPRM): NPRM 83-24, NPRM 83-15, and NPRM 84-5. NPRM's 83-14 and 83-15 were issued on October 11, 1983. The proposed rules contained in NPRM 83-14 establish more stringent flammability requirements for type certification of transport category airplanes and would require that previously certified airplanes conform to the more stringent criteria within 3 years from the date the proposed rules are made effective.

NPRM 83-15 would establish the requirement to provide floor proximity emergency escape path markings in transport category airplanes. The proposed rule requires #at the floor proximity emergency escape path provide visual guidance to passengers when all sources of illumination more than 4 feet above the cabin aisle floor are obscured by dense smoke. Previously certified airplanes would have to comply with the new standard within 2 years from the date the proposed rule becomes effective.

On May 17, 1984, NPRM 84-5, which contains three proposed rules, was issued. The proposed rules would require the installation of automatic fire extinguishers for each lavatory disposal receptacle for towels, paper, and waste. The rules would also require the installation of smoke detector systems in the galleys end lavatories of air transport category airplanes and increase the number of hand fire extinguishers to be located in passenger compartments. Because the chemical agent Halon 1211 has demonstrated superior performance and effectiveness in combating fires, the proposed rule would require that at leas: two Halon 1211 hand fire extinguishers be installed in the airplane cabins. All air carriers would have to comply with these provisions within 1 year after the rules become effective.

Upon its consideration of this accident report, the Safety Board issued the following additional recommendations to the Federal Aviation Administration:

> Require that Air Cerrier Principal Operations Inspectors review the training programs of their respective carriers and if necessary specify that they be amended to emphasize requirements:
>
> - for flightcrews to take immediate and aggressive action to determine the source and severity of any reported cabin fire and to begin an emergency descent for landing or ditching if the source end severity of the fire are not positiveiy and quickly determined or if immediate extinction is not assured.
>
> - for flight attendants to recognize the urgency of informing flightcrews of the location, source, and severity of any fire or smoke within the cabin.

- for both flightcrews and flight attendants to be knowledgable of the proper methods of aggressively attacking a cabin fire by including hands-on-training in the donning of prctective breathing equipment, the use of the fire ax to gain access to the source of the fire through interior panels which can be penetrated without risk to essential aircraft components, and the discharge of an appropriate hand fire extinguisher on an actual fire. (Class II, Priority Action) (A-84-76)

Require that Airplane Flight Manuals, Air Carrier Flight Operations Manuals, and Flight Attendant Manuals be amended to include comprehensive discussions and illustrations showing the proper use of a fire ax and the locations in each modei of aircraft operated where a fire ax can be used safely to gain access to e fire or smoke emission source. (Class II, Priority Action) (X-84-73

Require that those interior cabin panels of transport category airplanes, including panels of the lavatories and galleys. which can be safely penetrated with a fire ax be identified by an acceptable and standardized means. (Class II, Priority Action) (A-84-33)

The Safety Board believes that its recommendations when implemented will reduce or eliminate possible sources of ignition, provide earlier detection of cabin fires, and provide improved procedures and equipment for flightcrew and cabin crew personnel to combat and control cabin fires. Since these recommendations address every possible fire source and every possible area where cabin fires most logically could originate, the Safety Board also believes that its actions will either prevent or reduce the possibility of a recurrence of a fire similar to thet encountered on board Flight 797.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ G.H. PATRICK BURSLEY
Member

/s/ VERNON L. GROSE
Member

August 8, 1984

5. APPENDIXES

APPENDIX A

INVESTIGATION AND PUBLIC HEARING

1. investigation

The National Transportation Safety Board was notified of the accident about **1930,** on June **2,** 1983, and immediately dispatched an investigative team to the scene from its Washington, D.C. headquarters. Investigative groups were formed for operations and witnesses, air traffic control, meteorology, human factors, structures, powerplants, systems, flight data recorder, maintenance records and cockpit voice recorder.

Parties to the investigation were the Federal Aviation Administration, **Air** Canada, McDonnell Douglas Corporation, United Technologies Corporation, and the Greater Cincinnati International Airport. Transport Canada appointed an accredited representative to assist the Safety Board during the investigation. The accredited representative was assisted by advisors from Air Canada, Canadian Air Line Pilots Association, and Canadian Air Lines Flight Attendants Association. Transport Canada also made available its laboratories and laboratory personnel.

2. Public Hearing

A 4-day public hearing was held in Fort Mitchell, Kentucky, beginning August 16, 1983. Parties represented at the hearing were the Federal Aviation Administration, Air Canada, McDonnell Couglas Corporation, Heath Tecna Corporation, Canadian Air Line Pilots Association, and the Greater Cincinnati International Airport. Transport Canada appointed an accredited representative to assist the Safety Board during the public hearing.

APPENDIX B

PERSONNEL INFORMATION

Captain Cameron

Captain Donald S. Cameron, 51, was employed by Air Canada on March 28, 1956. He holds Canadian Airline Transport Certificate No. YZA 000964 with airplane single and multiengine land ratings. The captain is type rated in Grumman G-73, Vickers VC-9, Lockheed L-49, and McDonnell Douglas DC-3, -4, -8, and -9 airplanes. The captain's last class-1, group-1 Canadian Medical Certificate was issued February 17, 1983, End contained the following limitation, "Valid only when required glasses are available.':

Captain Cameron qualified as captain in the DC-9 during November 1974. He passed his last proficiency check on February 14, 1983; his last line check on July 16, 1982; and completed his last recurrent training on January 24, 1983. The captain had flcwn about 13,000 hours, 4,939 of which were in the DC-9. During the fast 90 days, 30 days, and 24 hours before the accident, he had flown 111 hours, 39 hours, and 9 hours, respectively. The captain had been off duty about 11 hours 55 minutes before reporting for this flight. At the time of the accident, he had Seen on duty about 7 hours 35 minutes, 5 hours 10 minutes of which was flight time.

First Officer Ouimet

First Officer Cleude Ouimet, 34, was employed by Air Canada on November 25, 1973. tie holds Canadian Senior Commercial Pilot Certificate No. ULS 102366 with 2 Class 1. *Group* I Instrumen? Rating valid to February 1, 1984; ratings *for all* types of Class 7 airplanes of 12,500 pounds or less, and for the DC-9. The license is not *valid* for pilot-in-command in "airplanes *of* more then 12,500 pounds engaged in commercial air service and passengers carried." His last class-I, group-1 Canadian Medical Certificate was issued April 21, 1983, with no iimitations.

First Officer Ouimet qualified as first officer in the DC-9 during February 1979. He passed hi? last proficiency check on July 14, 1982: his last line check on May 26, 1983; and completed his last recurrent training on January 12, 1983. The first officer had flown about 5.659 hours, 2,499 of which were in the DC-9. During the last 90 days, 30 days, and 24 hcurs before the accident, he *had* flown 144 hours, 75 hours, and 9 hours, respectively. The first officer had been off duty about 11 hours 55 minutes before reporting for this flight. At the time of the accident, he had been on duty about 7 hours 35 minutes, 5 hours 10 minutes of which was flight time.

14 CFR 129.15 states:

> No person may *art* as a flight crew-member unless he holds a current certificate or license issued or validated by the country in which that aircraft is registered showing his ability to perform his duties connected with that aircraft.

Since both the captain and first officer possessed Canadian certificates with DC-9 type ratings, they were qualified to operate DC-9 type airplanes within the United States.

Flight Attendant Benetti

Flight Attendant Sergio Benetti, 37, was employed by Air Canada January 2, 1972. The flight attendant completed his initial training Jenuary 3, 1972, and his last recurrent training on August 11, 1982. The flight attendant had been off duty for 11 hours 55 minutes before reporting for this flight. At the time of the accident, he had been on duty about 7 hours 35 minutes, 5 hours 10 minutes of which was flight tine.

Flight Attendant Kayama

Flight Attendant Laura Kayama, 28, was employed by Air Canada in May 1975. The flight attendant completed her initial training in June 1976; and her latest recurrent training on February 16, 1983. Her duty and off duty times were identical with those of Flight Attendant Benetti.

Flight Attendan? Davidson

Flight Attendant Judith L. Davidson, 33, was employed by Air Canada on July 9, 1973. She had completed her initial training on September 7, 1973, and her latest recurrent training on June 17, 1982. Her duty and off duty times were identical with those of Flight Attendant Benetti.

Gregory L. Karam

Gregory L. Karam, 36, was the approach controller at the Cincinnati TRACOM. The approach controller was employed by the FAA on January 9, 1374, and is a full performance level controller. His last second-class medica: certificate was issued November 5, 1982, and the controller was required to "possess glasses for near and distant vision." On June 2, 1983, the controller reported for duty at 1500 and assumed his approach control station at 1557.

James L. Ferguson

James L. Ferguson, 49, was the Louisville high altitude radar controller. He was employed by the FAA on December 12, 1956. He is a full performance level controller and is also an area supervisor at the Indianapolis XRTCC. The controller's last second class medical certificate was issued February 16, 1983 and contained no waivers or limitations. On June 2, 1983, the controller reported for duty at 1245 and assumed the Louisville high altitude radar controller duties at 1744.

Jack B. Martin

Jack Martin, 50, was the LEX-D controller. He was employed by the FAA on December 2, 1957, and is e full performance level controller. His last second-class medical certificate was issued February 24, 1983, and contained no waivers or limitations. On June 2, 1983, the controller reported for duty at 1200 and assumed the LEX-D position at 1745.

APPENDIX *C*

AIRPLANE INFORMATION

McDonnell Douglas DC-9-32, C-FTLU

The airplane manufacturer's serial No. 47196 was delivered to Air Canada on April 7, 1968, and had been opersted by the airline continuously since that time. A review of the airplane's flight logs and maintenance records showed that ali applicable Airworthiness Directives had been complied with, and that all checks and inspections were completed within their specified time limits. The records review showed that the airplane had Seen maintained in accordance with nompany procedures and Canadian rules and regulations and disclosed no discrepancies that could have affected adversely the performance *of* the airplane and any of its components.

The airplane was powered by Pratt and Whitney JT8D1-7B engines rated at 14,000 pounds of static thrust *for* takeoff at sea level at 84° F.

The following is pertinent statistical data:

Airplane

Total Airplane Time	-	36,825 hours
Total Airplane Landings	-	34,987

Powerplants

Engine	No. 1	No. 2
Serial Number	P657758D	P657360D
Total Time	20,942 hours	28,990 hours
Total Cycles	21,459	29,598

APPENDIX D

TRANSCRIPT OF AN AIR CANADA COCKPIT VOICE RECORDER, S/N 1613
REMOVED FROM A DOUGLAS DC-9 WHICH WAS INVOLVED IN AN ACCIDENT
AT CINCINNATI, OHIO, OS JUNE 2, 1983

LEGESD

CAM	Cockpit ares microphone voice or sound source
RDO	Radio transmission from accident aircraft
-1	voice identified as Captain
-2	Voice identified as First Officer
-3	Voice identified as male Flight Attendant
-4	Voice identified as female flight Attendant
-5	Voice identified a; a male passenger
CTR	Indianapolis Center
XXX	Varous aircraft
*	Unintelligible word
#	Nonpertinent word
( )	Questionable text
(( ))	Editorial insertion
---	Pause
Note:	All times are expressed in central standard time.

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
1848:12 CAM	((Sound similar to arcing))		
1848:15 CAM	((Sound similar to arcing))		
1851:03 CAM	((Two sounds similar to arcing))		
1851:04 CAM-1	How is your sea food, nice?		
CAM	((Sounds similar to arcing and snapping))		
CAM-2	It's good		
CAM-1	• steak nice?		
1851:09 CAM-2	Different, a little bit dry but okay		
1851:14 CAM	((Sounds similar to arcing and snapping))		
CAM-2	(What was that?)		
CAM-1	#		
1851:19 CAM-2	It's right there, I see it		
CAM-1	Yeah		
CAM-1	DC bus		
CAM-2	Which one is that.?		

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
CAM-1	DC bus the, ah, left toilet, left toilet flushing		
1851:27 CAM-1	(I) better try it again, eh, push 'em in		
CAM-2	Push it in one more time, I guess		
1851:41 CAM	((Sound of arcing))		
CAM-2	What!		
1851:42 CAM	((Sound of arcing and snap))		
CAM-1	That's it		
1851:43 CAM	((Sound of arcing and snap))		
CAM-1	Won't take it		
CAM-2	No		
CAM-1	See anything else?		
CAM-1	(There's nothing) on the panel		
CAM-1	Ha		
1852:08 CAM-1	Like a machine gun		
CAM-2	Yeah, zap, zap, zap		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-1	* put it in the book, there
CAM-2	Log it
1852:26 CAM-1	Now I want to log it, eh
1853:16 CAM-1	Somebody must hove pushed a rag down the old toilet or something, ch?
1853:21 CAM-1	Jammed it, and it overheated
1853:25 CAM-2	Is it flushing you pushed?
CAM-1	It's flushing, yeah
CAM-2	(Motor) *
1853:30 CAM-I	Toilet flushing, three breakers banged

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1853:35 CTK	Air Canada seven ninety seven, contact Indianapolis on one three three point zero five
1853:40 RDO-2	Air Canada seven nine seven, so long
1853:41 CTR	so long

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1854:18 CAM-1	Don't see the ground too often, today eh?
CAM-1	No, a lot of, a lotta cloud eh• the whole * * * the whole area
1856:56 CAM-2	Yeah, that feels good
1857:09 CAM-1	What the # does this mean
1857:12 CAM-1	(Reg a bail)
CAM-2	I don't know
CAM-2	Regional examiner, regional * regional
1857:36 CAM-1	We may be, I don't know, A.J. would be a three letter code if it was an airport, eh
CAM-2	I don't know it might be in the, ah, charts
CAM-1	Regional --- here's regional A.J.

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1853:53 RDO-1	Indianapolis Center, this is Air Canada seven nine seven maintaining three three zero direct Louisville on course
1853:59 CTR	Air Canada seven ninety seven Indianapolis Center roger
RDO-?	* * *

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-1	(Well it's)
1858:16 CAM-2	That (one) is lettered D.G. *
CAM-1	Oh I see, oh yeah, yeah *
1858:27 CAM-1	Alternate, ah, must be our alternate here
CAM-1	Ah who gives a #
1858:43 CAM-1	Nothing to do with us
CAM	((Sound similar to cockpit door))
CAM-3	Yeah thank you sir
1859:02 CAM-?	UWX
1859:30 CAM-1	Twenty nine U, W, and X twenty nine, those are the grid references
1859:37 CAM-2	Twenty nine, yeah
1859:42 CAM-1	Twenty nine UWX three --- the left toilet flushing
CAM-2	Left

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
1859:47 CAM-1	Yeah aft left toilet flush, and they wouldn't accept a reset		
1859:58 CAM	((Sound of first attempt to reset and sound similar to arcing))		
1859:59 CAM	((Sound of second attempt to reset' and sound similar to arcing))		
1900:00 CAM	((Sound of third attempt to reset and sound similar to arcing))		
NOTE:	((When questioned later, the captain and copilot said they did not hear the sound of arcing noted on the CVR CAM channel. They said they attempted to reset breakers just one time each))		
CAM-1	Pops as I push it		
CAM-2	Yeah, right		
CAM-1	Yeah		
1900:51 CAM	((Sound of cough))		
1901:12 CAM-2	Zero two seven set for ya Don		
1901:33 CAM-1	Better --- have dinner here		
1901:42 CAM	((Sound of chime))		

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
CAM-3	Yes		
1901:49 CAM-1	Sergio could I try for mine now please		
CAM-3	Sure		
CAM-1	Thank you very much		
1901:59 CAM-1	Do you want any of that fruit or should we give it to the girls --- far as I'm concerned		
CAM-2	No		
CAM-1	I don't want it		
1902:13 CAM-1	There you go		
CAM-2	Thanks		
1902:15 CAM-1	You're in a left turn here to pick up oh two seven		
CAM-2	So okay twenty seven		
CAM-1	Louisville to Rosewood		
1902:28 CAM-1	The next chart yeah that's it		
CAM-2	Yeah		
1902:34 CAM-1	We're just over Louisville here		

INTRA-COCKPIT

TIME 8 SOURCE	CONTENT
CAM-2	((Sound of whistling))
CAM-2	Louisville --- Rosewood, okay
1902:40 CAM-4	Excuse me, there's a fire in the washroom at the back, they're just oh # went hack to go to put it out
CAM-1	Oh yeah
CAM-4	They're still, well they're just gonna go back now
CAM-2	Want me to go there
1902:50 CAM-1	Yeah go
CAM-2	* the brakers # up
CAM-1	Leave my, leave my, leave my dinner in the thing there for a minute
CAM-4	Okay
CAM-5	(Can I buy you a drink cause there's something going on, drink or a shot)
CAM-?	Ah, I wouldn't say that
1903:06 CAM-5	Yeah okay
CAM-?	Still there huh?
CAM-5	Yeah
1903:10 CAM-2	Got the, ah, breakers pulled

AJR-GROUND COMMUNICATIONS

TIME 4 SOURCE	CONTENT

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-1	It's the motor
1903:15 CAM-4	Pardon me
CAM-2	You got all the breakers pulled out?
CAM-I	The breakers are all pulled, yeah
1903:21 CAM-4	(* * make 'em all seat?)
1903:31 CAM-4	Captain is it okay to move everybody up as far forward as possible
1904:07 CAM-2	Okay I eh, you don't have to do it now, I can't go back now, it's too heavy, I think we'd better go down
1904:16 CAM-3	I got all the passengers seated up front, you don't have to worry I think its gonna be easing up
1904:23 CAM-2	Okay, it's starting to clear now

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
CTR	Republic two eighty eight Indianapolis, Memphis one three three point eight five three three eight. five, goodbye
77L	* * seven seven lima (Knoxsville) * * two none zero --
CTR	Seven seven lima (Knoxsville) roger
1903:54 CTR	Delta sixteen twenty six continue descent to flight level two four zero, Indianapolis
1904:00 CTR	Center one two eight five live on two four zero at twenty eight fifty five, so long
RDO-?	(Cleared) ah okay

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
CAM-1	Okay		
1904:25 CAM-1	Well I want --- hold on then		
CAM-3	(Mike) I just can't go back it too		
CAM-2	I will go back,if that's appears better, okay		
CAM-1	Yeah that's okay		
CAM-?	That's okay, yeah ((simultaneous with above))		
CAM-2	So ---		
CAM-1	Take the, take the smoke mask		
CAM-2	You have control		
CAM-1	Take the goggles		
1904:36 CAM-1	I'll leave the mask on		
CAM-2	Okay		
Note	((Orignated in back)) Okay I want ---		
1904:46 CAM-1	Okay go back whenever you can but don't get yourself incapacitated		((This appears on radio channel as well))
CAM-2	No problem, no problem		
CAM-1	Okay		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1905:35 CAM	((Electrical pulse appears on tape radio channels))
1905:36 CAM-4	Captain, your first officer wanted me to tell you that Sergio has put a big discharge of CO2 in the washroom, it seems to be subsiding, all right

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1905:15 286G	Indianapolis good evening Citation two eight six golf, three one oh
1905:18 CTR	Citation two eight six gold Indianapolis
286G	Okay we're proceeding direct Pocket City
CTR	Affirmative sir, direct Pocket, direct Evensville
286G	Six gold
1905:48 B747	Center Poca seven four seven level four three zero
CTR	Poca seven four seven Indianapolis roger
1906:07 RDO-1	Memphis Center this is Air Canada seven nine seven

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-1	(Coming along okay)
CAM-3	Getting much better, okay
1906:42 CAM-3	I was able to discharge half of the CO2 inside the washroom even though I could not see the source bot its definitely inside the lavatory.
1906:50 CAM-1	Yeah, it's From the toilet, it's from the toilet
1906:52 CAM-3	CO2 it was almost half a bottle and it now almost cleared
1906:54 CAM-1	Okay, thank you
1906:55 CAM-3	Okay, good luck
CAM	((Sound similar to cockpit door))
CAM-2	Okay, you got it *

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1906:09 CTR	Canada seven ninety seven Indianapolis Center, go ahead
1906:12 RDO-1	Yeah, we've got an electrical problem here, we may be off communication shortly ah stand by

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-1	Yeah
CAM-1	Okay
1907:11 CAM-2	I don't like what's happening, I think we better go down, okay?
CAM-1	Okay
1907:14 CAM-2	Okay, I'll he back there in a minute
1907:41	((Recorder goes off))

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1907:28 Q362	Hello Center, Piedmont three sixty two, we're level at flight level three three zero
1907:32 CIR	Three sixty two Indianapolis Center roger
1907:35 1'362	We'll take direct Holston Mountain if you can do that

APPENDIX E

14 CFR 25 FLAME RESISTANCE CRITERIA

Flame resistance criteria for airplane compartment materials are contained in 14 CFR 25.853. Section 14 CFR 25.853(a) states in part:

> Interior ceiling panels, interior wall panels, partitions: galley structure, large cabinet walls, structural flooring and materials used in the construction of stowage compartments (other than underseat stowage compartments for stowing small items such as magazines ana maps) must be self-extinguishing when tested vertically in accordance with the applicable portions of appendix F of this part, or other approved equivalent methods. The average burn length may not exceed *6* inches and the average flame time after removal of the flame source may not exceed 15 seconds. Drippings from the test specimen may not continue to flame for more than an average of 3 seconds after falling.

Section 14 CFR 25.853(b) states, in part:

> Floor covering textiles (including draperies and upholstery) seat cushions, padding, decorative and nondecorative coated fabrics, leather trays and galley furnishings, electrical conduit, thermal and acoustical insulation and insulation covering air ducting, joint and edge covering, cargo compartment liners, insulation blankets, . . . must be self-extinguishing when tested vertically in accordance with the applicable portions of appendix F of this part, or other approved equivalent methods. The average burn length may not exceed 8 inches and the average flame time after the removal of the flame source may not exceed 15 seconds. Drippings from the test specimen may not continue to flame for more than an average *of* 5 seconds after falling.

The acceptable test procedures, fiame heat, and apparatus required to demonstrate compliance with i.4 CFR 25.853 are contained in appendix F of 14 CFR 25. Kith regard to vertical and horizontal flame testing, the appendix states, in part:

> (d) Vertical test. . . . For materials covered by section 25.853(a), the flame must be applied for *60* seconds and then removed. Flame time, burn length, and flaming time of drippings, if any, must be recorded. The burn length determined in accordance with paragraph (h) of this appendix must be measured to the nearest one-tenth inch.
>
> *(e)* Horizontal test. . . . The fiame must be spplied for 15 seconds and then removed. Minimum of 10 inches of the specimen must be used for timing purposes, approximately 1 1/2 inches must burn before the burning front reaches the timing zone, and the average burn rate must be recorded.
>
> (h) Burn length. Burn length is the distance from the original edge to the farthest evidence of damage to the test specimen due to flame impingement, including areas of partial or complete consumption, charring, or embrittlement, but not including areas sooted, stained, warped, or discolored. nor areas where material has shrunk or melted away from the heat source.

Appendix F. Air Canada DC-9 Emergency Equipment