Fire Investigation Report

Air Canada DC-9 Aircraft Fire
Greater Cincinnati Airport
June 2, 1983

Prepared by

Thomas J. Klem, Director
Fire Investigations and Applied Research Division
National Fire Protection Association

In Cooperation with

Federal Emergency Management Agency
United States Fire Administration

and

National Bureau of Standards
Center for Fire Research
The substance of this investigation report is dedicated to the public. It may be freely reprinted with the customary crediting of the source. The author and publisher are solely responsible for the accuracy of statements or interpretations contained herein.
ABSTRACT

About 7:02 p.m. on June 2, 1983, a flight attendant on Air Canada flight 797 reported a fire in the rear lavatory section of the aircraft to the captain. Air Canada flight 797 was a McDonnell-Douglas, DC-9 aircraft with 41 passengers and a crew of five enroute from Dallas-Fort Worth to Toronto, flying at an altitude of 33,000 feet. Following unsuccessful attempts by the crew to extinguish the concealed fire, an emergency was declared and a decision made to land the aircraft. The aircraft was located approximately 25 miles southwest of the Greater Cincinnati Airport at this time. During the eleven minutes required to land the aircraft, conditions within the cabin and cockpit deteriorated rapidly with the penetration of dense smoke and heat into these areas. Despite these conditions and the loss of nearly all the aircraft's flight instrumentation, the flight deck crew, with the assistance and guidance given by air traffic controllers, was able to safely land the aircraft (7:20 p.m.).

Smoke conditions were so severe at landing that some passengers reported not being able to see passengers seated next to them. Once on the ground, flight attendants moved to some of the emergency exits; while passengers seated near over-wing emergency exits began to open these exits. These passengers followed the instructions of the flight attendants, given during the descent, opening the over-wing exits. Once the aircraft's emergency exits were opened, the severity of the interior fire increased. Only a short time interval was available for occupants to evacuate before untenable conditions were reached. Despite these conditions, 23 persons safely evacuated the aircraft unassisted within an estimated minute of landing. Twenty-three passengers died as a result of the intense interior cabin fire.
Significant factors contributing to the loss of life in this incident are considered to be:

- The lack of automatic detection and effective suppression of a developing, concealed fire in the rear lavatory area,
- The rapid fire and smoke development due to available fuels, aircraft cabin configuration, and the lack of adequate fire barriers,
- The reduced occupant evacuation time resulting from one or more of the following: the rapid developing fire; the effects of heat, smoke and toxic gases on passengers; and the nature of in-flight emergency egress design.

Occupant survival of this incident appears to be related to one or more of the following:

- Relocating passengers to positions forward of the area of origin and adjacent to emergency exits,
- Adhering to emergency instructions given by flight attendants during descent and escape,
- Prompt movement of occupants toward emergency exits once the aircraft landed,
- Utilization of oxygen masks by the flight deck crew during descent, and
- Passengers and flight attendants filtering breathing air through clothes, fabric materials and/or wet towels distributed by flight attendants.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>II. Background</td>
<td>3</td>
</tr>
<tr>
<td>- Greater Cincinnati Airport</td>
<td>5</td>
</tr>
<tr>
<td>- Aircraft</td>
<td>7</td>
</tr>
<tr>
<td>- Interior Cabin Materials</td>
<td>10</td>
</tr>
<tr>
<td>- Weather</td>
<td>12</td>
</tr>
<tr>
<td>- In-Flight Cabin Fire</td>
<td>13</td>
</tr>
<tr>
<td>- Escape from the Aircraft</td>
<td>18</td>
</tr>
<tr>
<td>- Crash Rescue Operations</td>
<td>22</td>
</tr>
<tr>
<td>- Damage to the Aircraft</td>
<td>27</td>
</tr>
<tr>
<td>- Survivors</td>
<td>28</td>
</tr>
<tr>
<td>- Casualties</td>
<td>29</td>
</tr>
<tr>
<td>III. Analysis</td>
<td>30</td>
</tr>
<tr>
<td>- Fire Development and Smoke Spread</td>
<td>30</td>
</tr>
<tr>
<td>- Discussion</td>
<td>33</td>
</tr>
<tr>
<td>- Major Contributing Factors</td>
<td>34</td>
</tr>
<tr>
<td>- Recommendations</td>
<td></td>
</tr>
<tr>
<td>IV. Appendices</td>
<td>39</td>
</tr>
<tr>
<td>A. Casualty Information</td>
<td></td>
</tr>
<tr>
<td>B. Interior Cabin Materials Test Method</td>
<td></td>
</tr>
<tr>
<td>Interior Material Description</td>
<td></td>
</tr>
<tr>
<td>C. Figures</td>
<td></td>
</tr>
<tr>
<td>D. Photographs</td>
<td></td>
</tr>
</tbody>
</table>
I. INTRODUCTION

The National Fire Protection Association (NFPA) investigated the Air Canada aircraft fire in order to document and analyze significant factors that resulted in the loss of life. This study was conducted under a Major Fires Investigation Agreement with the Federal Emergency Management Agency/United States Fire Administration (FEMA/USFA) and the National Bureau of Standards/Center for Fire Research (NBS/CFR).

The agreement, funded by all three organizations, provides for the investigation of technically significant fires by the NFPA Fire Investigations and Applied Research Division to document and analyze incident details and report lessons learned for loss prevention purposes.

The NFPA became aware of the Air Canada aircraft fire on June 2, 1983. Thomas J. Klem, Director, Fire Investigations and Applied Research Division, traveled to the Greater Cincinnati Airport to document the facts related to this fire. An initial five days of on-site study and a subsequent visit to the Federal Aviation Administration's test site facility located in Atlantic City, New Jersey, to observe interior aircraft material testing were the basis for this report and NFPA's analysis of the event. Entry to the fire scene and data collection activities were made possible through the cooperation of the National Transportation Safety Board (NTSB).

The NTSB is an independent federal accident investigation agency. The Board's mission is to determine the "probable cause" of transportation accidents and to formulate safety recommendations to improve transportation safety. An investigative report of this incident will soon be released. NFPA's representative was assigned to the NTSB investigative team comprised of aviation experts (from a number of disciplines such as fire testing, human factors, etc.) assembled from government and private enterprise. The investigation team was headed by Rudolf Kapustin, Senior Air Safety Investigator (NTSB).
This report is another of NFPA's studies of fires having particularly important educational or technical interest. The information presented is based on the best data available immediately after the fire incident and that obtained during subsequent follow-up. This report describes fire protection considerations of the Air Canada DC-9 and presents findings on the contributing factors to the loss of life based on the NFPA's analysis of collected data, observations made during FAA's fire tests of interior material taken from the aircraft, and observations made during the on-site investigation. The scope of this report is limited to those portions of the Air Canada DC-9 pertinent to an examination of fire problems and factors associated with the loss of life. It is not NFPA's intention that this report pass judgment on, or fix liability for, the loss of life and property damage of the aircraft.

The assistance of Charles Arena, Massport, Director of Public Safety, is acknowledged. In addition, the data collection, research and input to report writing from Tom Timoney of NFPA's Fire Investigations and Applied Research Division is recognized and acknowledged.
II. BACKGROUND

The Air Canada DC-9 aircraft fire was a unique incident in that the ignition, growth, development, and spread of the fire was confined to, and primarily involved, the aircraft's interior cabin materials. This incident represents the first fatal, in-flight, on-board fire of a commercial passenger aircraft ever in the United States.*

This incident contrasts with the vast majority of commercial passenger aircraft fires which involve scenarios which link the rupture of aircraft fuel cells to occurrences such as impact damage sustained in crashes or the penetration of a landing gear assembly following landings or takeoffs. Some of these incidents are termed "survivable crashes," i.e., incidents in which occupants survived the trauma of impact. Fire fatalities which have resulted from survivable crash incidents have occurred when an external fuel fire has exposed the interior cabin. Over the past 20 years, all fire fatalities in United States air carrier accidents have occurred from this type of fire scenario. Because of the severe fire conditions created from ignition of a fuel spill, the importance and role of interior cabin materials on occupant survivability has been difficult to assess.

Cognizant of these facts and recognizing that time for interior fire attack is limited, airport crash, fire and rescue (CFR) operations, manning, equipment and training place emphasis on large volume delivery of extinguishing agents to protect exiting passengers and crew members from large

*Several fatal accidents have occurred in U.S. manufactured aircraft operated by foreign carriers as a result of an interior fire while the aircraft was in-flight. These in-flight fatal fires consist of a Varig 707 in 1974, a Pakistani 707 in 1979, and a Saudia L-1011 in 1980. These incidents resulted in over 500 fatalities. There also has been several commuter airline and cargo aircraft in-flight on-board fatal incidents.
exposure fires.¹

Many airport training manuals and other nationally recognized standards also address interior cabin fires. Interior cabin fires are recognized as extremely hazardous and difficult to extinguish. This is in part due to the pressure build-up within the aircraft from the combustion process and the introduction of fresh air (from forced entry, crew opening doors, etc.) which can result in a flashover or a fire gas explosion. Further, it is recognized that the configuration, i.e., long, narrow structure with a low ceiling height, and the large quantities of combustibles present make control and extinguishment difficult. Ventilation (a tactic utilized in achieving fire control in structural fire fighting) through the top of the fuselage may be difficult to achieve.

CFR personnel, in controlling interior aircraft fires, must be aware of peculiarities of the structure of the aircraft. For example, the absence of fire stops at floor lines, behind wall panelling, and above ceiling spaces, as well as the combustibility and toxicity of burning cabin furnishings, exemplify the hazards to which fire fighters are exposed.²

In the event of an interior cabin fire, CFR crews are usually trained to allow occupants to self-evacuate. Other actions such as forced entry during this time could compromise evacuation by interfering with slide deployment. If there is no evidence of evacuation, immediate steps are taken to make entry for rescue and/or extrication. When entry into the interior of the aircraft is made, fire fighters must be equipped with self-contained breathing apparatus (SCBA) and prepared with extinguishment agent for fire fighting.

¹ See NFPA 402-1978, Recommended Practice for Aircraft Rescue and Fire Fighting Operational Procedures for Airport Fire Departments.
² Ibid.
Because of these reasons, it is common practice to support fire fighting capability of the airport fire department (cabin fires and crashes) with mutual aid support from surrounding fire departments. In order to coordinate these efforts among response crews, emergency operating plans are developed. Frequent training drills are usually held to familiarize the departments with procedures, operations, and facility locations, etc.

Regardless of the type of incident, i.e., crash with or without fuel spill, or interior cabin fire, survival of the aircraft occupants takes precedence over all other operations in deploying apparatus, designing strategies and/or training CFR crews. Fire control is frequently an essential condition to assure occupant survival. As a result, priority is usually given to providing protective extinguishing agent over the fuel containing portions of aircraft when the areas are exposed to heat and flame from a cabin fire, for example. Further, because of the severe danger, priority must be given to controlling external fires, including spill fires, before beginning rescue activities. If a severe interior cabin fire occurs on an occupied aircraft, CFR crews are likely to be confronted with extreme heat and smoke conditions which would make rescue of occupants difficult. Further, manpower needed for such an effort is likely to be limited and mutual aid assistance may not be present during the interval that survival is possible.

Greater Cincinnati Airport

In order to obtain an airport operating certificate, Federal Aviation Regulations (FAR) Part 139 requires that an airport "must show that it has, and will have, available during air carrier user operations, at least the airport fire fighting and rescue equipment with the vehicle response time capability and trained personnel prescribed in this section" (section 139.49, "Airport Fire Fighting and Rescue Equipment and Service"). The required fire
fighting and rescue equipment is based on an airport index which is determined by the longest large aircraft with an average of five or more scheduled departures per day served by the airport. The Greater Cincinnati Airport holds an Index D classification,* i.e., aircraft more than 160 and not more than 200 feet long. For this airport index, one lightweight vehicle with at least 500 pounds of dry chemical or 450 pounds of dry chemical and 50 gallons of water for aqueous film forming foam (AFFF) production, and two additional self-propelled fire extinguishing vehicles are required. The total quantity of water for protein foam production required for this index is 4000 gallons.

Discharge rates for each foam-type fire fighting and rescue vehicles for this index must be capable of discharging one complete tank capacity with appropriate foam concentrate in 2 1/4 minutes with all orifices open. Further, reflecting the objective for large volume deliveries for fuel spill fires, airport fire fighters must be able to provide at least 85 percent of the required maximum agent discharge rate of fire fighting equipment.

The FAR also specifies that the airport have an Emergency Plan which includes mutual aid assistance for fire fighting and ambulance transportation. Further, the emergency plan requires that the airport have the capability to communicate with all internal and external support agencies. Testing, training and reporting procedures are also specified by the FAR.

Fire Department

The Greater Cincinnati International Airport Fire Department has a training program that includes all aspects of aircraft fire fighting and rescue. All the crash crew are involved in the various training exercises during each year. The training is arranged in phases so that as a fire fighter completes

*The Greater Cincinnati Airport Fire Department had sufficient equipment; and manning to meet the more stringent Index E.
one phase he moves on to the next. When a cycle has been completed, the sequence is repeated by the individual fire fighter. The training is continuous throughout the fire fighter's career.

A command vehicle is operated by the G.C.I.A. Fire Department that is extensively equipped to handle aircraft disasters and to provide emergency communications among the various agencies involved in such a occurrence.

The Greater Cincinnati Airport Fire Department exceeds all aspects* of the FAR requirements for "Airport Fire Fighting and Rescue Equipment and Service" (see Table 1).

An airport disaster drill was conducted on May 7, 1983, and included several of the local communities' emergency service organizations. Boone and Kenton Counties have county disaster plans as do the area's hospitals.

Aircraft

Air Canada is a Canadian Crown owned corporation and the national airline of Canada. The airline was formed in April, 1937, with its first scheduled flights between Vancouver and Seattle. Since that time, Air Canada has expanded services and established passenger, freight, and mail routes throughout North America and internationally with routes to Europe and South America. Air Canada ranks in the top ten airlines of the world with respect to the number of passengers carried, fleet size, and route miles.

The aircraft involved in the June 2 incident was a McDonnell-Douglas DC-9-32, certified by the FAA (Federal Aviation Administration) on March 22, 1968. The aircraft was configured with a standard two-man cockpit and cabin designed to accommodate 100 passengers with a maximum of four flight

*This includes fire station location, vehicle response time to specific runway locations, extinguishing agent deliveries, etc.
**TABLE 1**
Greater Cincinnati Airport Fire Department Equipment and Manning
for DC 9 Air Canada Incident

<table>
<thead>
<tr>
<th>Type Vehicle</th>
<th>F.D. Unit Designation</th>
<th>Assignment</th>
<th>Manning</th>
<th>Agent Capacity</th>
<th>Pump Capabilities</th>
<th>Turret Discharge Rates (Foam)</th>
</tr>
</thead>
<tbody>
<tr>
<td>crash unit</td>
<td>907</td>
<td>crash</td>
<td>1 f/f</td>
<td>3000 gal water 500 gal AFFFF</td>
<td>2-750 gpm</td>
<td>750/1500 gpm</td>
</tr>
<tr>
<td>crash unit</td>
<td>913</td>
<td>crash</td>
<td>1 f/f</td>
<td>3000 gal water 500 gal foam</td>
<td>2-750 gpm</td>
<td>750/1500 gpm</td>
</tr>
<tr>
<td>quick response</td>
<td>967</td>
<td>officer in charge</td>
<td>1 Capt.</td>
<td>450 lbs, dry powder 100 gal AFFFF</td>
<td>Apx. 100 gpm (Handline)</td>
<td>N/A</td>
</tr>
<tr>
<td>engine Co.</td>
<td>951</td>
<td>structural</td>
<td>1 Lt. 2 f/f</td>
<td>1000 gal water 100 gal AFFFF</td>
<td>1000 gpm</td>
<td>500/100 gpm</td>
</tr>
<tr>
<td>quint (100' aerial)</td>
<td>960</td>
<td>structural</td>
<td>1 f/f</td>
<td>300 gal water</td>
<td>1500 gpm</td>
<td>N/A</td>
</tr>
<tr>
<td>rescue squad</td>
<td>980</td>
<td>emergency treatment of sick/injured</td>
<td>1 f/f</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
attendants. The aircraft was equipped with seven emergency exits. There were four over-wing exits, two exits located in the front of the aircraft and a rear exit that could be utilized if activated by a crew member. This action by a crew member would jettison the aircraft's tail cone and occupants would then traverse through the rear cone section and down an escape ladder. In addition, there were two emergency escape windows which could be utilized by the flight deck crew (see Figure 1). Some of the exits are designed only to be opened by crew members, while others provide written operating instructions for passengers. During pre-flight instructions, flight attendants are required to brief passengers on the location and activation of emergency exits.

The aircraft was equipped with portable fire extinguishers (water and CO₂) and a fixed, heat activated, 4 ounce, Halon extinguishing system which protected the trash bins in the lavatory areas. Other emergency equipment included portable oxygen masks, a medical kit, flashlights and megaphones, crash axe, etc. Flight crews have been trained in emergency evacuation procedures and in the selection and use of portable fire extinguishers.

Smoke goggles and oxygen masks (an independent source of oxygen from that used by passengers during an emergency) are available to the flight deck crew. Passengers have access to "oxygen" masks which can be deployed and used during some specific emergencies such as the loss of cabin pressure. These masks provide a small concentration of oxygen (approximately 3 percent mixture) that mixes with interior cabin air. The masks do not provide a tight seal around the user's nose and mouth area. As a result, their effectiveness during an on-board fire emergency is not recommended. Further, they are not recognized or recommended for use by Air Canada in its emergencies procedures for on-board, in-flight fires.
The aircraft was involved in an earlier incident on September 17, 1979 when its tail cone was jettisoned in-flight between Boston and Halifax, Nova Scotia. The aircraft successfully made an emergency landing at Boston's Logan Airport. Damage to the aircraft was reported to be in the rear portion of the plane including the rear lavatory area. The aircraft was repaired by McDonnell-Douglas and returned to service November 1, 1979.

In July, 1982, the aircraft was refitted with a new interior (see Discussion below) DC-9-30 CORI-X retrofit kit. When the aircraft was refitted with a "Wide Body" style interior, Air Canada added decorative finishes to existing lavatory components.

The aircraft was equipped with 100 passenger seats that were arranged in twenty-one rows. Three seats were provided on the right side of the aircraft and two were arranged along its left side. A center aisle separated the seat arrangement.

The cabin length of the aircraft was approximately 100 feet, its width was approximately 10 feet 6 inches and it had an approximate 6 foot 8 inch ceiling height.

The long, narrow interior of the aircraft contained no fire barriers between the finished ceiling and the inside skin of the aircraft, nor were there areas of the occupied portions of the aircraft that were designed for fire containment.

At the time of the fire incident, the aircraft had logged 36,835 hours of flight time.

**Interior Cabin Materials**

Materials intended for use in the interior of aircraft operating in the United States are required to meet the FAA flammability regulations set forth in Section 25.893, paragraph 25.853 (a) of the Federal Aviation Regulations (FAR) part 25, Amendment 25-17, effective June 20, 1968. Since the adoption
of these requirements, more stringent flammability requirements, found in Amendment 25-32, paragraphs 25.853(a) and 25.853(b), were developed and adopted by May 1, 1972. (See Appendix, "Interior Cabin Materials Test Method.")

When the aircraft was refitted with the "Wide Body" style interior module in July, 1982, the materials used to fabricate the assemblies met the flammability requirements of the FAR adopted in May 1972. Not included in the interior modification however, were the food modules, galleys, lavatories, and passenger seats, and the decorative finish materials added to the existing lavatory assemblies by Air Canada.

The rear lavatory of the aircraft contained toilet and sink facilities. The configuration of the lavatory was such that the toilet was along the outboard portion of the fuselage. An acrylonitrile/butadiene/styrene//polyvinyl chloride (ABS/PVC) shroud covered the lavatory tank containing fluid, flush motor, and auxiliary plumbing. A stainless steel sink was perpendicular to and forward of the toilet along the aft wall of the lavatory. The sink was enclosed by a vanity which was also of ABS/PVC materials (see Photo 6).

Finish materials of the aft lavatory including the sidewall panel, aft panel, and vanity counter were ABS/PVC materials covered with a polyurethane paint or tedlar decorative finish. The lavatory door was wood veneer material, finished with tedlar paint. The forward panel of the lavatory was also wood veneer finish. Information on the performance of these components when tested using the appropriate FAA flammability regulations was not available to the NFPA at the time of the investigation and report.

The vanity contained compartments for sick bags, hand towels, sanitary napkins, an oxygen mask and toilet paper. The area under the sink formed by the vanity, contained a small trash container for hand towel disposal, a hot
water heater, drain pipes, electrical wiring, piping for an adjustable flow, fresh air discharge and a copper supply line for the emergency oxygen mask. A high air exchange rate in the lavatories is designed to exhaust odors. In the void space created by the sidewall panel and the inside skin of the fuselage was a support pylon for one of the aircraft's engines, a fuel supply line for the left rear, side mounted engine, and electrical wiring to the push button toilet flush mechanism.

The passenger seat cushions (back and bottom) of the aircraft were polyurethane foam with a seat covering of 90 percent lipro treated wool and 10 percent nylon fabric. Seat frames were steel and aluminum.

Major components of the cabin interior (see Figure 2) were comprised of fiberglass/nomex honeycomb and thermoformed plastic materials.

Weather

Surface weather observations for the Greater Cincinnati Airport on June 2, 1983 made by a certified observer of the National Weather Service are as follows for the following times indicated:

1850 hrs.- 2,500 feet scattered, measured ceiling 8,000 feet overcast, visibility 12 miles, light rain, temperature 63°F, dew point 55°F, wind 190° at 07 knots, altimeter setting 30.04 inches of Hg.

1930 hrs.- 2,500 feet scattered, estimated ceiling 8,000 feet overcast, visibility 12 miles, light rain, temperature 62°F, dew point 55°F, wind 180° at 05 knots, altimeter setting 30.03 inches of Hg.

According to the National Weather Service light rain began at the Greater Cincinnati Airport at 1734 and ended at 2024 hrs. During the crew interview on June 4, 1983, it was learned, that other than for the cloud conditions at about 3,000 feet, the emergency descent and landing was not delayed by the weather conditions encountered by Flight 797.
In-Flight Cabin Fire

Air Canada Flight 797 was progressing routinely enroute from Dallas-Fort Worth to Toronto until 18:51:14 hours (6:51 p.m.), when the three circuit breakers protecting the aft lavatory's toilet flush motor tripped. The captain unsuccessfully attempted to reset the circuit breakers. He instructed the first officer to enter the occurrence in the flight log.

A flight attendant checking on a passenger who had become ill and was moved to the last row of seats (Row 21, Seats CDE) detected a strange smell in the rear of the aircraft. The attendant checked the storage compartment behind row 21 and, as she reached across the aisle for a CO₂ extinguisher located on the forward wall of the aft lavatory, the smell became stronger. She opened the rear lavatory door several inches and found the area filling with "light gray smoke from the floor to the ceiling." She closed the lavatory door and moved forward in the cabin to notify the flight attendant-in-charge and the flight deck crew. The aircraft's cabin voice recorder logged the flight attendant's notification to the captain of "a fire in the lavatory" at 19:02:40 hours, approximately 12 minutes after the unsuccessful attempt to reset the circuit protection.

The flight attendant-in-charge proceeded to the aft lavatory to investigate the fire. He describes opening the lavatory door and seeing "... curls of smoke, almost black with gray edges." He observed smoke coming from the seam formed by the aft lavatory wall and ceiling materials. From the flight attendants position, the smoke build-up in the lavatory at this time was sufficient to obscure the sink. He discharged agent from a CO₂ extinguisher into the lavatory area in a circular motion, aiming at the seam and then at the trash bin, located under the sink area. He described the smoke as having "an electrical, acrid smell" that burned his throat and caused him to "feel dizzy."
While the flight attendant-in-charge was attempting to extinguish the fire, the two other flight attendants began moving passengers forward in the aircraft and began to open overhead air vents to disperse the smoke. The cabin voice recorder indicates that they asked permission of the captain to move passengers forward in the aircraft at 19:04:03 hours (approximately 1 minute after discovery). All passengers were ultimately seated forward of Row 13.

The captain sent the first officer to investigate the situation. At 19:04:36 hours, the cabin voice recorder logged the captain directing the first officer to "do what you can, but don't get yourself incapacitated." As the first officer proceeded to the rear of the aircraft, he observed the passengers being moved forward and smoke in the rear area of the cabin. Smoke was reported to have progressed four to five rows from the lavatory area by this time.

During his check, the first officer was advised that the flight attendant had discharged the CO₂ extinguisher into the lavatory. The first officer instructed the flight attendants to continue to move all passengers forward in the aircraft and to have them seated. Before checking for the severity of the fire, the first officer returned to the cockpit to retrieve smoke goggles because the smoke was beginning to irritate his eyes. Upon his return to the cockpit at 19:06:08 hours, the cockpit voice recorder logged his report to the captain: "Made big discharge in lav, smoke clearing." On his second trip to the aft lavatory, the first officer reported that he felt that the situation was improving. However, when the first officer touched the lavatory door, he found it to be very hot. Recalling a lesson from an emergency training film, the first officer instructed the flight attendants not to open the door.
During this assessment period, a master caution light, indicating an electrical system failure, illuminated in the flight deck area (the flight data recorder logged at 19:06:11 hours). The captain motioned to the first officer through the open cockpit door to return to the flight deck (the cockpit door would remain in the open position throughout descent). The cockpit voice recorder logged a discussion at 19:07:11 hours between the captain and the first officer: "I don't like what's happening. Let's go down" (approximately 4 1/2 minutes after report of fire). The cockpit voice recorder failed at 19:08:13 hours, eliminating recording of further internal discussions; however, conversations between the aircraft and air traffic controllers were able to be recorded.

"Mayday" calls were made by the crew to the tracking station at Indianapolis Center at 19:08:12 hours. As the aircraft prepared to land, tracking of the flight and emergency landing responsibilities were switched from Indianapolis Center to Cincinnati Approach Control, who began to guide the aircraft to the Greater Cincinnati International Airport and to notify emergency crews.

During emergency descent, the aircraft lost other important instrumentation which resulted in the Air Traffic Controller having to guide the aircraft's descent and approach with verbal instructions to the captain. Since only the aircraft's stand-by horizon was operating, the approach controller instructed the captain when to start and stop turns in the aircraft's final approach. The captain would make the approach using visual references and the late afternoon, overcast light.

Following Air Canada's procedures for passenger cabin smoke or fire, the aircraft was reported to have been depressurized between 10,000 and 12,000 feet. The flight deck crew donned their oxygen masks and smoke goggles as
smoke began to penetrate into the cockpit. The first officer cleared some of the smoke in the cockpit by opening and closing his side window. This procedure is specified in Air Canada's instructions for passenger cabin smoke or fumes. The flight deck crew did not deploy passenger oxygen masks, also specified in the instructions.

During the approximate 10 minutes required to land the aircraft, two attempts were made by the Approach Controller to obtain specific information about the aircraft and the severity of fire in order to inform the CFR crews. At 19:10:48 hours, the crew informed the Approach Controller, "We have a fire in the washroom. We're filling up with smoke." The crew then radioed at 19:17:06 hours, "We're going to need fire trucks," at which point the Approach Controller informed the flight deck crew that the trucks were standing by. The Approach Controller then asked the crew for the second time for the number of people and the amount of fuel onboard, to which the crew again responded, "Don't have time" and added to the second radio transmission, "It's getting worse here."

In the cabin of the aircraft, flight attendants instructed passengers in emergency evacuating procedures. The flight attendants did not assign passengers to specific emergency exits for fear of sending them to an exit which would be unuseable (due to smoke and/or heat build-up). The flight attendants instructed passengers, seated near the overwing window exits, how and when to open the emergency exits. A passenger seated in an adjacent row to the overwing exits was briefed on how to hold people back in order to allow for the space required to open the overwing exit windows. One passenger in Row 2 were briefed on how to block the aisle so as to allow the flight attendants the time needed to open the forward main exits and deploy the emergency egress chutes.
During this time, the flight attendants described conditions within the cabin as deteriorating rapidly following a "bump" as if the aircraft had flown into turbulence (the "bump" was the result of the descent being made with full spoilers which occurred at approximately 19:09 hours or about 11 minutes before the aircraft landed). Using the "bump" as a time reference, passengers and flight attendants noted that smoke obscured the aft section of the aircraft. The color of the smoke is described as changing from gray to black at this point.

Following the detailed instructions on emergency evacuation, the flight attendants distributed wet towels to the passengers. They instructed passengers to hold the towels over their faces and breathe through them. The idea of distributing wet towels apparently came from a hotel fire safety bulletin which had been issued to the flight attendants in October, 1982, by the Canadian Air Line Flight Attendants Association. Approximately 20 wet towels had been distributed when the first officer ordered everyone to be seated as the aircraft was on its final approach. Those passengers who did not receive a wet towel were encouraged to breathe through clothing or similar materials.

At this point during the descent, one flight attendant indicated that she could not get to Row 12 to check passenger seatbelts because the smoke was too thick. Another flight attendant seated on the floor at the front of the aircraft reported she could only see the passengers' knees due to the dense smoke. Further, she thought that a position in a passenger seat would better prepare her for landing and her evacuation responsibilities. She got up and used the seat backs as guides and found her way back to Row 7 or 9. She describes barely being able to see the passenger seated next to her at this time. She instructed the passengers to place their "heads on their laps" and
"brace for landing." Some passengers described being "covered with soot" at about this time. A "confused and mesmerized passenger" was directed to the front of the aircraft and was administered oxygen by the flight attendant-in-charge. Passengers described that there were people coughing and choking and that a flight attendant was "choking" while giving emergency instructions.

The aircraft made a smooth landing at 19:19:59 hours, approximately 17 minutes after the first notification of a fire. The captain, aware of the urgency of the situation, made a maximum effort to stop the aircraft, accepting the possibility of blowing the tires (which did occur).

Escape from the Aircraft

As soon as the aircraft touched down, the flight attendants, concerned that the dense smoke conditions within the cabin would obscure exit markings and exit door operating mechanisms, moved quickly to open the aircraft's forward left and right side main exits and deploy the emergency slides.

The flight attendant-in-charge, who was seated in a jump seat adjacent to the left main exit, opened the exit and deployed the emergency slide. Seated in a jump seat next to the flight attendant was the passenger who was receiving oxygen. The flight attendant-in-charge assisted this passenger out the left main exit. He shouted instructions (e.g. "come this way," etc.) to the remaining passengers in the cabin until the heat and smoke became unbearable and forced him to exit.* A total of seven passengers and two flight attendants exited the aircraft through the left main exit.

The seven passengers who escaped through the left main exit later described conditions in the cabin and their individual evacuation actions in the following way: A male passenger in Seat 2B blocked the exit path to the

*The flight attendant may have been the last, or one of the last persons, to have evacuated the aircraft.
forward main exits as instructed by the flight attendants. He described being unable to see activity within the cabin and did not feel anyone pushing against him. He heard the exit commands of the flight attendants in the front of the aircraft. He moved in an unobstructed path to the exit. He was able to locate the exit from an outside light illuminating through the smoke.

The passenger in seat 3A began to exit by moving to the rear of the aircraft; however, she had only traveled one row when she bumped into another passenger and realized her mistake. She reversed her direction and, as she approached the forward main exit, she heard the instructions of the flight attendant and left the aircraft. She described being sprayed with foam once outside the aircraft and saw flames in the cabin approximately 30 seconds after she exited. The passenger in seat 3E hesitated a few moments and then felt the seat next to him and found the passenger seated there had already moved to exit the aircraft. He then dove onto the floor and described crawling over one person on the floor while making his way forward. During his evacuation, he felt the heat migrating forward in the cabin. The passenger seated in 5C noted heat migrating forward in the cabin as he travelled forward keeping his head down to breathe better air. Before exiting the aircraft, he found the forward bulkhead was hot to his touch. Two passengers seated in 2E and 8E did not recount in any detail the events they experienced during their escape from the aircraft; however, neither described encountering any other passengers.

The flight attendant, seated in seat 7B or 9B, quickly moved forward in the aircraft and did not encounter any passengers. She opened the right main exit door (in the galley area) and deployed the emergency slide. She instructed passengers to "come this way"; however, there was no response. She waited three to four seconds, then exited the aircraft down the emergency
slide. She paused again for a couple of seconds at the bottom of the slide and, when no passengers appeared at the exit, she ran to the left forward side of the aircraft to help move passengers away from the aircraft. The flight attendant was the only person to exit the aircraft through the right main exit door.

The first overwing window exit opened appears to have been the forward right overwing exit at Row 12. The passenger in seat 12E reported that the overwing window exit assembly operated easily. His wife, next to him in Seat 12D, followed him out onto the right wing. From their position on the wing they saw the right forward main exit emergency slide being deployed at the front of the aircraft. A passenger in seat 11C heard the window exits being opened and made her way through dense smoke to Row 12 where she exited through the front right overwing exit. She described the cabin erupting into flames soon after she evacuated the aircraft and was hit with foam directed onto the fuselage as she was stepping through the exit onto the wing. A passenger in seat 10E moved quickly to the forward right overwing exit and exited over the right wing.

The flight attendants assigned the opening of the rear right overwing window exit to a passenger in seat 9C. He moved to its location in Row 13 and described having some difficulty locating the rescue handle due to smoke conditions. Once he had located the release mechanism and removed the window exit assembly, he evacuated over the right wing.

Five passengers were now clustered at the tip of the right wing. One passenger jumped off the front of the wing. The remaining four passengers decided they would jump to the ground from the trailing edge of the wing. One passenger suffered a transverse fracture of the patella (knee cap) and a 3/4-inch laceration of the palm of his left hand as a result of his jump. He was assisted away from the aircraft by another passenger.
Opening of the forward left overwing window exit was assigned to the passenger in seat 10B. He got up from his seat seconds after the aircraft landed and moved to Row 12 where he opened the window exit and stepped out onto the left wing. The passenger next to him in seat 10A followed by holding onto his belt. Due to smoke conditions she could not see him remove the window exit assembly. The passenger in seat 11E got up from her seat as soon as the aircraft came to a stop. She recalled hearing the overwing exits being opened as she was making her way to the right overwing exit. Due to the severe smoke conditions, she was using passenger seats in attempting to locate the exit. She described becoming disoriented and traveled past the exit. She was able to locate the exit by feeling a breeze on the back of her legs. She then exited through the left overwing window exit. The passenger in seat 9E decided to move toward the rear of the aircraft and exit through an overwing window exit. He described bending down as he moved toward the exit. He then saw a little light at the left forward overwing window exit and walked out onto the wing.* A fire fighter and a flight attendant on the ground instructed passengers on the left wing to jump to the ground.

During this time, the captain shut down the engines and remaining systems, and activated the fire suppression systems, turned off the fuel supply and set the brake before preparing to leave the aircraft. During the final shutdown of the aircraft, he pushed back his seat, removed his oxygen mask, and began to exit through the interior of the aircraft. He later described being affected by the products of combustion. The captain was aroused from this state when extinguishing agent was directed toward him by CFR crews. The

*Two other passengers also exited through the left forward overwing window exit. They were seated in Row 11, seats A and B. Detailed accounts of their experiences were not available.
captain exited the aircraft through his emergency escape window. The first officer first attempted to exit the aircraft using an interior exit. Heat and smoke conditions prevented his using this escape route, and he then opened his emergency window exit and lowered himself to the ground.

The exact positions of all occupants during final approach is not known nor it is known if all occupants were following flight attendant's instructions by breathing through wet towels, clothing, etc. It is known that some passengers were seated (kneeling, etc.) on the floor between passenger seats and others were seated in their seats and braced for landing. A majority of survivors described filtering breathing air through some type of material. The effect that this had on survival is not known.

**Crash Rescue Operations**

At 19:10 hours, the Greater Cincinnati International Airport Fire Department was notified by air traffic controllers via an interlocking telephone circuit (crash phone) that a "Boeing 707" with a fire in the cabin was preparing to land on Runway 36. The Fire Department responded to Runway 36 with four crash/fire rescue units and assumed their standby positions (Units No. 907, No. 913, No. 967, No. 980). When the four CFR units had set up for a Runway 36 landing, the officer-in-charge contacted the control tower seeking specific information on the number of people on-board, the quantity of fuel, and information on the onboard cabin fire. The tower was unable to give specific information on the number of people on-board or the fuel remaining, but did confirm the aircraft had fire and smoke on-board.

The crews from two pieces of structural apparatus (Units #951, #960) who remained at the fire station were monitoring the radio transmission between Flight 797 and air traffic controllers. The crew members (2 fire fighters and an officer) overheard that the aircraft had lost most of its instrumentation.
Realizing the severity of the incident, the crew decided to respond to the outer edge of the main ramp until the aircraft touched down.

At 19:17 hours, approximately 3 minutes prior to touchdown, the tower informed the officer-in-charge that the aircraft was a Boeing 727 not a Boeing 707 and that the aircraft had been redirected to land on Runway 27L. The four CFR units responded and set up for a Runway 27L landing (see Figure 3). While the CFR units were repositioning to Runway 27L, the tower informed the officer-in-charge that the aircraft was 5 miles due east of the airport and would be the next aircraft to land. When the officer-in-charge made visual contact with the aircraft on its final approach, he identified the aircraft as a DC-9 and confirmed with the tower that this was the aircraft. As the aircraft was landing a "light stream" of smoke trailing the aircraft was observed by CFR crews (and other airport personnel).

At 19:20 hours, the aircraft touched down on Runway 27L and came to a stop short of taxiway "J". The officer-in-charge directed all equipment to respond to the scene. The four CFR units began to set up for rescue and exposure protection. The forward exit emergency slides were being deployed and passengers were beginning to exit the aircraft as the CFR apparatus arrived. The two pieces of structural apparatus (#951, #960) standing by on the outer edge of the main ramp responded to a position behind 907 and 913, now positioned in front of the aircraft (see Figure 4).

The CFR officer-in-charge decided that initial operations would concentrate on protecting passengers exiting the aircraft by establishing and maintaining exit path which would allow the self-evacuation to continue. To accomplish these objectives, Units No. 907 and No. 913 discharged foam from their turrets onto the fuselage of the aircraft. There was concern among the crew regarding the amount of fuel that remained on-board, the integrity of the fuel cells after landing, and the impact that an exposure fire would have on
the fuel system. The OIC requested that the "move-up systems" be put into effect (Time - 19:21 hours). This initial command to initiate the move-up system was either not heard or not understood by personnel at the communications room, for documentation shows that first mutual aid companies from Hebron, Kentucky were not dispatched until 19:30 hours, approximately 9 minutes after the initial command was given.*

The fire fighter operating Unit #913 noticed a member of the flight deck crew (later identified at the captain) struggling to exit through the emergency window exit in the cockpit. The first officer also brought the captain's condition to the attention of CFR crew members. The fire fighter directed 913's turret and discharged foam onto the nose of the aircraft which was then deflected onto the captain reviving him. When the captain had safely exited, additional foam was then discharged from the turret into the cockpit.

During these initial actions and while the self-evacuation process was taking place, CFR crews noted that the severity of the interior cabin fire began to intensify beginning with the opening of the emergency exit doors. Flames now began to be observed in the interior of the aircraft. In response to this observation, Units No. 907 and No. 903 blanketed the fuselage with foam, while other crew members assisted passengers from the slides and from the overwing exits. Other members of the CFR crew assisted in these operations.

At this time, smoke from the aircraft at this time changed from black to brown several different times. There were no additional unassisted persons exiting the aircraft after approximately 1 minute of landing. CFR crews began to obtain the information that some people remained on-board.

*Some of the fire apparatus responded when the CFR OIC requested rescue companies to respond to the scene.
Manpower from the structural apparatus advanced a 1 1/2-inch handline (taken from Unit 907) to the left wing area in an attempt to extinguish the fire while Units 907 and 913 protected their positions.

The two fire fighters at the left wing area were equipped with self-contained breathing apparatus (SCBA) and attempted to advance their line into the interior of the aircraft but were driven back by the intense heat. They did, however, continue to discharge foam into the interior of the aircraft. The heaviest fire conditions were now found in the rear of the aircraft and the first blistering of outside paint was now observed above the left engine of the aircraft.

The OIC obtained information from the captain estimating that 12,000 pounds of fuel remained in the aircraft and that 23 persons might still be on-board.

In an attempt to ventilate the aircraft, gain control and lessen the severity of fire, and gain entry into the aircraft, the officer-in-charge released the rear tail cone. A ladder was placed to the tail area and fire fighters using SCBA equipment eventually (delayed by severe heat conditions) were able to open the rear exit door located approximately 20 feet within the interior of the aircraft. The fire fighters on the left wing temporarily abandoned their position to assist in the ventilation. They returned to the left wing area and resumed their attack and attempted to push the fire out the rear of the aircraft. Due to the severe fire conditions, this attack was not successful and the handline operation was abandoned.

Crash units continued to bank foam into the interior in further attempts to gain control of the fire and to continue the defensive protection of crew members.

A 1 1/2-inch handline from Unit No. 907 was stretched to the rear of the aircraft with the intention of advancing this line through the emergency exit
door. However, the handline was approximately 20 feet short. Unit #951 was then moved to the rear of the aircraft and the turret was raised into the rear exit door. Foam from the turret was discharged through the rear exit. However, because of a difference between the height of the aircraft and the height of the turret, an insufficient amount of agent was reaching the fire and this operation was abandoned. Fire was now clearly visible in the rear of the aircraft. A 1 1/2-inch handline from Unit No. 951 was advanced through the rear exit door and began to control the fire.

While the 1 1/2-inch handline was being advanced through the rear exit of the aircraft, a second 1 1/2-inch handline was stretched from Unit #951 to the left side rear of the aircraft just forward of the aircraft's engine. A fire fighter raised a ground ladder to the aircraft and discharged agent through the cabin windows. When it was determined that the fire was beginning to be controlled in the rear area, the fire fighter repositioned the ground ladder to the left forward main exit door. He entered the aircraft and began to control the fire in the forward section of the cabin. The fire was being controlled when the water supply for Unit No. 951 was depleted (approximately 19:32 hours).

Unit No. 907 was also running out of water and Unit No. 960 was used to replenish No. 907 until supply lines could be laid. Crash Unit No. 913 was directed by the OIC to conserve its remaining foam until supply lines were in place. At this point in the fire suppression operations, water supply was a major problem. Mutual aid companies were arriving on the scene to support the extinguishment efforts, and preparing to lay supply lines.

Hebron Unit No. 355 was the first mutual aid engine company to arrive on the scene at 19:38 hours. The command officer of the Hebron units was instructed to lay a 2 1/2-inch supply line from the underground hydrant on
taxiway "K" (approximately 800 feet from the aircraft) using airport Unit #960. There are no markings to indicate the location of the underground hydrants and the mutual aid personnel were unable to locate the hydrants. The unit returned to the aircraft area and picked up an airport fire fighter who directed them to the hydrant. This 2 1/2-inch supply line was connected to a second mutual aid engine company (Point Pleasant Unit No. 1351) which pumped water to airport Unit No. 913. An additional 5-inch supply line was laid (by the Erlanger Unit) from the same underground hydrant to the Hebron Unit.

During the interruption in fire suppression operations and while supply lines were prepared, the fire within the cabin of the aircraft gained headway and was burning freely before the final attack began. Fire had now penetrated (ventilated) the aircraft in two locations. When the water supply was replenished, the units quickly began to bring the fire under control. Complete extinguishment was accomplished at 20:17 hours, 56 minutes after fire suppression operations began.

Damage to the Aircraft

The major external damage to the aircraft was the result of direct flame exposure and impingement to the fuselage skin from the cabin fire within (see Photo 2.) Before extinguishment of the cabin fire was accomplished, the upper portion of the fuselage skin had burned through at three distinct areas of the aircraft. The melting of cabin windows and window seals was evidence of intense heat generated by the fire.

The interior fire damage was limited mostly to the passenger cabin area. Cockpit damage was limited to smoke and extinguishment residue with only mild fire damage evident. Ceiling and upper sidewall panel assemblies in the passenger cabin area were almost completely consumed. Overhead storage compartments were burned and had collapsed onto the seats along the right and

27
left sides of the aircraft. The only remaining identifiable cabin sidewall panelling assemblies were found below the window line. Carpet, particularly in the aisle of the cabin, was undamaged by the fire and exhibited only signs of smoke and extinguishment agent damage. All the passenger seat cushions were partially burned or consumed in the fire.

The aft lavatory including its wall and door assemblies was nearly totally consumed by the fire. Only materials close to the floor remained undamaged by the fire. The hot water heater, toilet pump motor and other equipment displayed signs of heat damage. Melting of copper and aluminum materials indicated that high temperatures were present in the lavatory area. The trash receptacle was intact and some unburned trash was found in the container.

Survivors

Eighteen passengers and the crew of five were able to safely exit the aircraft following landing. All eighteen passengers were transported to surrounding hospitals. Thirteen passengers were treated for smoke inhalation. They described conditions such as coughing, mild sore throats, chest pains, and some irritation of the eyes which are characteristic of exposure to products of combustion. Two passengers experienced more serious effects from their exposure to products of combustion, however in both cases there was no evidence of significant heat or lung damage. One passenger suffered a fracture of the left patella and a laceration of the left hand. He sustained these injuries when he jumped from the right wing of the aircraft to the ground. The remaining two passengers were transported to a hospital but declined treatment.

Two hospitals, St. Elizabeth Hospital-South and Booth Memorial Hospital, received notification of the fire incident at 19:55 hours. Both hospitals activated their disaster plans (St. Elizabeth South had participated in an area-wide disaster drill three to four weeks prior to the incident). St.
Elizabeth South received three patients and Booth Memorial Hospital received 15 patients, 14 of whom were admitted for further observation and/or treatment.

At some point, blood samples were taken from the 18 surviving passengers and analyzed for the levels of carbon monoxide and cyanide. The analysis indicated no significant elevation in the levels of either carbon monoxide or cyanide.

Casualties

All 23 fatalities in this incident were passengers. Medical reports indicate that there was evidence of burns on each of the 23 victims. The magnitude of the burns ranged from widespread second degree burns of exposed areas to fourth degree burns with charring of exposed skin. Autopsies were performed on five victims under the direction of the Boone County Coroner and five others were autopsied under contract with Air Canada.

Blood samples were taken from all 23 victims and analyzed for levels of carbon monoxide, cyanide, and ethyl alcohol (see Table 1). The results of the analysis showed the victims had carbon monoxide levels ranging from 20 to 63 percent saturation. Cyanide levels ranged from a low of .80 to a high of 5.12 micrograms/ml. Alcohol levels in samples from three of the victims were in excess of .10 percent concentration.
III. ANALYSIS

Fire Development and Smoke Spread

As of this time, the NTSB investigative team has not determined a specific cause of the fire aboard the Air Canada aircraft. As a result, the cause is currently listed as "undetermined." More information regarding the specific ignition scenario may be revealed upon the release of NTSB's final report of the incident. Several observations regarding the area of origin were made during the on-site investigation. First, the physical evidence examined indicates that the fire originated in the rear lavatory area of the aircraft. Severe damage and low burning of combustibles was noted in an area bounded by the vanity and the union of the aft and outboard lavatory walls. Contained in this area were the electrical wiring for the toilet flush motor and for the hot water heater. An electrical fire was initially listed as the probable cause of the fire by the NTSB. Interviews conducted with passengers and crew members confirm the rear lavatory as the general area of origin and they place the first visible products of combustion in an area congruent to the severely damaged area of the lavatory.

Several ignition scenarios were also thought to be possible; however, the team eliminated "smoking materials igniting combustibles within the trash bin" as a possible ignition scenario. The fixed-temperature Halon extinguisher protecting the hand towel disposal container activated and many of the discarded hand towels were found intact.

Regardless of the specific heat of ignition, once ignition took place, a sufficient amount of readily available combustibles was present in the lavatory area to continue the growth of the fire. These materials included paper products, ABS/PVC interior wall, toilet shroud, vanity and ceiling materials, electrical insulation, and a wood veneer forward wall and lavatory door.
The activation of the three circuit breaker devices to the rear lavatory toilet flush motor at approximately 18:52 hours may or may not have been related to the ignition of the fire. This was, however, the first indication that some type of a problem existed in the rear lavatory. The flight deck crew followed McDonnel-Douglas operating instructions that indicate that, when circuit protection devices activate, an attempt should be made to reset them. The instructions further note that, "It may be necessary to wait approximately 3 minutes cooling time before the circuit breaker will accept a reset." The captain could not reset the circuit protection and instructed the first officer to note the problem in the aircraft's log. No attempt was made to further examine the cause of the failure.

The problem in the rear lavatory was identified as a "fire" when the flight attendant opened the lavatory door and observed smoke conditions. She reported the fire condition to the flight deck crew at approximately 19:03 hours.

The fire at this time was concealed and only in evidence at the seam of the rear wall assemblies. The extinguishing method used by the flight attendant was ineffective for suppressing a concealed, interior partition fire.

During the next 6 1/2 minutes of assessment, Flight 797 continued on its course and the captain received conflicting information regarding the severity of the fire and results of the crew's extinguishment attempt. Apparently the loss of most of the aircraft's electrical system and the developing smoke conditions were enough to elicit a "Mayday" call at approximately 19:09 hours. It would take an additional eleven minutes to land the aircraft.

Once in the free burning phase, fire growth was very rapid. The flight attendant did not describe severe heat conditions within the lavatory at discovery. However, the first officer found the lavatory door "hot to the
touch" within an approximate 5-minute time period. The fire at this time was likely to have been in a free burning, fuel controlled phase, spreading to adjacent combustibles within the lavatory. The small, confined lavatory area with combustible interior materials, the low ceiling height and the corner location of the area of origin would have greatly affected the growth of the fire. Thick, acrid smoke was also being produced during this initial development phase, and beginning to be distributed throughout the occupied area of the aircraft.

Smoke and heat penetrated in the cabin area by two primary means. First, they penetrated the ceiling and spread (at first undetected) throughout the void area between the finished ceiling material and skin of the aircraft, and were distributed throughout the entire length of the aircraft. As the fire continued to develop, materials in the overhead area began to be ignited, and smoke spread into occupied areas of the aircraft.

Smoke and toxic gases were temporarily prevented from spreading into the cabin area by the closed lavatory door. As the fire continued to grow, some smoke penetrated into the cabin around the door. Smoke stratified at the ceiling level of the passenger area and spread toward the front of the aircraft. As the fire continued to grow, smoke began to build down to the level of the seated passengers.

Before the landing, the smoke began to obstruct passengers' vision and obscure the locations of emergency exits. Once the aircraft landed and emergency exits were opened, the in-rush of air resulted in an increased fire intensity. The fire then began to involve other materials (unburned gases, etc.) and severely limit available evacuation time. As conditions continued to deteriorate, the smoke (and other products of combustion) and the
decrease of available oxygen was likely factors affecting the ability of passengers to safely evacuate the aircraft.

When the aircraft landed, smoke conditions within the aircraft obscured seated occupants' vision. There were some reports of passengers feeling heat at the overhead compartment level as they evacuated the aircraft. One of the last persons to exit the aircraft, the flight-attendant-in-charge, evacuated after smoke and heat conditions became so severe that he "...could not stand it any longer."

Discussion

Records indicate that in-flight fires on-board commercial aircraft is not a rare occurrence. Few of these past fires have developed to the stage where occupants were threatened. However, when cabin fires (from trash, cigarettes, electrical wiring, etc.) begin to impinge on interior materials such as passengers seats, wall assemblies, etc., the risk to the flying public is unacceptable as evidenced by the Air Canada incident. Ignition controls such as eliminating smoking, open flames and/or providing fixed detection/suppression systems for early awareness can lower the probability of a fire occurrence.

The primary materials involved in the initial growth, development and spread of the fire were the contents of the lavatory, combustible materials in the void space above the ceiling, the ceiling materials and overhead compartments. Other materials, although ultimately consumed, such as seat cushions and covering, and passenger area wall materials, likely became involved after the untenable conditions were reached in the aircraft.

Only a very short interval of time existed before conditions deteriorated to an untenable state within the aircraft. During this time period, survival depended on a number of factors including: (1) Occupants' location in relation to emergency exits. Those occupants located near emergency exits and
those who moved quickly toward the exits appear to have had a higher chance for survival. The flight deck crew had emergency exits immediately available to them. The last passengers to exit describe heat conditions becoming worse as they moved toward exits. The first flames were observed by a passenger just after she stepped onto the wing and looked back at the aircraft. It was highly unlikely that occupants could exit the aircraft once this stage of fire development was reached.

(2) **Following flight attendants' instructions during descent.** Moving the passengers to a forward position and adjacent to emergency exits was vital. Instructions to "stay low," "move this way," etc., aided passengers during escape. Further, filtering breathing air through wet hand towels, clothing and other materials may have filtered some toxic gases, sooty particulate matter and/or may have had a positive psychological effect on users. A majority of survivors mentioned breathing through various materials during descent.

(3) **Utilization of oxygen masks by the flight deck crew.** The flight deck crew donned their oxygen masks early during the emergency. This prevented their breathing toxic gases present in the interior of the aircraft. As a result, they were able to safely land the aircraft. The use of smoke goggles and the clearing of smoke from the flight deck area, when the first officer opened his emergency exit window prevented eye irritation and helped the captain keep a clear view of the airport for landing.

**Major Contributing Factors**

Based on the NFPA investigative study, the following are considered to be major contributing factors to the loss of life in this fire:

- The lack of automatic detection and effective suppression of a developing, concealed fire in the rear lavatory area.
Since evacuation of an in-flight commercial passenger aircraft is not feasible, emphasis must be placed on other strategies, such as fire protection systems to provide early detection and suppression of an interior cabin fire.

Detection of a fire is usually prompt when occupants are alert and adjacent to the area of origin. In this incident, however, the high rate of air exchange in the lavatory may have delayed the human detection of the concealed fire. As a result, the installation of automatic smoke detection equipment in this area may have provided earlier warning.

Because of the concealed nature of the fire in the rear lavatory of the aircraft, it could not have been effectively extinguished by the method used by the crew. Flight crew training does not include methods for suppressing a concealed interior fire. Special training and equipment is required to suppress concealed fires.

- The rapid fire and smoke development due to available fuels, aircraft configuration and the lack of adequate fire barriers.

Once the combustible interior finish materials were exposed to a sufficient amount of heat from the developing fire, they became involved. There was a sufficient amount of these materials present to continue the growth of the fire. Because of the small area of the lavatory, combustible materials were in close proximity to one another in the developing fire. This arrangement of fuels, plus the location (corner of lavatory) of the area of origin, resulted in a rapid development of the fire. Spread of the fire into adjacent occupied areas of the aircraft would have been rapid since there were no fire barriers present. Fire test results indentifying specific fire hazard characteristics of materials from the lavatory were not available. (See Appendix for discussion of federal aircraft interior finish requirements and generic small scale fire test results.)

- The reduced occupant evacuation time resulted from one or more of the following factors: the rapid developing fire; the effects of heat, smoke and toxic gases on passengers, and the nature of in-flight emergency egress.

35
Evacuation of the Air Canada aircraft could not begin until the aircraft landed, came to a stop and emergency exits were opened. During this time, the fire within the cabin of the aircraft was unchecked in its growth. There was a sufficient amount of combustible materials present to result in an extremely intense, life-threatening fire. Toxic gases spread into the occupied area of the aircraft and began to affect the occupants' chances of survival and their ability to safely exit the aircraft. In addition to these toxic products, smoke obscured occupants' vision and hindering their ability to locate emergency exits.

The following are considered significant additional findings of the NFPA investigative study:

(1) The flight deck crew apparently did not perceive of the danger presented by a fire within the aircraft. Because of the earlier mentioned factors, interior aircraft fires can progress to a life threatening phase very rapidly. A period of approximately 6 1/2 minutes elapsed from the time the flight deck crew was notified of a "fire" within the cabin until the decision to land the aircraft was made. An uncontrolled fire within an aircraft represents a severe threat to occupants. Although the flight deck crew did adhere to the emergency operation procedures for activation of circuit breakers, they did not conduct a visual inspection of the area affected by the circuit breaker operation. Operation of these safety devices are indicative of an electrical problem.

(2) Once self-evacuation of the aircraft stopped and the intensity of the interior fire increased, it was highly unlikely that the CFR crew could rescue the remaining passengers. Manual fire suppression could not ensure life safety given the extent of fire growth.

(3) Current concern exists regarding the flammability of passenger seating materials. Although ignition of the seat material currently being
used in aircraft would present a life-threatening scenario, it was not until untenable condition was reached that these materials became involved in the interior fire.

(4) CFR crews failed to quickly initiate a move-up system as soon as it became obvious the severity of the interior aircraft fire would necessitate a supplementary water supply. The lack of information regarding the amount of fuel, type of aircraft, and severity of the interior fire may have been a factor in this delay. Given the factors in this incident, however, mutual aid would not have reduced the loss of life.

Recommendations

In addition to the above findings, the following are recommendations for further study and the improvement of aircraft fire safety based on the analysis of this incident.

(1) The victims of the Air Canada fire, like an estimated 80 percent of all fire fatalities, were most likely prevented from escaping by the smoke and toxic gases. Current FAA regulations regarding material flammability does not assess the effects of toxic products of combustion or other factors when judging ignitability. A fire hazard assessment should be developed that considers: (1) ignitability, (2) flame spread, (3) heat release rate, (4) smoke toxicity, (5) smoke generation rate, (6) quantity of use of materials needs. Further, this hazard assessment must recognize that these materials are affected by (1) the geometry of the aircraft, (2) ventilation, and, (3) protection systems.

(2) Flight deck crews need to be trained in fire dynamics of an interior aircraft fire. Interior fires (if not detected and suppressed) involving combustible materials can present a life-threatening situation to occupants. Flight crews should be trained to recognize this danger and integrate this
awareness of fire dynamics into their overall knowledge of emergency procedures.

(3) Continued emphasis needs to be placed on the importance of instructing flight attendants in emergency evacuation procedures. Further, training in the use and selection of portable extinguishers for combatting fires needs to be emphasized during yearly flight attendant training recertification. During flight attendant training for certification, specific emphasis needs to be placed on gaining access to and extinguishing concealed interior partition fires.

(4) Research needs to be conducted, that would lead to the development of a portable fire extinguisher penetrating nozzle for suppression of concealed, fires. The research should consist of feasibility for use by flight crews utilizing portable fire extinguishers and various extinguishing agents.

(5) Emphasis needs to be placed (and extensive training given) on proper tactics, for fighting interior aircraft fires as compared to tactics for past crash fires.

(6) Further research should be conducted regarding the Air Canada incident to study survival time of occupants, including the migration of toxic gases, given the specifics of the ignition scenario, materials involved, etc. Computer models could be utilized to study, for example, the effects of oxygen mask deployment, rescue strategies, human reaction, tail cone activation during descent, etc.

(7) Research is needed regarding fixed detection and fire suppression systems for hazardous locations to detect and control fires in the incipient stage.
IV. APPENDICES

A. Casualty Information

B. Interior Cabin Materials Test Method
   Interior Material Description

C. Figures

D. Photographs
<table>
<thead>
<tr>
<th>Sex</th>
<th>Carbon Monoxide (Gas Chromatography): % saturation</th>
<th>Cyanide (Conway Diffusion): ug/ml</th>
<th>Ethyl Alcohol (Gas Chromatography): %</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>53</td>
<td>2.96</td>
<td>0.199</td>
</tr>
<tr>
<td>M</td>
<td>33</td>
<td>5.12</td>
<td>0.133</td>
</tr>
<tr>
<td>M</td>
<td>31</td>
<td>0.80</td>
<td>0.052</td>
</tr>
<tr>
<td>F</td>
<td>36</td>
<td>3.68</td>
<td>0.079</td>
</tr>
<tr>
<td>M</td>
<td>28</td>
<td>3.54</td>
<td>0</td>
</tr>
<tr>
<td>M</td>
<td>37</td>
<td>4.440</td>
<td>0</td>
</tr>
<tr>
<td>M</td>
<td>42</td>
<td>2.08</td>
<td>0.024</td>
</tr>
<tr>
<td>M</td>
<td>38</td>
<td>2.06</td>
<td>0</td>
</tr>
<tr>
<td>M</td>
<td>42</td>
<td>5.04</td>
<td>0.095</td>
</tr>
<tr>
<td>M</td>
<td>20</td>
<td>2.20</td>
<td>0.014</td>
</tr>
<tr>
<td>M</td>
<td>63</td>
<td>(quantity not sufficient)</td>
<td>0</td>
</tr>
<tr>
<td>M</td>
<td>38</td>
<td>2.00</td>
<td>0.028</td>
</tr>
<tr>
<td>M</td>
<td>39</td>
<td>2.10</td>
<td>0</td>
</tr>
<tr>
<td>M</td>
<td>43</td>
<td>1.16</td>
<td>0.139</td>
</tr>
<tr>
<td>M</td>
<td>46</td>
<td>2.12</td>
<td>0</td>
</tr>
<tr>
<td>M</td>
<td>51</td>
<td>1.68</td>
<td>0</td>
</tr>
</tbody>
</table>

*Data from Department of Transportation, Federal Aviation Administration Toxicology Report (RIS AC 8025-2).
Interior Cabin Materials Test Method

Federal regulations adopted in 1947 for aircraft interior materials classified the materials in four separate categories, depending upon their intended use or location within the aircraft. These materials were classified as: (1) fireproof, (2) fire resistant, (3) flame resistant, and (4) flash resistant. The first two categories were for materials either completely or largely noncombustible in composition. Materials such as metals, glass, and asbestos usually fall into the first two categories. In contrast, flame and flash-resistant materials are primarily organic and therefore combustible.

The test apparatus consists of a ventilated metal cabinet to provide a draft-free environment, a specimen holder to assure rigid specimen support, and a timer. Although this test method was originally designed to measure the horizontal burn rate of fabrics, it is applied equally to all cabin materials without distinction to their composition or end use.

The Bunsen burner flame temperature is set at 1500°F and the flame height is adjusted to 1 1/2 inches. A specimen is exposed for 12 seconds. Flame-out time is measured from the instant the burner flame is removed until the time flaming of the material ceases.*

*It is important to recognize that laboratory tests using a small ignition source, such as a Bunsen burner flame are severely limited in their ability to simulate fire behavior of materials in a full-scale environment such as an aircraft. At elevated temperatures materials are much more flammable than will be indicated by Bunsen burner tests under the normal ambient temperature conditions typical of an incipient fire.
The 1947 FAR regulations specified a maximum burn rate of four inches per minute for test samples placed in the horizontal position and exposed to a controlled flame from a Bunsen burner in order to be designated as "flame-resistant." A wide range of plastic materials were able to pass this test requirement and be used as interior aircraft materials. With the exception of certain types of materials, notably seat upholstery and foam padding, most of the materials tested by this method were classified as "self-extinguishing," achieving a zero horizontal burn rate. However, subsequent tests conducted by the FAA on a large selection of cabin interior materials showed that, for the majority of interior cabin materials, the maximum burn rate was too lenient.

In response to greater awareness of the dangers of cabin fires and to take advantage of the latest developments in material technology, a goal was set that would require all interior materials eventually to be self-extinguishing.\(^1\)

In 1966, a revision of the federal standards required that certain types of interior materials used in wall, ceiling, partition, and floor construction be self-extinguishing when tested (using the Bunsen burner procedure) in the "vertical" position with an 8-inch char length.\(^2\) The revised FAA standards eliminated the lowest category of flash resistant materials which permitted some high burn rate materials for use.

---


2 "Federal Aviation Regulations" (FAR), Part 25, Airworthiness Standards Transport Category Airplanes (amended October 24, 1967, as per Docket 7522).
Further upgraded standards were issued by the FAA in 1969 and were adopted as a regulation in May, 1972. The severity of the test was again increased and the maximum allowable char and/or burn for some materials such as panels was decreased to 6 inches, and for upholstery fabrics and other cabin furnishings, the decrease was to 8 inches.

In more recent times, the FAA conducted other tests of current state-of-the-art interior cabin materials. These tests were conducted to obtain heat release rates of various cabin materials. The tests (using radiant panel apparatus) found that the magnitude of the values obtained depends on the thickness of the specimen, the extent of ablation, char formation, chemical treatments and the ability of a coating to seal and protect the surface from progressive decomposition. The rate of heat release found for typical interior cabin materials ranged from 0 up to 950 BTU per minute and the total heat release was as high as 4,650 BTU.³

Gas measurements taken during the laboratory testing of typical interior cabin materials indicates, in general, that HCL was produced by polyvinyl chloride and monacrylic materials, HF from polyvinyl fluoride, HCN from wool, urethane, ABS, and modacrylics, and SO₂ from polysulfene and rubber materials. Carbon monoxide was produced by almost all the samples in varying amounts depending on the type of material and other factors.

It has been shown\textsuperscript{4} that the amounts of these given gases produced during pyrolysis and the rate of generation are strongly temperature dependent. For certain materials, higher concentrations of some gases may be produced under conditions of insufficient air, e.g., 10 percent oxygen.

\textbf{Interior Material Description}

The lower cabin sidewall panel assembly is a thermoformed plastic sheet with tufted monacryl carpeting bonded to the lower portion. The cabin side of the thermoformed plastic sheet is covered with a vinyl laminate decorative finish.

The cabin side panel assembly is a thermoformed plastic sheet with foam reinforcement, covered with a vinyl laminate decorative finish.

The sidewall light panel assembly has a Nomex honeycomb core covered on either side with a sheet of phenolic/glass cloth. A decorative covering on the cabin face is vinyl laminate with tedlar facing.

The outboard ceiling panel assembly and the center ceiling panel assembly have a .450 inch thick Nomex honeycomb core covered with a sheet of phenolic/glass cloth on the outer side. The cabin face has a sheet of fabric base phenolic/glass screen covered by a decorative vinyl laminate with tedlar facing.

The overhead compartment door assembly has a .450 inch thick Nomex honeycomb core on the inner surface. The honeycomb is covered with a phenolic/glass cloth and white tedlar decorative cover. The cabin face has two sheets of phenolic/glass cloth and a vinyl laminate with tedlar facing decorative cover.

The overhead compartment bin back assembly has a .450 inch thick Nomex honeycomb core. On the inner surface, the honeycomb core is covered with phenolic/glass cloth. The compartment face has a layer of phenolic/glass cloth covered by decorative white tedlar.

The base panel assembly has a .450 inch thick Nomex honeycomb core covered on either surface with epoxy/glass cloth. The compartment face has a white tedlar decorative cover over the epoxy/glass cloth.
LEGEND

1. Sidewall light panel
2. Bin back assembly
3. Base panel assembly
4. Panel assembly — Ceiling, outboard
5. Door assembly
6. Panel assembly — Ceiling, center
7. Panel assembly — Lower cabin sidewall
8. Panel assembly — Cabin side

Figure 2.
Photo 2: The interior fire vented through the top of the fuselage at the front and rear portions of the aircraft.

Credit: NFPA
Photo 1: Smoke was observed by CFR crews "trailing" the aircraft from this location during its final approach.
Credit: NFPA
Photo 3: Right rear section of the aircraft. Several passengers used the emergency exits located over the wings to evacuate the aircraft.
Credit: NFPA
Photo 4: Interior configuration of the aircraft. A center aisle provides access to passenger seats and the rear lavatory. Credit: NFPA
Photo 5: Investigator examines the rear portion of the aircraft. Most of the combustible contents of the aircraft were consumed by the fire.

Credit: NPA
Photo 6: Rear lavatory, vanity and sink area of a similar type aircraft. An oxygen supply line and mask was located within the vanity.
Credit: NPPA
Photo 7: Rear lavatory, sink and vanity area. The fire is thought to have originated in this area, consuming adjacent combustible interior finish materials. Lavatory air is discharged from the aircraft at this location.

Credit: NGPA