Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A02O0123

CARGO BAY FIRE

AIR CANADA
BOEING 767–300 C–GHML
TORONTO/LESTER B. PEARSON INTERNATIONAL AIRPORT, ONTARIO
13 MAY 2002

Canada

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The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Aviation Investigation Report

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Synopsis

The Boeing 767–300 aircraft (C–GHML, serial number 24948), operating as Air Canada Flight 116 with 8 crew members and 177 passengers on board, was on a scheduled flight from Vancouver, British Columbia, to Toronto/Lester B. Pearson International Airport, Ontario. At 2132 Coordinated Universal Time, while on final approach, approximately 10 miles from the airport, the flight crew received an aft cargo bay fire warning. The flight crew followed emergency checklist procedures, activated the cargo bay fire extinguishers, and declared an emergency. The fire warning light extinguished approximately 50 seconds after activation of the fire extinguishers. Flight 116 landed on runway 06L and stopped to allow airport firefighters to inspect the aircraft for indications of fire.

Firefighters, using infrared sensing equipment, did not detect any sign of fire, but an odour of smoke was noted by both the cabin crew and flight crew. The flight crew taxied the aircraft to the terminal but stopped approximately 40 feet back from the gate to allow firefighters to open the aft cargo compartment for a detailed inspection. When firefighters entered the cargo compartment, they encountered a significant amount of smoke but did not detect any other signs of fire. During this time, the flight crew had prepared the aircraft for emergency evacuation. However, the situation was secured and passengers were deplaned using portable stairs. The aircraft was taken to a hangar for further inspection; company maintenance personnel discovered substantial soot and fire damage on the floor of the cargo bay.

Ce rapport est également disponible en français.

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Figures

Photos

1.0 Factual Information

1.1 History of the Flight

On 13 May 2002, at 1617:00,[1] Flight 116 departed Vancouver International Airport, British Columbia, on a scheduled instrument flight rules (IFR)[2] flight to Toronto/Lester B. Pearson International Airport, Ontario. The flight was uneventful until 2132:07, when the Master Warning Fire/Overheat light illuminated, the fire warning bell sounded, and the Aft Cargo Fire light illuminated. At 2132:09, the master warning was reset. The flight crew followed the procedures for a cargo fire, as outlined in Air Canada's 767 Quick Reference Handbook, and activated the cargo fire extinguishing system. An emergency was declared and emergency vehicles were requested to meet the flight on arrival. At 2132:59 the Aft Cargo Fire light returned to normal. The flight crew advised the flight attendants that there had been a fire indication, but that it was now indicating safe.

At 2138:31, the aircraft stopped on the runway. The aircraft was examined externally by airport firefighters both visually and by using forward-looking infrared (FLIR) cameras. Firefighters did not see or detect anything unusual; however, the crew members reported an acrid smell and a slight haze inside the passenger cabin. The aircraft was given taxi instructions and proceeded to the gate, with firefighters following.

Concerned that the fire might reignite, the captain stopped the aircraft approximately 40 feet back from the gate and requested that firefighters inspect the aft cargo compartment. The aircraft exits remained armed while maintenance crews opened the aft cargo compartment. When the cargo doors were opened, smoke and fumes flowed out of the compartment. The firefighters entered the compartment with a handheld FLIR camera and located a single heat source behind the aft wall of the cargo compartment (see Figure 1). Maintenance personnel removed the aft wall, and the heat source was identified as a recirculating fan. With no other indications

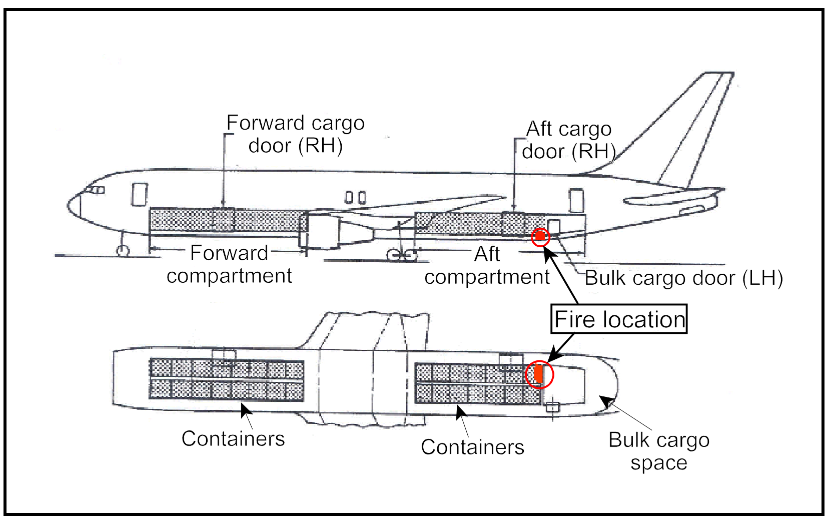

Figure 1. Fire location

1 All times are Coordinated Universal Time (eastern daylight time plus four hours).

2 See Glossary at Appendix B for all abbreviations and acronyms.

of fire, the aircraft was assessed as safe and the passengers were deplaned. Several hours later, after the aircraft had been towed to a hangar, the maintenance crew discovered that there had been a fire in the bilge area of the cargo compartment under the last two baggage containers. They also determined that the recirculating fan had been operating and was serviceable.

The following morning, the Transportation Safety Board of Canada (TSB) was notified of the occurrence. A preliminary examination showed that the B110 heater ribbon, made by Electrofilm Manufacturing Co., on the aft water supply/drain line had failed and ignited the fire.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	–	–	–	–
Serious	–	–	–	–
Minor/None	8	177	–	185
Total	8	177	–	185

1.3 Damage to Aircraft

The fire was located below the floor level of the aft cargo compartment in an area defined longitudinally by fuselage station (FS) 1385 and FS 1412 and laterally by left buttock line[3] (LBL) 6 and right buttock line (RBL) 50. The fire burned holes through the structural floor beam web at FS 1395, and consumed the thermal acoustic insulation on both sides of the floor beam. Also damaged were the underside of the floor board between RBL 22 and RBL 44, potable water lines, heater ribbons, and associated electrical wiring (see Photo 1).

Photo 1. Fire-damaged area

[3] An aerospace term used to describe a reference line that runs along the length or the longitudinal axis of the aircraft. An aircraft contains several buttock line sections.

1.4 Personnel Information

	Captain	First Officer
Pilot Licence	ATPL	ATPL
Medical Expiry Date	01 November 2002	01 January 2003
Total Flying Hours	21 400	12 000
Hours on Type	1508	654
Hours Last 90 Days	96	74
Hours on Type Last 90 Days	96	74
Hours on Duty Prior to Occurrence	7	7
Hours Off Duty Prior to Work Period	216	72

The captain was at the controls and in the left seat. Both pilots were certified and qualified for the flight, in accordance with existing regulations.

1.5 Aircraft Information

1.5.1 General

Manufacturer	Boeing
Type and Model	767–300
Year of Manufacture	1991
Serial Number	24948
Certificate of Airworthiness	issued 12 December 2000
Total Airframe Time	46 830 hours
Engine Type (number of)	Pratt & Whitney PW 4060 (2)
Maximum Allowable Take-off Weight	184 614 kg
Recommended Fuel Type(s)	Jet A
Fuel Type Used	Jet A

1.5.2 *Aircraft History*

The aircraft was manufactured by the Boeing Aircraft Company in 1991, as VN532. It was originally ordered by Lan Chile Airlines in South America, but the order was cancelled before delivery. The aircraft was then purchased by a leasing company and leased to Trans Brazil Airways, where it was operated for the next eight years. In 2000, Air Canada leased the aircraft and imported it to Canada. The aircraft was imported from Brazil through the United States under a U.S. Export Certificate of Airworthiness.

The importation was done in accordance with the procedures described in Aircraft Certification Policy Letter (ACPL) No. 50, Canadian Type Certification – Import Aeronautical Products, dated 30 May 1996, using the Level 1 process and Maintenance Staff Instruction (MSI) 26, Checklist 1. An Export Certificate of Airworthiness was issued by the Federal Aviation Administration (FAA) on 12 December 2000. The aircraft was issued a Certificate of Airworthiness on 18 December 2000 and a Certificate of Registration on 19 December 2000.

1.5.3 *Aft Cargo Compartment*

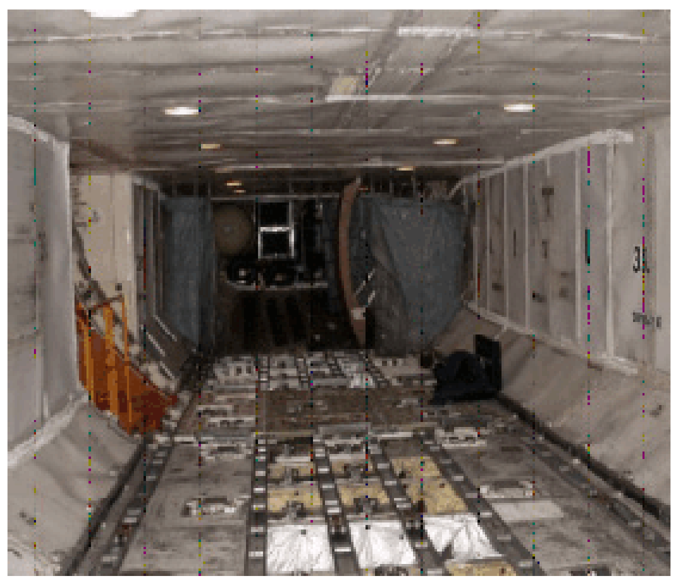

Photo 2. Aft cargo compartment

There are two cargo compartments on the passenger version of the Boeing 767: the forward compartment located ahead of the wings and the aft compartment located behind the wings. The aft compartment is subdivided into a main section and a bulk cargo section (see Photo 2). The bulk cargo section is at the aft end of the aft compartment and has an aluminum sloping floor due to the geometry of the aircraft. The bulk cargo area is separated from the main section by a cargo-restraining net and can be accessed independently through a door on the left side of the aircraft. There are six roller tracks with power drive units (PDUs) to facilitate moving cargo/baggage containers longitudinally through the cargo compartments. The tracks are located at buttock line (BL) 44, BL 22 and BL 6 left and right. The PDUs are controlled by externally accessed controls located behind a panel, adjacent to the cargo compartment door, on the right side of the aircraft.

The cargo compartments in C–GHML are certified as Class C. Canadian Aviation Regulation (CAR) 525.857 (c) defines Class C cargo compartments as follows:

> A Class C cargo or baggage compartment is one not meeting the requirements for either a Class A or B compartment but in which:
>
> (1) There is a separate approved smoke detector or fire detector system to give warning at the pilot or flight engineer station;
>
> (2) There is an approved built-in fire extinguishing or suppression system controllable from the cockpit;
>
> (3) There are means to exclude hazardous quantities of smoke, flames, or extinguishing agent, from any compartment occupied by the crew or passengers;
>
> (4) There are means to control ventilation and drafts within the compartment so that the extinguishing agent used can control any fire that may start within the compartment.

In C–GHML, fire detection is provided by smoke sensors installed in the ceiling of the cargo compartments, which provide a fire warning indication to the flight crew. Fire suppression is provided by a built-in Halon fire extinguishing system, activated remotely by the flight crew.

The compartment must also meet the requirements of CAR 525.855. As stipulated in CAR 525.855 (b) and (c), the cargo compartment must be lined, and the ceiling and sidewall liner panels must meet the requirement of CAR 525, Appendix F. In C–GHML, the ceiling and sidewall liners are constructed of fireproof fibreglass panels sealed with fireproof tape, and the belly or bilge area of the compartment is lined with thermal acoustic insulation. Together, these components form the fireproof liner that prevents a fire from spreading outside the compartment.

Additionally, Airworthiness Directive (AD) 90–NM–107–AD calls for the installation of a fire stop near the bottom of the sloping sidewall cargo compartment liner. This is to prevent a cargo compartment fire from migrating up behind the cargo liner. Air Canada's records indicate that this AD was completed by Trans Brazil on 29 June 1993, by internal Engineering Order (EO) MDA 767–25–151, which referenced Service Bulletin (SB) 767–25–0193.

In the main section of the cargo compartment, there are floor boards, approximately 22 inches wide, running along the left and right side of the compartments between BL 22 and BL 44; however, the middle of the floor area is open to the fuselage skin below. In the bulk cargo section, there is no open floor area.

The cargo compartments are climate and pressure-controlled by modulating the flow of hot air into the area below the cargo floor. Hot air is piped through a two-inch-diameter "piccolo" tube that has numerous holes to direct the airflow between the frames, which also function as cargo floor support beams. Thermal acoustic insulation is used to reduce the rate of heat loss to the outside environment.

1.5.4 Fire Extinguishing System

The fire extinguishing system consists of three bottles of Halon 1301 mounted in the forward cargo compartment area and a series of smoke detectors mounted in the ceilings of the forward and aft cargo compartments. When the aft cargo extinguishing system is armed, the fire warning bell is silenced, the aft squib[4] test function is disabled, and the aft and bulk cargo compartment heat valves close. As well, electrical power is removed from the galleys, the left and right recirculation fans, and the aft lavatory 1 galley vent fan, but not from the water line heating system. The system is designed such that, after activation, one extinguishing bottle is discharged immediately into the affected cargo area to provide a dousing shot of Halon to the fire. After a 30-minute delay, the remaining extinguishing agent is "metered"out to provide 195 minutes of continuous fire suppression. In the event the aircraft lands before the system has been depleted, all remaining Halon is discharged on touchdown.

1.5.5 Water Line Heating System

1.5.5.1 Description

Heater ribbons are used extensively in transport category aircraft, including all Boeing aircraft, to prevent the water lines from freezing and rupturing. On newer generation aircraft, in-line water heaters or water lines that contain integral heating elements are more prevalent. Typically, these water lines are located in the areas below the passenger cabin. Some are easily accessed in the cargo compartment while on the ground, but access to most requires the removal of wall and floor panels.

The standard Boeing 767 incorporates 26 heater ribbons, but some operators request extra freeze protection, which adds additional heater ribbons for a total of 51. C–GHML was originally manufactured with standard freeze protection provided by Cox & Company heater ribbons. When Air Canada took delivery of the aircraft, it was modified to extra freeze protection by adding additional heater ribbons from both Cox & Company and Electrofilm.

4 A squib is a small pyrotechnic used, in this case, as a means of activating the fire extinguishing system when selected by the crew.

Many of the heater ribbons installed in aircraft are not accessible in flight, nor are they required to be by existing regulations. Also, they are not required to be protected by a fire extinguishing system, regardless of the configuration of open or closed style flooring. Heater ribbons manufactured for use in aircraft must comply with the requirements of U. S. Federal Aviation Regulation (FAR) 25.853 and Appendix F to Part 25. These FARs specify the flammability characteristics of materials used in transport category aircraft. The heater ribbons installed in C–GHML met these requirements.

Heater ribbons are manufactured by a variety of manufacturers, using an assortment of materials and manufacturing processes. Two of the manufacturers identified in this report are Cox & Company and Electrofilm. A heater ribbon is a heating element encased in a protective matrix. This matrix acts as an electrical insulator, preventing arcing between the heating elements and arcing to other parts of the aircraft. It also protects the heater ribbon from external damage caused by wear and abrasion. Cox & Company uses a vinyl or silicone rubber matrix and Electrofilm uses a rubber (ethylene propylene diene terpolymer (EPDM)) matrix. These protective matrices have the following approximate continuous operating temperatures: vinyl, 194°F; EPDM, 300°F; and silicone rubber, 392°F.

Heater ribbons are installed in accordance with the instructions set forth in the aircraft maintenance manual 30–71–01. This chapter contains the information for determining whether a heater ribbon will be installed longitudinally or spiral wrapped. It also contains the generic installation instructions and universal cautions about heater ribbon installations.

The heater ribbons are held in place by 3M 474, a flame-resistant vinyl tape. Depending on the specific installation, the water line may also be wrapped with additional insulation such as Rubatex, a closed-cell foam insulation tape approximately 1/8-inch thick and 2 inches wide that is wrapped around the water line, or an insulation blanket.

Typically, a heater ribbon is thermostatically controlled by either an integral thermostat sensing water line temperature or a remotely mounted external thermostat sensing ambient air temperature. These thermostats do not monitor or control the temperature of the heater ribbons; they simply turn them on or off. In C–GHML, the B110 heater ribbon thermostat was a remotely mounted external thermostat located 85 inches aft of FS 1395, below the bulk cargo floor. The thermostat was set to turn a number of heater ribbons on when the ambient air temperature reached 50°F and off at 60°F. When the water line and heater ribbon are wrapped with 3M vinyl tape and additional insulation such as Rubatex, the temperature of the heater ribbon can be significantly higher than the water line and ambient air temperature.

Heater ribbons are supplied with power through the aircraft electrical system. The power supply is protected by a resettable thermal circuit breaker (CB). Typically, several heater ribbons are grouped together so that power is supplied through one CB. In C–GHML, the B110 heater ribbon was powered through CB 1166, located on the P33 panel in the forward electronic equipment bay. This CB also provided power to the B212, B213, B44, B149, B241 and B425 heater ribbons located in the aft cargo compartment. The CB did not open; however, not all electrical fault situations will cause a CB to open. The CB is designed to protect the circuit when the temperature and time duration characteristics of the over-current condition exceed the design limits of the CB.

1.5.5.2 Water Line Repair

On 07 March 2002, water line P/N 417T2021–131 was found to be leaking water into the bilge area of the aft cargo compartment, documented as snag L1204736. The water line was a Teflon tube with a nylon outer braid. The water line was repaired under the authority of Air Canada Production Permit (ACPP) 6–38–10/351–38–093 by cutting out the damaged section and inserting a stainless steel tube, which was secured with two hose clamps at each end. At the same time, heater ribbon B110 was found to be unserviceable and was replaced with Electrofilm P/N 115529–78.

On 18 April 2002, the water line was found to be leaking in the repair location and was again repaired under ACPP 6–38–10/351–38–093. There was no mention of replacing the B110 heater ribbon. This ACPP, however, had been superseded 10 days earlier by ACPP 6–38–10/351–38–0095, the only difference being that the temporary repair would be made permanent by replacing the repaired water line with a new one no later than the next A07 check. At the time of the occurrence, the A07 check was due in 243 flight hours.

When examined after the fire, the repaired water line was still in place. There were three clamps securing each end of the hose to the stainless steel tube. The hose and the repair, including the six hose clamps, were covered with the 3M 474 tape. The failed B110 Electrofilm heater ribbon was installed longitudinally over the area of the repair, with 3M 474 tape securing the heater ribbon to the hose assembly. The entire assembly was then wrapped with Rubatex.

1.5.6 Thermal Acoustic Insulation

Thermal acoustic insulation materials are used extensively throughout the aircraft fuselage to maintain comfortable cabin temperatures and to reduce the noise entering the passenger cabin and cockpit. While material such as fluoropolymer composite or polyethylene foams have been used for this purpose, the most popular choice is the insulation blanket. These insulation blankets are typically installed immediately adjacent to the inside of the fuselage skin, over the frames and around the outside of air conditioning ducts.

Insulation blanket construction consists of a batt of fibreglass insulating material encapsulated by a protective cover of thin, moisture-barrier film. This protective cover is a composite construction in which a thin, web-like polyester or nylon scrim[5] is glued to the film material to produce a tear stop. Splicing tape may also be used to seal several insulation blankets into a single unit. The blanket assemblies are specifically manufactured to fit individual locations throughout the aircraft. Thermal acoustic insulation materials must comply with flammability requirements described in FAR 25.853.

Factors that are considered when selecting the cover material for the blankets include durability, fire resistance, weight, impermeability, and ease of fabrication. One material that is widely used in the aviation industry, and was used in the occurrence aircraft, is polyethylene terephthalate (PET). PET material is commonly known as Mylar. This material could be either metallized or non-metallized, and was approved for use based on the applicable FAA certification tests in place at the time of certification.

The flammability test used to certify PET-covered insulation blankets was the vertical Bunsen burner test. This test involved suspending a strip of insulation material vertically over a Bunsen burner, applying a flame for 12 seconds and then removing the flame. To pass the test, a minimum of three specimens of insulation blanket material must self-extinguish within an average flame time of 15 seconds after the flame is removed.

Also, the average burn length must not exceed 20 cm (8 inches), and drippings from the insulation blanket material must not flame for longer than an average of 5 seconds. When exposed to the Bunsen burner, PET-covered insulation blankets immediately shrivelled up and shrank away from the burner and did not ignite; the material met requirements. In the occurrence aircraft, which was built in 1991, non-metallized PET-covered insulation blankets were used to insulate the fuselage.

1.6 Notification and Flight Recorders

1.6.1 Notification of the Occurrence

The morning after the occurrence, the TSB was notified of the occurrence and deployed to the site. Subsection 6. (1) of the Transportation Safety Board Regulations states:

> Subject to subsection (5), where a reportable aviation accident or incident takes place, the owner, operator, pilot-in-command, any crew member of the aircraft and, where the accident or incident involves a loss of separation or a risk of collision, any air traffic controller having direct knowledge of the

5 Strong, coarse fabric used for heavy-duty lining to prevent shrinking, checking, etc.

> accident or incident shall report to the Board as much of the information listed in subsection (2) as is available, as soon as possible and by the quickest means available.

Although operators are required by the Transportation Safety Board Regulations to report aviation accidents or incidents as soon as possible, experience has shown that this is not the case. Operators across Canada, whether large or small, routinely fail to report occurrences in a timely manner. It is not uncommon for the initial notification of an occurrence to the TSB to take from 2 to 14 days.

1.6.2 Data Retention

When TSB investigators inquired about the status of the flight data recorder (FDR), they were informed that, immediately following the occurrence, the operator had removed the FDR and had it shipped to the operator’s download and playback facility in Montréal, Quebec, where it was being held. The TSB Engineering Laboratory requested the raw FDR data in original tape or ¼-inch copy tape format. However, the FDR was downloaded and returned to service without the TSB’s knowledge, with the result that the occurrence data were overwritten.

The ½-inch copy tape produced by the operator was not compatible with the TSB’s playback equipment. Therefore, the FDR data could not be provided in the required raw tape format for decoding. The operator did provide the TSB Engineering Laboratory with a paper printout that contained only 34 parameters, converted to engineering units, for the last 52 minutes of the flight. The printout did not contain all of the recorded data samples. For example, accelerations were recorded on the FDR at a sampling rate of 8 Hz, but the printout contained samples at a rate of only 1 Hz. Since the engineering unit conversions could not be verified, a thorough analysis of the data was not possible.

The cockpit voice recorder (CVR) was removed by the TSB on 17 May 2002, and forwarded to the TSB Engineering Laboratory eight days after the incident. The recorder was a Fairchild 93–A100–80, serial number 57085, with a recording duration of 30 minutes. Subsequent playback revealed that the occurrence had been overwritten. The CVR had not been deactivated following the occurrence.

Subsection 9. (1), titled Preservation of Evidence Respecting Reportable Accidents and Incidents, of the Transportation Safety Board Regulations states, “Subject to subsections (2) and (3), where a reportable accident or incident takes place, the owner, operator, master and any crew member shall, to the extent possible, and until otherwise instructed by the Board or except as otherwise required by law, preserve and protect any evidence relevant to the reportable accident or incident, including evidence contained in documents as defined in subsection 19(16) of the Act.”

A review of the TSB occurrence database was conducted to determine the frequency and circumstances of occasions when CVR recordings were not available to the investigation because they had been overwritten subsequent to the aircraft landing. The review indicated that, from 1990 to 2001, there were 14 such serious incidents. In these events, there was no attempt made to secure the recording, and the losses were directly attributed to either electrical power continuity following engine shutdown, or later re-application of electrical power. Loss of recorded information on serious incidents caused by overwriting or premature erasure is a recurring problem. Subsection 725.135 (i) of Commercial Air Services Standards requires that the company Operations Manual (OM) contain information regarding FDR and CVR procedures. The OMs, aircraft flight manuals and checklists of several Canadian operators were reviewed. Although the OMs did contain a reference to the requirement to consider protecting recorder information, there were no specific information, diagrams or procedures outlining how the preservation of recordings is to be accomplished. There is also no requirement to train crews on these issues.

On 29 August 2002, the National Transportation Safety Board (NTSB) of the United States issued Recommendation A–02–24 on "Overwritten Cockpit Voice Recordings." The NTSB, believing that reliable procedures are needed to safeguard CVR data, recommended that the Federal Aviation Administration:

> Require that all operators of airplanes equipped with a cockpit voice recorder (CVR) revise their procedures to stipulate that the CVR be deactivated (either manually or by automatic means) immediately upon completion of the flight, as part of an approved checklist procedure, after a reportable incident/accident has occurred. These procedures must also ensure that the recording remains preserved regardless of any subsequent operation of the aircraft or its systems. Any doubt as to whether or not the occurrence requires notification of the National Transportation Safety Board must be resolved after the steps have been taken to preserve the recording. (A–02–24)

1.7 Medical Information

There was the smell of smoke/fumes in the aft cabin area but there were no reported injuries associated with this occurrence.

1.8 Fire

Photo 3. Fire-damaged area

The Electrofilm brand heater ribbon failed aft of FS 1395. The heater ribbon was laid longitudinally along the water line and over the repair site. The heater ribbon overheated and arced at the forward edge of the repair, where the original water line ended and the stainless steel began. This resulted in the heater ribbon burning through the protective tape and the Rubatex foam insulation. Because electrical power was still being provided to the heater ribbon, the failure continued to move forward along the water line toward the source of electrical power. Approximately eight inches forward of the failure, where the water line passes through the FS 1395 floor beam web, the thermal acoustic insulation blanket mounted on the forward and aft face of the vertical web of the floor beam ignited. At this point, the fire became self-propagating and moved forward as far as FS 1385, aft as far FS 1412, left as far as LBL 6 and right as far as RBL 50 (see Photo 3).

The fire burned miscellaneous debris and partially consumed the insulation blankets on the forward and aft face of the FS 1395 floor beam and the insulation blanket lining the bottom of the pressurized hull. As well, the fire damaged the underside of the floor board between RBL 22 and RBL 44. It breached the cargo compartment liner at RBL 44 and progressed behind the right sloping sidewall to RBL 50. The undersides of the two baggage containers loaded directly above the fire were scorched and blackened with soot, but showed no signs of damage. There were no reported claims of damage for any of the associated luggage or cargo. Externally, the fuselage paint directly below the fire location was blistered.

The FS 1395 floor beam, constructed of 7075–T6511 aluminum alloy, is a structural support member for the baggage compartment floor. The web of this beam is chemically milled to a thickness of 0.020 inches. Overall, the floor beam was scorched and burned from LBL 6 to RBL 42, with the majority of the structural damage confined to the area between BL 0 and RBL 22. Between RBL 6 and RBL 22, the fire burned a four-inch hole through the floor beam web. The edges of the hole were forward facing and burned to a white powder of tissue paper thickness. The upper cap of the floor beam above the hole was buckled. Between BL 0 and RBL 6, the floor beam web had numerous cracks, and the material was thinned to the point where light could be seen through the material. During the examination of the floor beam web and surrounding area, no indication of molten aluminum droplets was found. However, it was observed that the bottom of the web below the damaged areas was considerably thicker, indicating that molten aluminum had accumulated in that area.


Photo 4. Contaminated insulation blankets and debris

Contaminated thermal acoustic insulation blankets in the vicinity of the heater ribbon provided fuel for the fire. The contamination consisted of soiled insulation blankets and of flammable debris in the form of paper, candy wrappers, Styrofoam packing peanuts, small polyethylene beads, and rubber powder from a PDU (see Photo 4). Samples of the burnt PET-covered insulation blankets were analyzed for the presence of fire accelerants. An isoparaffin solvent was detected. These types of solvents are often clear combustible liquids that readily form flammable mixtures; they are used for parts cleaning and degreasing applications and as solvents in inks, paints, and agrochemical formulations such as pesticides. They may have originated from sources such as aircraft cargo, luggage, recent repair or maintenance activities, or from pesticide products. The occurrence aircraft had been operated in South America and may have been exposed to pesticides in association with operations in a tropical environment. The isoparaffin contaminant would, if retained, create a significant heat release once ignited. The relatively high-temperature, localized fire damage observed on the floor beam web of the occurrence aircraft is consistent with a post-fire effect from the isoparaffin solvent alone or in combination with combustible debris.

1.9 Survival Aspects

The captain taxied the aircraft to a point short of the gate and the refuelling pits to minimize the danger. The cabin crew remained prepared for a rapid evacuation until confirmation was received from the emergency response personnel that the situation was secure. There was a delay while the crew arranged for two portable stairs to be put into position and the passengers were deplaned when it was deemed safe to do so. There were no injuries to either the passengers or crew.

1.10 Additional Information

1.10.1 Heater Ribbon Failures

1.10.1.1 History

Between June 1985 and June 2002, operators of Boeing aircraft made a total of 67 reports to Boeing of heater ribbon failures where thermal degradation was evident. Charred insulation material was identified in many of the reports, and structural damage from fire had occurred in at least two cases. In some instances, water had leaked from melted water lines, which, in one case, led to failure of an engine indication and crew alerting system (EICAS) computer.

Service Difficulty Reports USA 1999042300717, USA 1988040800197, AUS 19990967, and AUS 19991248 all reported burned heater ribbons. Two of the reports involved Boeing 767 aircraft and two involved Boeing 747 aircraft.

1.10.1.2 Additional Heater Ribbon Failures on C–GHML

In addition to the fire damage associated with the occurrence flight, TSB investigators found a burned Cox & Company heater ribbon, protective tape, and Rubatex foam insulation behind the aft wall of the aft cargo area on the occurrence aircraft (see Photo 5). Although a self-propagating fire had not occurred, the area had become hot enough to burn through the Rubatex foam insulation and a nearby plastic clamp.

Photo 5. Burned heater ribbon behind aft wall

On 24 September 1992, Boeing issued SB 767–30–0024, which specifically addressed an overheat problem with the B241 heater ribbon installation on certain 767 model aircraft. The existing spiral-wrapped heater ribbon rated at 24 watts per foot was continuously activated. Boeing recognized that if the heater ribbon was powered while no water was in the water fill line, overheating of the heater ribbon could occur resulting in the heater ribbon, adjacent insulation blankets, and any debris being scorched. The SB called for the replacement of the existing heater ribbon with a thermostatically controlled, 7-watt-per-foot, longitudinally installed heater ribbon. C–GHML was one of the affected 767 models, but neither the previous operator nor Air Canada complied with the SB.[6] Following this occurrence, a new Cox & Company 24-watt-per-foot heater ribbon was installed. The heater

[6] There was no regulatory requirement to comply with SB 767–30–0024.

ribbon was spiral wrapped, a thermostat was not installed, and an insulating jacket was included. The jacket was an insulation blanket assembly that was wrapped around the water fill line and heater ribbon, and secured with a hook-and-loop fastener system.

On 20 October 2002, while checking the heater ribbons on C–GHML prior to the winter season, heater ribbon B241 was found to have overheated and the insulating jacket was burned. The heater ribbon was completely destroyed during the overheat condition. The insulating jacket was charred on the inside and discoloured from overheating on the outside. There was no other damage to the aircraft or surrounding materials. This particular heater ribbon had only been in service for three months.

1.10.1.3 Heater Ribbon Failures on Other Air Canada Aircraft

Another Air Canada Boeing 767–300 aircraft was examined by TSB investigators, and a burned Cox & Company heater ribbon was found in the vicinity of FS 1395. In this case, the water line was wrapped in a jacket that consisted of an insulation blanket covered on one side with PET and on the other side with Bradley BF–6620, a polymer coated fabric. The jacket was held in place with a hook-and-loop fastener system similar to Velcro. The failure had burned a hole through the jacket. Further examination of the same aircraft revealed another overheated Cox & Company heater ribbon behind a sidewall panel in the aft cargo compartment near FS 1460.

Air Canada conducted an inspection of its fleet of 55 Boeing 767–200 and 767–300 aircraft. Numerous occurrences of overheated and/or burned heater ribbons were found in both visually accessible areas and hidden areas, such as behind wall and floor panels. Thirty of the aircraft were found to have defective heater ribbons (including both Cox & Company and Electrofilm brand), resulting in 66 ribbons being either removed or de-activated.

On 20 December 2002, while passengers were boarding C–GAVA, another Air Canada 767 aircraft, smoke was seen coming from the aft galley. The problem was traced to the B195 heater ribbon on the aft galley drain line P/N 417T2004–13. The heater ribbon, a vinyl Cox & Company brand heater ribbon, was completely destroyed during the overheat condition. The jacket was charred on the inside and discoloured from overheating on the outside. There was no other damage to the aircraft or surrounding materials.

1.10.2 Insulation Blanket Contamination

1.10.2.1 History

There is little industry guidance available to quantify the effects of blanket contamination. According to documentation from various sources indicated in this section of the report, the flammability characteristics of materials can degrade in service when they are exposed to contaminants such as dust, lint, adhesives, grease, oil, or corrosion inhibitors. The aviation industry has yet to quantify the impact of contamination on the continuing airworthiness of insulation blankets. However, as this section of the report shows, there is a definite connection between contamination and flammability.

Various types of thermal acoustic insulation blankets have fuelled aircraft fires on several occasions. For example, a Lan Chile Airlines aircraft (Miami, Florida, B767–375ER, 28 January 2002) had a fire in the forward (lower) cargo compartment that was fuelled by contaminated insulation blankets. These insulation blankets showed significant signs of contamination and wear.

In 1991, following an occurrence involving a fire in a Lockheed L1011 (TSB report A91A0053), the TSB issued a Safety Advisory (A910106) concerning the fire hazard associated with lint accumulation. The Advisory suggested that Transport Canada (TC) notify maintenance inspectors and operators of transport category aircraft of the fire hazard, and require that maintenance procedures be amended as required to ensure inspection and cleaning of areas where lint and debris can accumulate. In response, TC issued Service Difficulty Advisory AV–92–04 on 10 April 1992, which, in part, recommended that, whenever planned inspections allow, an inspection be carried out for accumulation of lint, dust and cabin debris, and that visible accumulations be cleaned out to remove the fire hazards.

In the United States, the NTSB issued recommendations A–91–71 and A–91–72 to address the safety deficiencies identified in the TSB occurrence investigation. The NTSB recommended that the FAA notify principal maintenance inspectors (PMIs) and operators of transport category aircraft of the fire hazard posed by accumulations of lint and other debris on wire bundles. It was also recommended that the FAA require transport category aircraft manufacturers and airlines to amend maintenance manuals as necessary, to ensure thorough inspection and cleaning of areas where lint and other debris may accumulate and pose a potential fire hazard. In response to the recommendations, the FAA issued an airworthiness inspector's handbook bulletin entitled, "Origin and Propagation of Inaccessible Aircraft Fire Under In-flight Airflow Conditions." The Bulletin provides information on the potential safety hazard applicable to all transport category aircraft from the accumulation of lint and other debris on wire bundles. It also requests that PMIs disseminate this information to all operators of transport category aircraft and review their operators' maintenance programs to ensure that they include an inspection of aircraft wiring and removal of contaminants, especially in inaccessible areas.

In March 1998, as a result of a fire in a cargo compartment of a 747–200 freighter, Boeing issued Service Letters (e.g. 767–SL–25–084, 747–SL–25–170) for all its aircraft models (per Multi-Model Service-Related Problem 25–0103). An investigation by Boeing had revealed that the presence of corrosion inhibiting compounds may have contributed to the fire and could have been the reason the fire was not self-extinguishing. The investigation also looked at the accumulation of dust, lint, and other debris on the insulation blankets outside of the passenger/cargo compartment, and concluded that it was conceivable that a large buildup of contaminants on these blankets could ignite as a result of a high-temperature source. The Service Letters informed operators that applicable Boeing manuals would be revised to address the effects of corrosion inhibiting compound and other materials on the flammability of aircraft insulation blankets. They also informed operators that Boeing would provide presentations on this subject at future airline conferences to increase airline awareness. Operators were advised to remove foreign materials and to increase attention to periodic inspections and cleaning of the aircraft during maintenance to avoid blanket contamination.

In relation to the Swissair 111 accident investigation (TSB report A98H0003), the TSB issued safety recommendations concerning flammability test criteria (A99–07 and A99–08) and material flammability standards (A01–02 to A01–04). The fire hazards associated with contaminated insulation materials, dust, lint, or debris were not an issue in that investigation.

On 28 September 2000, the FAA issued Flight Standards Information Bulletin for Airworthiness (FSAW) 00–09 entitled “Special Emphasis Inspection on Contamination of Thermal/Acoustic Insulation.” Also, on 08 November 2001, TC published Maintenance Staff Instruction (MSI) 42, “Procedures for the Inspection of Thermal/Acoustic Insulation During Heavy Maintenance Checks for Contamination,” which reflected the FAA requirements of FSAW 00–09. Recognizing that the flammability of most materials can change if the materials are contaminated and that contamination may be in the form of lint, dust, grease, etc., all of which can increase the material’s susceptibility to ignition and flame propagation, the FSAW and MSI require specific action on the part of PMIs with responsibility for 14 Code of Federal Regulations (U.S.) parts 121 and 125 operators. PMIs should ensure that the operator has established procedures in their approved maintenance program for the inspection of contamination on thermal/acoustic insulation during heavy maintenance checks. If the operator discovers contamination of the insulation, the operator should take corrective action, cleaning or replacing the insulation as appropriate. However, as evidenced by the recent Air Canada and Lan Chile 767 cargo area fires, blanket contamination has persisted.

TC raised the issue of contamination at the International Aircraft Materials Fire Test Working Group, and a task group has been formed to address this issue.

1.10.2.2 Insulation Blanket Condition on C–GHML

During the inspection of the occurrence aircraft, the TSB found significant contamination of the insulation blankets throughout the cargo compartments, including the areas behind the sidewalls and in the belly of the aircraft. This contamination consisted of soiled insulation blankets and large accumulations of lint, dust and other flammable debris. In the forward cargo compartment, numerous insulation blankets were incorrectly installed, were ripped and torn, or not installed at all. Furthermore, there were unapproved blanket assemblies in the forward cargo compartment. These included blanket assemblies with Douglas Material Specifications numbers and blanket assemblies of unknown origin.

1.10.2.3 Insulation Blanket Contamination on Other Air Canada Aircraft

The inspection of the occurrence aircraft and other 767 aircraft showed the existence of contaminated insulation blankets and debris in many cargo compartments with open floors. A considerable amount of blanket contamination in the form of dust, dirt, and lint was found under and behind panels in areas that are not readily accessible without the removal of panels. Subsequent to the occurrence, Air Canada examined the open forward and aft cargo areas of its 767 aircraft. A general clean-up of debris found in these areas was carried out. This action did not fully address contaminated blankets.

1.10.3 Circuit Protection Devices

Regulations require that electrical wires and cables be protected from an over-current condition. Typically, a circuit protection device (CPD) is used to provide this defence. CPDs are designed to protect the wire or cable; they are not designed to protect the associated electrical components, such as heater ribbons or line replaceable units, which may require their own internal CPDs.

The majority of CPDs used in aerospace applications are resettable, thermal circuit breakers (CBs), developed as a replacement for fuses. These conventional CBs typically contain a circuit consisting of a bimetallic element and two electrical contacts, one of which is spring-loaded. When an over-current condition occurs, the circuit heats as a function of current flow and time. When the heat exceeds a preset amount, the bimetallic element bends, causing the spring-loaded contact to trip and open the circuit. The design is known as a “trip-free” CB, in that it cannot be reset in the presence of an over-current condition. After a predetermined interval for cooling, the CB is capable of being manually reset.

This type of CB has proven to be effective in accomplishing its primary role, which is to protect wire and cable from damage due to an over-current condition. Specifically, this type of CB successfully protects the circuit when the temperature and time duration characteristics of the over-current condition are within the CB’s design limits.

However, some types of wire and cable failures involve arc faults. Arc faults can create circumstances that do not fall within the design limits of the over-current/time protection curve of conventional CBs. One such phenomenon is an intermittent metal-to-metal event (conductor-to-conductor or conductor-to-frame) known as a “ticking fault.” Such events can generate extremely high temperatures at the location of the insulation failure; however, the current draw may not be sufficient to heat the bimetal element to the temperature necessary to cause the CB to trip.

In some cases, a breakdown of wire insulation can lead to other types of arc fault failures, such as arc tracking. The arc tracking phenomenon involves carbonization of the wire insulation material that can result in intermittent arc faults between conductors, or between a conductor and the aircraft or other grounded conducting material. Although the hazards created by ticking faults and electrical arc tracking are widely known, existing technology is such that there are no CPDs available for use in aircraft that can accurately and reliably detect faults associated with wire insulation breakdown. The U.S. Navy, the FAA, and aircraft manufacturers are sponsoring initiatives to address this shortfall in CPD technology. The goal is to develop an arc fault CB device appropriate for aircraft use.

1.10.4 Material Flammability Standards

1.10.4.1 Development

Among the Civil Aviation Authorities (CAA), the FAA has traditionally taken a lead role in research and development to improve fire safety in aviation. In 1988, the U.S. *Aviation Safety Research Act* mandated the FAA to conduct fundamental research related to aircraft fire safety. The FARs are used internationally as the primary source for aircraft certification requirements, including material flammability standards. Current FAA regulations reflect a philosophy adopted following a study in 1975 to 1976, to determine the feasibility of, and the trade-offs between, two basic approaches to providing fire safety improvements to a modern, wide-bodied transport aircraft fuselage. The purpose of the study was to examine the impact of in-flight, post-crash, and ramp fires on fuselage compartments, and to assess the fire protection requirements.

The first approach looked at the potential of applying the latest available technologies in early-warning fire detection and fire extinguishing systems. This approach would involve what was described as a "fire management system," i.e. one that would incorporate fire detection, monitoring, and suppression throughout the aircraft. The second approach looked at the potential for improving the flammability standards of materials to be used in cabin interiors so that they would have high fire-retardant qualities and low emissions of smoke and toxic gas. The study concluded that there were merits and limitations to each approach, and that an approach combining a fire management system with selective material improvements may offer the most potential for providing timely fire protection in all cases.

Subsequently, as recommended in the FAA's Special Aviation Fire and Explosion Reduction Advisory Committee report, FAA–ASF–80–4, dated 1980, the FAA's main research and development efforts were directed toward what was determined to be the greatest threat: a post-crash fire. The post-crash fire scenario that was envisioned was an intact fuselage adjacent to a fire being sustained by uncontained aviation fuel. It was determined that the most significant threat to surviving passengers in such a scenario would be from burning cabin interior materials. FAA research concluded that in such a scenario, surviving passengers could become incapacitated owing to toxic gases generated by a phenomenon known as “flashover.” Therefore, to increase survivability, the FAA concentrated its efforts on improving the flammability standards for cabin interior materials to delay the onset of flashover.

In-flight fires were considered to be rare, and the FAA concluded that the best defence against them would be through the use of cabin materials that had high fire-containment and ignition-resistance properties, and through the use of fire-detection and suppression devices in potential fire zones.

Research and development related to in-flight fires has led to increased fire protection in areas such as cargo compartments and lavatories.

1.10.4.2 Testing Procedures

As part of the FAA aircraft certification process, materials to be used in the construction of aircraft are required to meet specified performance (test) criteria or standards when exposed to heat or flame. These flammability test criteria are designed, in principle, to expose a given material to a representative in-service fire environment. When deciding on the type and amount of testing for a particular material, assessments are made of the composition of the material, the quantity to be used, and its location within the aircraft. The testing is designed to measure the tendency of each material to ignite and propagate a flame.

For the majority of materials used in the pressure vessel, the flammability tests in place at the time the Boeing 767 was certified consisted primarily of a variety of Bunsen burner tests. A single Bunsen burner was used as the ignition source. Each test could be varied in several ways. For example, the orientation of the material to the flame could be varied from the horizontal through to the vertical, the orientation being specific to the test objectives, which were based on the perceived threat. The vertical burn test would normally be the most severe. Also, the length of time that the material was exposed to the flame could be varied. A longer exposure time would normally equate to a more severe test.

For each of the various Bunsen burner tests, requirements were established to differentiate between a pass or a fail for the material being tested, the performance of the material being averaged over a minimum of three test specimens. The following is a list of criteria that could be used to measure a material’s flammability characteristics:

- ignition time (how long it takes the material to ignite when exposed to the Bunsen burner flame; the tests typically use 12, 15, 30 or 60 seconds of flame exposure);
- glow time (the average time the material continues to glow after the ignition source is removed);
- flame time (the average time the material continues to produce a flame after the ignition source is removed);
- drip flame time (the average time that any dripped material continues to produce a flame);
- burn length (average value for burn length measured to the nearest 0.3 cm (0.1 inches)); and
- rate of burn (measured in inches per minute).

Except for selected materials in Class C cargo compartments, the most stringent material flammability standards were applied to those materials that were to be used in the occupied areas of the aircraft. Of particular interest were large surface panels such as sidewalls, ceilings, stowage bins, and partitions. Not only were the materials used in the panels subjected to the most aggressive test procedures, the materials also had to be self-extinguishing, i.e. they would not propagate flame beyond a certain distance, typically less than 20 cm (8 inches). Cabin materials were also subjected to tests for heat release and smoke. No testing was required for toxicity.

As a consequence of the testing requirements, less stringent material flammability standards were applied to those materials intended for use within the pressure vessel but that were outside the occupied areas. Certain materials only required the horizontal Bunsen burner test. To pass, the material could not exceed a certain rate of burn. Depending on the intended use of the material, the rate of burn could not exceed either 6 or 10 cm (2.4 or 4 inches) per minute. No requirement existed for these materials to be self-extinguishing.

In effect, the different flammability testing requirements, as described above, resulted in the following material flammability hierarchy:

- materials that would self-extinguish within an acceptable flame time and burn length;
- selected cabin materials that would self-extinguish and release no more than a predetermined amount of heat and smoke; and
- flammable materials with an acceptable rate of burn.

Therefore, many aircraft materials were certified even though they were either flammable or would burn within established performance criteria.

Many materials are installed in aircraft as part of a system, even though they are normally tested individually for flammability. For example, thermal acoustic insulation materials are typically installed as a system that includes cover material, insulation, and related components such as splicing tape, fasteners, and breathers. However, by regulation, the testing of the finished product only consists of insulation and cover material together. Consequently, the as-installed thermal acoustic insulation materials may pose a different propensity to ignite and propagate fire than its testing would reveal.

1.10.5 Certification of Imported Aircraft

The process of importing an aircraft into Canada is complex and entails a variety of detailed checks. The documents used for the importation of aeronautical products into Canada are ACPL No. 50 Canadian Type Certification – Import Aeronautical Products, dated 30 May 1996, and MSI 26, Importation of Aircraft. The detail and level to which an aircraft will be inspected is based on where the aircraft is being imported from and the type of aircraft. In the case of C–GHML, the checks included a detailed inspection of the aircraft by the Triad International Maintenance Corporation while it was still in the United States, and a detailed examination of the aircraft records to ensure that all applicable standards of airworthiness had been complied with and the aircraft was in conformity with the type design.

The aircraft inspection produced a detailed list of 1959 deficiencies and maintenance tasks to be completed. Of particular note is the fact that every area of the aircraft was identified as requiring cleaning, but there were very few references to contaminated insulation blankets. Also, hundreds of discrepancies were noted within the forward and aft cargo compartments, including items such as missing light covers, the wrong type of lamp in a light fixture, and inoperable PDUs. Although the list was very detailed, the inspection failed to identify the unapproved insulation blankets in the forward cargo compartment.

2.0 Analysis

2.1 General

Several factors led to the safe conclusion of Air Canada Flight 116 at its planned destination. The duration of the flight was approximately 5 hours and 21 minutes. The Master Warning Fire/Overheat light illuminated very near the end of the flight, 6 minutes and 24 seconds before the aircraft stopped on the runway. The aircraft fire detection and extinguishing system functioned properly, and the fire was effectively extinguished even though it was beginning to spread up behind the right sloping sidewall of the aircraft, outside the cargo compartment. The last line of defence, the compartment liner that was designed to contain the fire, had been breached. The fire spread and increased in intensity until it was successfully detected and extinguished by the on-board system. The primary factors involved in this occurrence include:

- the condition that resulted in the ignition source; and
- the flammable materials that were available to be ignited and which then sustained and propagated the fire.

The analysis will look at these safety deficiencies and other aspects of the occurrence that, although not causal, present some degree of increased risk to aviation safety.

2.2 Ignition

Early in the investigation, it became known that the source of ignition was the B110 heater ribbon laid longitudinally along the water supply line. The heater ribbon failed just aft of FS 1395, at a recent water line repair.

It is likely that the temporary repair to the water line resulted in dissimilar heat sinks that produced localized overheating of the heater ribbon, which was exacerbated by multiple layers of 3M 474 tape and Rubatex foam insulation. This localized overheating degraded the surrounding EPDM insulating matrix to the point where the heating elements arced and ignited the surrounding material. The failure continued until a conductive path was no longer available and the arcing ceased. The dissimilar heat sinks comprised the following: the original Teflon water line; the stainless steel clamps used to secure the repair in place; the stainless steel tube used for the repair; and the air gap created by the difference in diameters of the stainless steel tube and the original water line.

The water line to which the heater ribbon was attached was constructed of a Teflon tube with a braided Nylon outer sheath, neither of which are efficient conductors of heat. The stainless steel clamps and tube, on the other hand, were very efficient conductors of heat. The least efficient conductor of heat in this scenario was the air. Heat generated by the heater ribbon is absorbed in two ways. A portion of the heat generated is absorbed evenly along the length of the water line, and the remainder of the heat is dissipated evenly into the surrounding ambient air. The repair to the water line resulted in an uneven heat distribution and localized heating. The localized heating compounded by the layers of 3M 474 tape and Rubatex foam insulation raised the temperature above the design specifications of the heater ribbon, thereby allowing thermal degradation of the heater ribbon's insulating matrix and surrounding material. Degradation of the insulating matrix allowed the heating elements to migrate towards each other and eventually arc.

Circuit breakers (CBs) are designed to protect aircraft wiring from an over-current condition; however, not all electrical fault situations will cause a CB to open. The failure mode of the heater ribbon did not produce an over-current condition that would endanger the aircraft wiring or trip the CB. Once the fire was detected and the fire extinguishing system activated, it would be expected that power would be removed from all but the required essential systems as a means of eliminating potential ignition sources. This was not the case in the Boeing 767, nor is it a regulatory requirement. The heater ribbons remained powered throughout this entire event, and there was no means of deactivating them from the flight deck. As long as power is available to the heater ribbon, the potential for the heater ribbon to arc exists and presents an ongoing risk.

Research clearly indicates that heater ribbons have a propensity to fail and are replaced on a regular basis. It is also noted that the older style of vinyl-covered Cox & Company heater ribbons, with a lower continuous operating temperature, fail most frequently. Often, the failures go undetected for long periods of time and are not discovered until a major inspection, such as the yearly winterization check. The most common form of failure appears to be overheating, which often leads to the complete destruction of the heater ribbon. Some of the failures resulted in self-extinguishing fires. In most cases, the failed heater ribbons caused localized damage, which was easily repaired. In one instance, a failed heater ribbon melted a water line; water leaked from the line and resulted in the failure of an EICAS computer.

The Flight 116 occurrence showed that it is possible for a failed heater ribbon to ignite a self-propagating fire. It is also significant that, while the fire occurred in a sealed compartment with a fire extinguishing system, the fire had breached the cargo compartment and entered an inaccessible and unprotected area. Had the fire extinguishing system not extinguished the fire quickly, the results could have been catastrophic.

The procedures for the installation of heater ribbons were generic and often ambiguous. This led to difficulties and confusion in determining how a heater ribbon should be installed. The exact installation of each and every heater ribbon is critical, as an improper installation can result in an overheat condition that can lead to a fire. There should be no ambiguity in the installation instructions.

There also appears to be a general sense of complacency in the aviation industry with regard to heater ribbon failures. Personnel working in the industry have known for years that heater ribbons fail regularly. They are considered by most to be non-critical systems, the failure of which usually results in very little damage. It is not until a serious occurrence that the potential danger posed by a faulty heater ribbon is fully realized.

The above information concerning heater ribbon failures supports the existence of an unsafe condition relating to the potential for water line heater ribbon installations to provide a source of ignition, combined with the availability of flammable materials sufficiently close to the ignition source to ignite.

2.3 *Contamination*

The most significant deficiency in the chain of events that resulted in the fire on C–GHML was the presence of flammable materials that allowed the fire to ignite and propagate. The PET covering material on the insulation blankets was contaminated and flammable. This was the most significant source of combustible materials that contributed to the fire. The PET-covered insulation blanket was also most likely the first material to ignite. Debris in the area of the fire damage was found to be combustible and was consumed as the fire progressed through the insulation blanket. This debris included paper, candy wrappers, Styrofoam packing peanuts, and small polyethylene beads that had collected in the bilge area.

Research clearly indicates that contamination in aircraft is an ongoing problem. Although many steps have been taken by the regulators, manufacturers, and operators to reduce the risk, contamination still exists. Open cargo floors in aircraft provide a gathering area for flammable debris to collect, but they also permit easy access for the clean-up of debris. Even though the debris can be easily cleaned, fluids of unknown flammability can leak from baggage and cargo and go undetected. Additionally, fluids used for cleaning and lubricating cargo compartment components during routine maintenance can also spill and go undetected. Of more concern are the areas that are not readily accessible. It is in these areas that heavy accumulations of dust, lint, and small flammable materials such as paper collect on insulation blankets, aircraft wiring, and electrical components. As well, fluids spilled from the passenger cabin, lavatories and galleys can leak into these areas. These areas are not easily accessible, have no protection from fire, and are usually only accessed every few years during heavy maintenance checks.

Inspection of the occurrence aircraft and other aircraft in the Air Canada fleet during the investigation showed heavy accumulations of dust and lint on insulation blankets and electrical components behind panels.

It is noted that little is known about how age and contamination affect the flammability of existing in-service materials. However, testing has indicated that materials that once passed old certification standards often do not pass current standards, and there is no requirement to replace most of these materials.

2.4 *Drain Line Repair*

The drain line repair was most likely the catalyst that initiated the B110 heater ribbon failure. The drain line was repaired twice prior to the occurrence, under a repair scheme that was approved and issued by Air Canada's engineering department. The repair was meant to serve as a temporary fix until a new drain line could be installed. The repair was not authorized by Boeing, nor was Boeing's authorization required.

The first time the repair was carried out, the heater ribbon had failed and it was replaced. The second time the repair was carried out, the heater ribbon was not replaced. While carrying out the second drain line repair, the heater ribbon may have been inadvertently damaged; however, fire damage to the heater ribbon precluded the possibility of determining if this was the case.

The fact that a minor repair could possibly affect the serviceability of a component in such an adverse manner supports the need to carefully examine heater ribbon installations.

2.5 *Certification*

Prior to the aircraft entering Canada, it was inspected in accordance with existing procedures. The inspection was detailed and generated an extensive list of discrepancies and maintenance tasks to be completed. Eventually the aircraft was issued an Export Certificate of Airworthiness from a country with which Canada has a bilateral agreement (U.S.). This was accepted by the TC delegate assigned to the project.

Although the inspection was detailed and the reports generated did make reference to some discrepancies with the insulation blankets in the cargo holds, these references were not very detailed. It is possible that the unapproved blankets found during the investigation were missed during the importation process, or were noted during the process but, due to the lack of detail of some of the references, were not addressed prior to the aircraft entering the country. Regardless of how the aircraft was imported, it is the responsibility of the owner to maintain the aircraft in accordance with its type design certification. If the aircraft were dirty or there were unapproved insulation blankets installed, it was Air Canada's responsibility to rectify the problem.

2.6 *Notification and Data Preservation*

The delay of the operator in notifying the TSB in a timely manner following the occurrence and the loss of flight recorder information did not adversely affect the investigation for the following reasons:

- The crew survived and was able to provide factual information.
- Physical evidence was not destroyed by a catastrophic hull loss or post-crash fire.
- Air Traffic Services recordings provided additional information regarding crew communications and aircraft position data.

Notwithstanding, had the circumstances been different, the lack of data following the cargo fire or the delayed notification could have severely affected the ability of the investigation to make findings as to the causes and contributing factors.

Although NTSB Recommendation A–02–24, "Overwritten Cockpit Voice Recordings," was issued on 29 August 2002, implementation of the recommendation by the FAA would only affect aircraft operators certified to conduct operations in the United States.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. The B110 heater ribbon attached to the water supply line failed at the site of a recent water line repair, which allowed the elements of the heater ribbon to electrically arc, providing a source of ignition to surrounding materials.

2. The polyethylene terephthalate (PET) covering material of the thermal acoustic insulation was contaminated. The contaminated material provided an ignitable source of fuel for a self-sustaining fire.

3. The open cargo floor provided a trap that collected contaminants and debris in the bilge area of the cargo compartment; the debris and contaminants were an ignitable source of fuel to sustain a fire.

4. Circuit protection devices are designed to protect aircraft wiring and not aircraft components. The lack of circuit protection of the heater ribbon system permitted the heater ribbon failure to result in an arcing event.

3.2 Findings as to Risk

1. Unlike the cargo compartments, there are many areas that are solely dependent on human intervention for fire detection and suppression. However, there is no requirement that the design of the aircraft provide for ready access to these areas. The lack of such access could delay the detection of a fire and significantly inhibit firefighting.

2. The consequence of contamination of an aircraft on its continuing airworthiness is not fully understood by the aviation industry. Various types of contamination may damage wire insulation, alter the flammability properties of materials, or provide fuel to spread a fire. The aviation industry has yet to quantify the impact of contamination on the continuing airworthiness and safe operation of an aircraft.

3. There are no industry standards for detecting, accessing, or cleaning contamination from thermal acoustic insulation.

4. The impact of age on thermal acoustic insulation is not fully understood by the aviation industry. Age may alter the flammability properties of the materials, providing fuel for a fire. The aviation industry has yet to quantify the impact of age on thermal acoustic insulation and the continuing airworthiness and safe operation of an aircraft.

5. Regulations do not require that aircraft be designed to allow for the immediate de-powering of all but the essential systems as part of an isolation process for the purpose of eliminating potential ignition sources.

6. Heat damage was found on other in-service heater ribbons. Although self-propagating fires did not occur in these instances, their design and installation near combustible materials constituted a fire risk.

7. There is no fire suppression beyond the cargo compartment, in the sidewall area of the aircraft, nor is it accessible in flight. A sustained fire in this area could burn out of control, with catastrophic results.

8. Maintenance manual procedures for the installation of heater ribbons are generalized and ambiguous. The ambiguity in the installation procedures could lead to an improperly installed heater ribbon and possible component failure.

3.3 *Other Findings*

1. The operator did not notify the TSB in a timely manner and, therefore, failed to meet the requirements of the Transportation Safety Board Regulations.

2. The operator did not take appropriate measures to preserve all the available data on the flight data recorder and, therefore, failed to meet the requirements of the Transportation Safety Board Regulations.

3. Thermal acoustic insulation blankets of an unknown origin were discovered in the forward cargo compartment. The flammability characteristics of these blankets were unknown and could constitute a fire risk.

4.0 Safety Action

4.1 Action Taken

4.1.1 Air Canada

Air Canada took immediate action to reduce the risk of heater ribbon fires. An inspection of specified areas of the 767 aircraft fleet was conducted, and defective heater ribbons in these areas were removed or de-activated and a general clean-up of debris found in these areas was carried out. Not all of the heater ribbons in the 767 aircraft were examined.

Air Canada amended its Boeing 767 Service Check (96-hour maximum interval) to include a requirement to remove all debris found below the floor level of both the forward and aft cargo compartments. They also enhanced their zonal general visual inspection to ensure that heater ribbons are inspected during the scheduled 24-month "M" checks.

Air Canada has initiated new procedures to ensure that the required flight recorder information is provided. For any given situation, there are several individuals within Air Canada who can request that a flight data recorder (FDR) or cockpit voice recorder (CVR) be quarantined, but only the Director of Flight Safety or a delegate has the authority to release flight recorder information and then only to the TSB.

4.1.2 Boeing

As a result of the fire on aircraft C–GHML, Boeing released Alert Service Bulletin (ASB) 767–30A0037 on 28 May 2002, to provide instructions and corrective action necessary to avoid a possible fire in the forward and aft cargo areas. The bulletin is applicable to all 767–200, 300 and 300F aircraft with non-fully enclosed cargo floors in the lower cargo areas. The bulletin called for operators to take the following actions with respect to visually accessible potable water and drain lines located under the cargo floor in the forward and aft cargo areas:

- remove all foreign object debris (FOD) found on, near, or around the potable water and drain line;
- inspect all heater ribbons on the potable water and drain lines for excessive heat damage;
- inspect all heater ribbons on the potable water and drain lines for damaged or missing protective tape; and
- replace heater ribbon and add protective tape, if necessary.

In a letter dated 31 October 2003, Boeing provided additional information regarding TSB recommendations A02–04 and A02–05 (see Section 4.1.3)

- Boeing has selected new Adel Wiggins replacement heater ribbon designs for improved durability and reliability for water supply, fill lines, and, where needed, drain lines on 767–200, 767–300 and 767–300F aircraft with non-fully enclosed cargo floors. In addition, Boeing has concluded that heater ribbons can be eliminated from gray water drain lines in sections 43 and 46 (retrofit action only). Sections 43 and 46 are pressurized fuselage sections immediately forward and aft of the wing, respectively (forward and aft cargo compartments).

- Production final action: Starting at production line number 919, revise thermal protection on Section 43 gray water drain lines by deleting current heater ribbons and installing insulation around the drain lines in areas previously protected by heater ribbons. Similar action is not required in Section 46, because pre-formed Adel Wiggins heaters are currently used in production. For customers with a preselect system, add a new Adel Wiggins heater ribbon fill line installation.

- Retrofit final action: Provide Boeing Service Bulletin (SB) 767–30A0038 with retrofit instructions (i.e. no Boeing parts). Include deactivation directions for the gray water drain line heater ribbons, and insulation installation instructions (as required). Also, replace the potable water supply line heater ribbons with new Adel Wiggins heater ribbons. The scheduled SB release date is 16 December 2004.

- This issue is also applicable to all 747 aircraft due to their use of similar heater ribbons and open floor cargo compartments. Boeing has selected new heater ribbon designs for replacing existing supply and drain line heaters.

- Interim Action: Boeing released SB 747–30A2079 on 12 December 2002, which mirrored ASB 767–30A0037 and was also only applicable to aircraft with non-fully enclosed cargo floors.

- Production final action 747–400 only: Starting at production line number 1347, revise sections 42 and 46 drain line modules by replacing existing heater ribbons with new Adel Wiggins heater ribbons.

- Retrofit final action: Provide Boeing ASB 747–30A2080 only (i.e. no parts and/or kits), with retrofit instructions to remove FOD and inspect heater ribbons in open cargo areas for excessive heat damage, as in SB 747–30A2079, at specific intervals. Closing actions that result in the termination of the above inspections are to replace gray water drain line heaters and potable water supply line heaters in open cargo areas with new Adel Wiggins heater ribbons. The scheduled ASB release date is 16 December 2004.

- Boeing is supporting the activities of the Contamination/Aging Task Group, a sub-group of the Federal Aviation Administration (FAA) International Materials Fire Test Working Group. This team is studying the effects of contamination and aging on the flammability properties of aircraft hidden materials. In accordance with the working group's process, the collective outcome will be provided in a published summary report by the FAA Technical Center. Conclusions will be communicated to the regulatory authorities and airline customers with recommendations as required.

4.1.3 Transportation Safety Board of Canada

On 14 November 2002, the TSB issued the following, regarding water line heater ribbon fires:

> Widespread use of heater ribbons on transport category aircraft exposes the travelling public to the risks associated with heater ribbon fires. Recent actions taken to reduce these risks are not comprehensive and do not address the risk in the long term. Consequently, there remains inadequate defences against heater ribbon installations starting a fire, therefore the Board recommends that:
>
>> The Department of Transport take action to reduce the short term risk and eliminate the long term risk of heater ribbon installation failures starting fires, and coordinate and encourage a similar response from other appropriate regulatory authorities. (A02–04)

On 14 November 2002, the TSB issued the following recommendation covering contaminated, thermal acoustic insulation as a source of fuel:

> The widespread existence of contaminated thermal acoustic insulation materials and debris on transport category aircraft exposes the travelling public to the risk of a self-propagating fire. Recent actions taken to reduce these risks are not comprehensive and do not adequately address risk in the long term. Consequently, there remains inadequate defences against contaminated insulation materials and debris propagating a fire, therefore the Board recommends that:

> The Department of Transport take action to reduce the short term risk and eliminate the long term risk of contaminated insulation materials and debris propagating fires, and coordinate and encourage a similar response from other appropriate regulatory authorities. (A02–05)

4.1.4 Federal Aviation Administration

On 07 June 2002, the FAA issued Airworthiness Directive (AD) 2002–11–11, which reflected Boeing's ASB 767–30A0037. The FAA indicated that action associated with the AD is considered interim until final action is identified, at which time the FAA may consider further rule-making.

In a letter dated 06 February 2003, the FAA's Seattle Aircraft Certification Office indicated that they agree in part with TSB Recommendation A02–04.

- A notice of proposed rule making (NPRM) Docket No. 2002–NM–341–AD is being prepared for the Boeing Model 747 aircraft to perform an inspection similar to that of AD 2002–11–11.
- Additionally, the Seattle Aircraft Certification Office has requested SBs from Boeing, to address the long-term risk for Boeing Model 747 and 767 aircraft without fully enclosed cargo floors. One corrective action is to identify any drain line hoses that do not require heat to keep from freezing and remove the heater ribbon via the requested SB. For the remaining drain and fill lines in the area under the cargo floor, a new, more reliable heater ribbon will be developed and installed in accordance with the requested SB. There is no date available as to the issuing of the SBs.
- The Seattle Aircraft Certification Office does not agree that additional actions are required for other Boeing aircraft or for areas that are not accessible. They indicate that debris and contamination and not heater ribbon or insulation materials provide the fuel for a fire. Areas that are not accessible are not as exposed to debris or contamination; therefore, there is no risk of fire. They also indicate that there has never been a failure of a heater ribbon in an inaccessible area that has resulted in a self-sustaining fire.

In a letter dated 19 March 2003, the FAA's Seattle Aircraft Certification Office indicated that they agree with TSB Recommendation A02–05.

- Currently, in the Boeing 767 Maintenance Review Board report and the Maintenance Planning Data documents, there are no dedicated or scheduled maintenance tasks aimed at monitoring the condition of wiring, insulation blankets, and debris.

- There are tasks in the Zonal Inspection Program and the Structures and Corrosion Prevention and Control programs that identify zones containing wiring, insulation blankets and debris.

- A new maintenance process called enhanced zonal analysis procedure (EZAP), an inspection program in wiring areas to remove debris, will be required to be implemented by aeroplane manufacturers under Maintenance Steering Group 3, revision 2001.

- The EZAP process was the result of efforts performed by the Aging Transport Systems Rulemaking Advisory Committee (ATSRAC), recommending mandatory changes that would modify aeroplane maintenance and training programs for all personnel involved in wiring installations on large transport type aircraft.

4.1.5 Transport Canada

Transport Canada (TC) responded to Recommendation A02–04 with the following action:

Short-term Actions

- TC's Aircraft Certification Branch, Continuing Airworthiness Division, is working closely with the FAA to determine if the actions mandated by AD 2002–11–11 should be applicable to other aircraft model types that use similar heater ribbons.

- On 27 December 2002, TC submitted a letter to the FAA and the manufacturer of the Boeing 767 aircraft, requesting that a review of the initial development of Maintenance Significant Items be performed. TC requested that if the review found the items inadequate, a complete re-analysis of the heater ribbon system be conducted to ensure all failure modes are included.

- Boeing has been asked to take into consideration the overheating/arcing failure mode combined with combustible contaminants, which may result in a fire. In addition, a request for a review of the installation instructions of the heater ribbon tape and the configuration of the related electrical circuit, including the circuit breaker (CB), will be made (see Section 4.1.2).

- TC contacted other foreign civil aviation authorities in January 2003, and requested their support in assessing the potential failure for similar heater ribbon installations on type certified aircraft for which they are the responsible design authority.

Long-term Actions

- TC is working closely with the FAA to determine corrective actions required to address this problem.

- Bombardier has been requested to provide TC with information regarding the type of heater ribbons installed on aircraft for which they are the type certificate holder.

TC responded to Recommendation A02–05 with the following action:

Short-term Actions

- TC recognized the potential for contamination to negatively affect the flame propagation characteristics of thermal/acoustic insulation materials.

- On 08 November 2001, TC published Maintenance Staff Instruction (MSI) 42, "Procedures for the Inspection of Thermal/Acoustic Insulation During Heavy Maintenance Checks for Contamination." This MSI requires that primary maintenance inspectors ensure that operators of large transport category aeroplanes have established procedures in their approved Maintenance Schedule for the inspection of thermal/acoustical insulation during heavy maintenance checks.

- TC raised the issue at the International Aircraft Materials Fire Test Working Group. A task group has been formed and work has already been initiated to review the subject and develop potential means for mitigation.

Long-term Actions

- TC has recognized the requirement to identify/develop "Harmonized International Standards" applicable to materials and material flammability that will address the aspects associated with material composition and the effects of contamination that will minimize the potential risks.

- TC is working with the ATSRAC on a new maintenance process, EZAP, to implement an inspection program in wiring areas to remove debris.

- TC indicated that its Risk Management Process will identify and quantify specific risk issues, and that this process will then lead to action plans and completion targets to be developed and implemented to reduce or mitigate these risks.

4.2 *Safety Concerns*

Photo 6. Dust and lint accumulation on wiring bundles behind wall panel

Photo 7. Dust and lint accumulation on thermal acoustic insulation behind wall panel

The Board is concerned that the FAA action is limited to Boeing 747 and 767 aircraft, because only these Boeing aircraft have open cargo floor areas. The FAA believes that heater ribbons do not need to be removed or replaced in closed-in areas, because such areas do not accumulate sufficient debris and contamination to pose a risk of a self-sustaining fire. The Board does not share this view. Both the TSB and the National Transportation Safety Board (NTSB) have previously issued safety communications concerning the fire hazard associated with the accumulation of lint, dust, and debris on wires. As well, both TC and the FAA have previously issued communications recognizing that the flammability of most materials can change if the materials are contaminated, and that contamination may be in the form of lint, dust, grease, etc., which can increase the material's susceptibility to ignition and flame propagation. Despite all of the action taken to date by the various agencies, the problem of contamination in closed-in areas still exists (see photos 6 and 7). As detailed in this report, dust and lint accumulation on wires has led to self-sustaining fires in closed-in areas, and the potential for such fires still exists. Consequently, the lack of FAA action concerning closed-in areas does not mitigate the safety deficiency in these areas.

FAA action will likely adequately address the potential for heater ribbon installations to start a fire in open cargo floor areas, but not in closed-in areas. Although the risk of a fire starting in open floor areas is likely greater due to their vulnerability to the accumulation of debris and contamination, the risk of a fire starting in a closed-in area will remain.

The Board is concerned that although TC has indicated its intention to work with the FAA and has made requests to the FAA, TC has not indicated an intent to take action to directly address the safety deficiencies identified by the Board beyond the areas being addressed by the FAA.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 26 August 2004.

*Visit the Transportation Safety Board's Web site (**www.tsb.gc.ca**) for information about the Transportation Safety Board and its products and services. There you will also find links to other safety organizations and related sites.*

Appendix A – List of Supporting Reports

The following TSB Engineering Laboratory reports were completed:

LP 35/02 – *Cargo Fire Examination*
LP 39/02 – *FDR/CVR Analysis*
LP 58/02 – *Heat Testing of 3M Vinyl Tape-Flame Resistant-474*
LP 106/02 – *Water Line Ribbon Examination*

These reports are available from the Transportation Safety Board of Canada upon request.

Appendix B – Glossary

ACPL	Aircraft Certification Policy Letter
ACPP	Air Canada Production Permit
AD	Airworthiness Directive
ASB	Alert Service Bulletin
ATPL	Airline Transport Pilot Licence
ATSRAC	Aging Transport Systems Rulemaking Advisory Committee
BL	buttock line
CAA	Civil Aviation Authorities
CARs	*Canadian Aviation Regulations*
CB	circuit breaker
cm	centimetre
CPD	circuit protection device
CVR	cockpit voice recorder
EICAS	engine indication and crew alerting system
EO	Engineering Order
EPDM	ethylene propylene diene terpolymer
EZAP	enhanced zonal analysis procedure
F	Fahrenheit
FAA	Federal Aviation Administration (U.S.)
FARs	*Federal Aviation Regulations* (U.S.)
FDR	flight data recorder
FLIR	forward-looking infrared
FOD	foreign object debris
FS	fuselage station
FSAW	Flight Standards Information Bulletin for Airworthiness
Hz	hertz
IFR	instrument flight rules
LBL	left buttock line
MSI	Maintenance Staff Instruction
NPRM	notice of proposed rule making
NTSB	National Transportation Safety Board
OM	Operations Manual
PDU	power drive unit
PET	polyethylene terephthalate
PMIs	principal maintenance inspectors
P/N	part number
RBL	right buttock line

SB	Service Bulletin
TC	Transport Canada
TSB	Transportation Safety Board of Canada
U.S.	United States
°	degree(s)