Ground Fire Aboard Cargo Airplane
ABX Air Flight 1611
Boeing 767-200, N799AX
San Francisco, California
June 28, 2008

Aircraft Accident Summary Report

NTSB/AAR-09/04/SUM
PB2009-910404

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AIRCRAFT ACCIDENT SUMMARY REPORT
NTSB/AAR-09-04/SUM (PB2009-910404)

GROUND FIRE ABOARD CARGO AIRPLANE, ABX AIR FLIGHT 1611, BOEING 767-200, N799AX, SAN FRANCISCO, CALIFORNIA, JUNE 28, 2008

- Page i has been changed to indicate that appendix B presents comments from the State of Israel, Ministry of Transport, Aviation Incidents and Accidents Investigation. *(July 21, 2009)*

  The report originally stated that appendix B presented comments from the Civil Aviation Authority of Israel (CAA Israel).

- Page iv has been changed to indicate that 11 safety recommendations were issued to the Federal Aviation Administration (FAA). *(July 21, 2009)*

  The report originally stated that 12 safety recommendations had been issued to the FAA.

- Page 17, footnote 34, has been changed to indicate that the State of Israel, Ministry of Transport, Aviation Incidents and Accidents Investigation, participated in this investigation and provided comments. *(July 21, 2009)*

  The report originally stated that CAA Israel had participated in the investigation.

- Page 61 has been changed to indicate that comments were received from the State of Israel, Ministry of Transport, Aviation Incidents and Accidents Investigation. *(July 21, 2009)*

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National
Transportation
Safety Board

490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

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Abstract: This report explains the June 28, 2008, accident involving a Boeing 767-200, N799AX, operated by ABX Air as a cargo flight. The airplane experienced a ground fire before engine startup. The captain and the first officer evacuated the airplane through the cockpit windows and were not injured, and the airplane was substantially damaged. The safety issues discussed in this report involve the conductivity and the aging of oxygen hoses, the FAA's airworthiness directive process, the proximity of oxygen system components to electrical wiring, the electrical grounding of oxygen systems, the potential for passenger reading lights on transport-category airplanes to become an ignition source, additional smoke detector systems for cargo airplanes, and the effectiveness of ABX Air's continuing analysis and surveillance program. Safety recommendations regarding these issues are addressed to the Federal Aviation Administration and to ABX Air.

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Abbreviations and Acronyms

AC	advisory circular
AD	airworthiness directive
ARFF	aircraft rescue and firefighting
CAA	Civil Aviation Authority of Israel
CAMP	continuous airworthiness maintenance program
CASP	continuing analysis and surveillance program
CFR	*Code of Federal Regulations*
CVR	cockpit voice recorder
FAA	Federal Aviation Administration
HRET	high-reach extendable turret
IAI	Israel Aerospace Industries
NTSB	National Transportation Safety Board
psig	pounds per square inch gauge
PMI	principal maintenance inspector
PSU	passenger service unit
PVC	polyvinyl chloride
SB	service bulletin
SFO	San Francisco International Airport
SPN	skin-penetrating nozzle
TSB	Transportation Safety Board of Canada

Executive Summary

On June 28, 2008, about 2215 Pacific daylight time, an ABX Air Boeing 767-200, N799AX, operating as flight 1611 from San Francisco International Airport, San Francisco, California, experienced a ground fire before engine startup. The captain and the first officer evacuated the airplane through the cockpit windows and were not injured, and the airplane was substantially damaged. The cargo flight was operating under the provisions of 14 *Code of Federal Regulations* Part 121. At the time of the fire, the airplane was parked near a loading facility, all of the cargo to be transported on the flight had been loaded, and the doors had been shut.

The National Transportation Safety Board determines that the probable cause of this accident was the design of the supplemental oxygen system hoses and the lack of positive separation between electrical wiring and electrically conductive oxygen system components. The lack of positive separation allowed a short circuit to breach a combustible oxygen hose, release oxygen, and initiate a fire in the supernumerary compartment that rapidly spread to other areas. Contributing to this accident was the Federal Aviation Administration's (FAA) failure to require the installation of nonconductive oxygen hoses after the safety issue concerning conductive hoses was initially identified by Boeing.

The safety issues discussed in this report involve the conductivity and the aging of oxygen hoses, the FAA's airworthiness directive process, the proximity of oxygen system components to electrical wiring, the electrical grounding of oxygen systems, the potential for passenger reading lights on transport-category airplanes to become an ignition source, additional smoke detector systems for cargo airplanes, and the effectiveness of ABX Air's continuing analysis and surveillance program. Eleven new safety recommendations to the FAA and one to ABX Air are included in the report.

1. The Accident

1.1 History of the Flight

On June 28, 2008, about 2215 Pacific daylight time,[1] an ABX Air Boeing 767-200, N799AX, operating as flight 1611 from San Francisco International Airport (SFO), San Francisco, California, experienced a ground fire before engine startup. The captain and the first officer evacuated the airplane through the cockpit windows and were not injured, and the airplane was substantially damaged. The cargo flight was operating under the provisions of 14 *Code of Federal Regulations* (CFR) Part 121. At the time of the fire, the airplane was parked near a loading facility, all of the cargo to be transported on the flight had been loaded, and the doors had been shut.[2]

The fire was located in the supernumerary compartment of the airplane. This compartment, which is present on some cargo airplanes, is located directly aft of the cockpit and forward of the main deck cargo compartment, as shown in figure 1.[3] This area is where the lavatory, galley, and three non-flight crew seats (in a bench configuration) are located.[4]

Flight 1611 was scheduled to depart SFO at 2230 for Airborne Airpark, Wilmington, Ohio. Earlier that day, maintenance personnel performed a service check of the airplane, which included a check of the supplemental oxygen system pressure. The supplemental oxygen system, which provided emergency oxygen, was supplied by two oxygen bottles located below the cockpit. During a postaccident interview, a mechanic reported that the supernumerary oxygen bottle, which also provided emergency oxygen to the cockpit, had a pressure between about

[1] All times in this report are Pacific daylight time based on a 24-hour clock.

[2] The NTSB's public docket for this accident investigation is available at <http://www.ntsb.gov/info/foia_fri-dockets.htm>.

[3] Some cargo airplanes have a similar area that is not specifically referred to as a supernumerary compartment by their operator.

[4] Occupants of the supernumerary seats are nonrevenue passengers, including airline employees and individuals who are specifically associated with the cargo aboard a flight. No one was occupying the seats at the time of the accident.

1,220 and 1,230 pounds per square inch gauge (psig)[5] and that the cockpit bottle had a pressure of about 1,560 psig.[6]

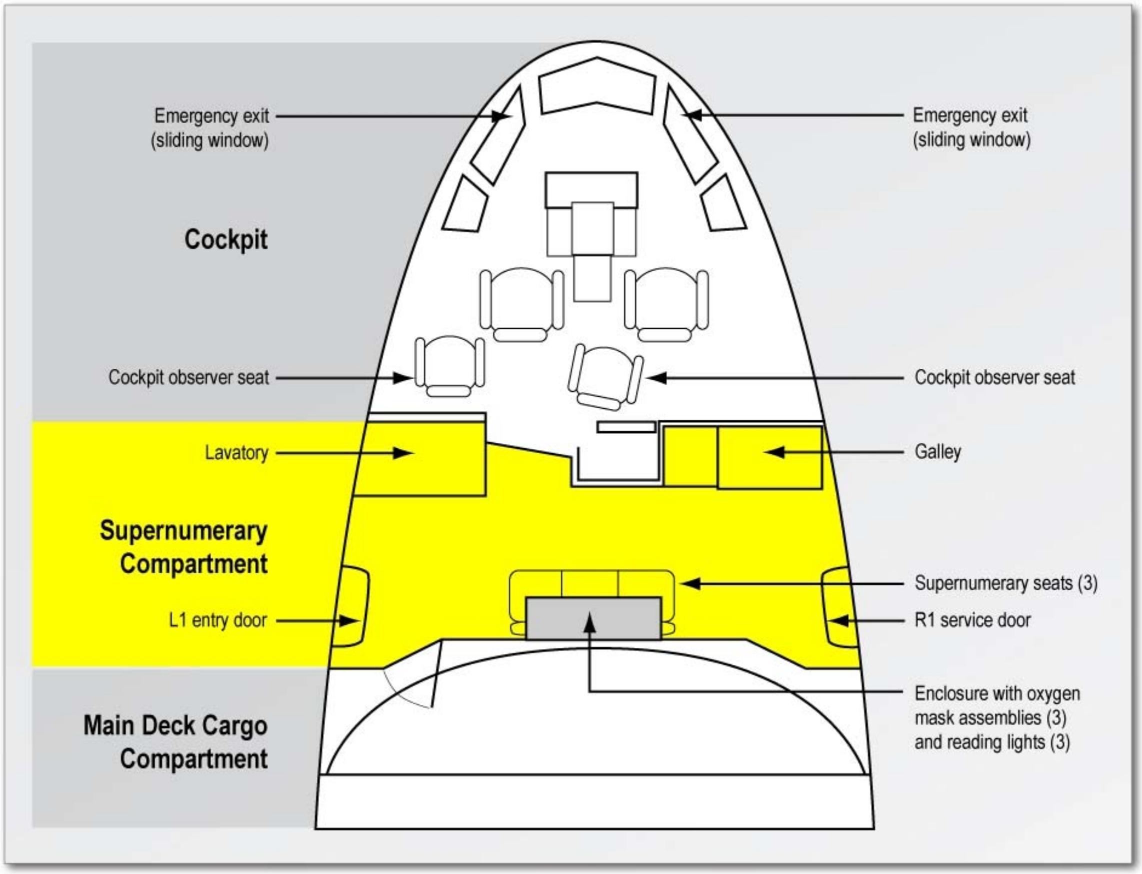

Figure 1. Cockpit and Forward Cabin of Airplane

The flight crew conducted preflight checks, including one for the supplemental oxygen system in the cockpit. The captain stated that he pushed the oxygen switch, tested his oxygen mask, and verified oxygen pressure using the engine indicating and crew alerting system. The captain reported that oxygen was flowing during the test and had stopped once the test was

[5] The oxygen system had a nominal pressure of 1,850 psig, and service check cards indicated that the system was to be serviced when pressure was below 1,300 psig. A mechanic performing the service check stated that he did not service the supernumerary oxygen bottle at that time because he knew that he would be rechecking the pressure during the predeparture check of the airplane. The mechanic also stated that, during the predeparture check, the supernumerary oxygen bottle pressure was still between about 1,220 and 1,230 psig, so he removed the bottle from the airplane but then reinstalled it after determining that no additional oxygen could be added to the bottle. (This issue is discussed further in section 2.2.) The mechanic indicated that an oxygen bottle would be placed on the minimum equipment list if its pressure were below 1,100 psig.

[6] The postaccident interview with the mechanic occurred about 1 month after the accident. However, on the day after the accident, the mechanic told the National Transportation Safety Board (NTSB) that the pressure to the supernumerary oxygen bottle was about 1,580 psig and that the pressure to the cockpit bottle was about 1,700 psig. (During its examination of the airplane wreckage, NTSB investigators found that the cockpit bottle had a pressure of 1,700 psig and that the supernumerary bottle was empty.)

completed and that the system check was normal. According to the cockpit voice recorder (CVR) recording,[7] a sound similar to an oxygen mask test and the first officer's statement "mask check" were recorded about 2200:07 and 2203:24, respectively.[8]

The pilots reported that, while performing the engine start checklist, they heard loud "pop" and "hissing" sounds. (The initiation of these sounds was not audible on the CVR recording.) According to the CVR, between about 2210:28 and 2210:41, the first officer stated, "hey, there's something going on in the back … we got a fire … got a big fire." The cockpit area microphones then recorded sounds similar to the lavatory smoke detector alarm and a fire warning bell.

The first officer reported that he had been in the supernumerary compartment turning off lights (except for possibly the galley light) less than 1 minute before hearing the pop and hissing sounds. (Although the first officer estimated that he had been in the supernumerary compartment less than 1 minute before hearing the sounds, the CVR recorded the sound of the cockpit door closing about 2207:32.) He indicated that no smoke or fire was visible at that time. He also reported that about 15 seconds had elapsed between the time that he heard the sounds and the time that he got out of his cockpit seat, opened the cockpit door, and looked inside the supernumerary compartment. (The CVR recorded the sound of the cockpit door closing about 2210:41. While the door was open, the hissing sound could be heard on the CVR.) The first officer further reported that the location where he first noticed smoke and fire was near the compartment ceiling and at the right end (his left) of an enclosure that contained components of the supernumerary supplemental oxygen system. The captain did not observe the fire but indicated that he could smell the smoke.

About 2211:04, the first officer contacted the ground controller to inform him that aircraft rescue and firefighting (ARFF) was needed because of a cargo fire. The controller then confirmed that the first officer was reporting an aircraft fire and stated, about 2211:24, "we're gonna roll the trucks right now." Afterward, the pilots began the fire and evacuation checklist. The CVR recording ended about 2211:38.

The exit doors that were normally available to the flight crew were an entry door on the left side of the supernumerary compartment (L1) and a service door on the right side of the compartment (R1). Because of the location and the intensity of the fire, the flight crew had to evacuate the airplane through the two cockpit window exits. Each window had an escape rope, and the first officer exited the airplane using the escape rope at his window. Afterward, the first officer instructed ground personnel to move the stairs under the captain's window. The captain then opened his window and climbed onto the stairs to exit the cockpit.

The captain and the first officer stated that they observed black smoke "pouring" out of the airplane. Information on the emergency response appears in section 2.3.

[7] The airplane was also equipped with a flight data recorder, but it was not recording at the time because the engines had not yet been started.

[8] The CVR transcript appears in appendix A.

1.2 Fire Damage to Airplane

In the cockpit, the ceiling and other surfaces were covered with soot. Extensive thermal damage was also present on the cockpit ceiling, especially in the aft portion. The bulkhead separating the cockpit and the supernumerary compartment was damaged by fire and had burn-through areas, especially in the upper portions of the bulkhead. Flight control cables to the tail were routed vertically along the aft side of this bulkhead, and their upper mounting point had fallen to the floor structure.

In the supernumerary compartment, the fire completely consumed the seat cushions and most of the seat structure; only small portions of the seat frame remained. The floor beneath the seats was fire damaged. The fire consumed most of the ceiling panels, and charred ceiling portions were found on the floor. Large burn-through areas were located to the left and the right of the crown centerline, and a smaller burn-through area was located on the skin above the lavatory. Two smaller burn-through holes were also found in the crown centerline. All of these burn-through areas were visible from outside the airplane, as shown in figure 2. Recovered electrical wiring from above the supernumerary compartment ceiling panels was found on the floor.

Figure 2. Fire Damage to Top of Airplane

The L1 and R1 doors were extensively fire damaged. The operating mechanism for the L1 door and the tracks for both doors, which allowed them to be opened upward and inward, had melted away, causing the doors to be inoperable. The door leading from the supernumerary compartment to the cockpit showed heavy soot in most areas but was not compromised by the fire. The lavatory (on the left side of the supernumerary compartment) sustained heavy fire damage. Most of the walls in the galley area (on the right side of the supernumerary compartment) were charred and covered with heavy soot. The left-most galley wall, located next to the center of the cockpit bulkhead, had buckled and collapsed as a result of fire damage. The ceiling above the galley area was mostly missing.

The stainless steel supply tubing for the supernumerary supplemental oxygen system was found intact (except for a portion of the supply tubing that was missing from the location where the fire had consumed the cockpit bulkhead).[9] One of the three aluminum oxygen mask stowage boxes was found partially consumed. A stainless steel 90° elbow assembly from each stowage box was recovered, but one of the assemblies was found in two separate pieces. Both of these pieces exhibited melting. The oxygen hose ends that were recovered from the supply tubing and elbow assembly were made of aluminum. No evidence of arcing was found on the recovered portions of the wiring, but an extensive amount of wiring was not found as a result of the fire.

The main deck cargo compartment extended the length of the airplane, from behind the supernumerary compartment to the aft pressure bulkhead.[10] A smoke barrier wall had separated the supernumerary and cargo compartments. The smoke barrier wall had been constructed with a lateral center section and aft angled outboard sections. The top edge of the lateral wall was damaged by the fire and was no longer connected to the upper aft angled section, causing the lateral section of the wall to collapse into the main deck cargo compartment. (The bottom edge of the wall remained mostly connected to the floor structure.) Aluminum strips on the lateral wall, including the one that connected the left and right sections of the wall, had melted away. Both angled outboard sections were still standing but were charred.

The two forward-most cargo containers, which were closest to the door on the smoke barrier wall, showed evidence of soot, thermal damage, burn-through, and melting.[11] The two containers located in the position directly aft of the two forward-most cargo containers showed external thermal damage and soot. The remaining cargo containers showed soot damage only.

ABX Air reported that the substantial damage to the airplane resulted in a hull loss.

[9] This missing supply tubing was in an area that had been damaged by fire, firefighting efforts, and the installation (after the fire) of posts to stabilize the structure above the area of investigation.

[10] The main deck cargo compartment was configured so that 19 containers could be loaded. The airplane was also configured with three lower deck cargo compartments. Access to these lower deck cargo compartments was provided by doors located in the lower fuselage.

[11] The cargo net, which was located directly in front of the two forward-most containers, was missing in some areas; the remaining sections of the net were heavily charred and had heavy soot deposits present. The cargo liners along the ceiling above the four forward-most cargo positions were heavily fire damaged and/or mostly missing.

2. Investigation and Analysis

2.1 Fire Initiation

The first officer reported that, less than 1 minute before he and the captain heard the pop and hissing sounds,[12] he had been in the supernumerary compartment with no fire or smoke present at the time. Within 15 seconds after hearing the sounds, the first officer opened the cockpit door and saw black smoke in the supernumerary compartment at ceiling height; through the smoke, he saw fire near the ceiling above the top of the right-most occupant seat and above the location of the weight and balance computer.[13]

The supernumerary compartment was constructed with low-flammability materials, in accordance with Federal regulations. The enclosure above the supernumerary occupant seats, the top right of which was consistent with the location where the first officer initially observed the fire, included panel material, an aluminum subframe, and three oxygen mask stowage boxes. The brief time during which the fire developed, the intensity of the fire, and the pop and hissing noises heard by the flight crew indicated that a source of pressurized oxygen was involved in the fire. Also, the supernumerary oxygen bottle was found empty (compared with the cockpit oxygen bottle, which was found almost full), further indicating that the oxygen system supplying the supernumerary compartment had been compromised.

Each of the three oxygen mask stowage boxes (in the enclosure above the supernumerary occupant seats) included an oxygen mask assembly, a flexible hose that was primarily made of polyvinyl chloride (PVC),[14] and rigid stainless steel supply tubing, as shown in figure 3. The manufacturer of the PVC flexible oxygen hoses installed a stainless steel coil spring in the hoses, as shown in figure 4, to prevent bends from collapsing the hose and disrupting the oxygen supply. The stainless steel coil was loosely attached to the aluminum fittings at each hose end, making the hoses electrically conductive.

[12] Section 1.1 of this report indicates that about 3 minutes had elapsed between the time that the CVR recorded the sound of the cockpit door closing and the first officer's statement, "hey, there's something going on in the back."

[13] The weight and balance computer was located below the right end of the supernumerary enclosure and to the right of the supernumerary occupant seats.

[14] PVC is a plastic.

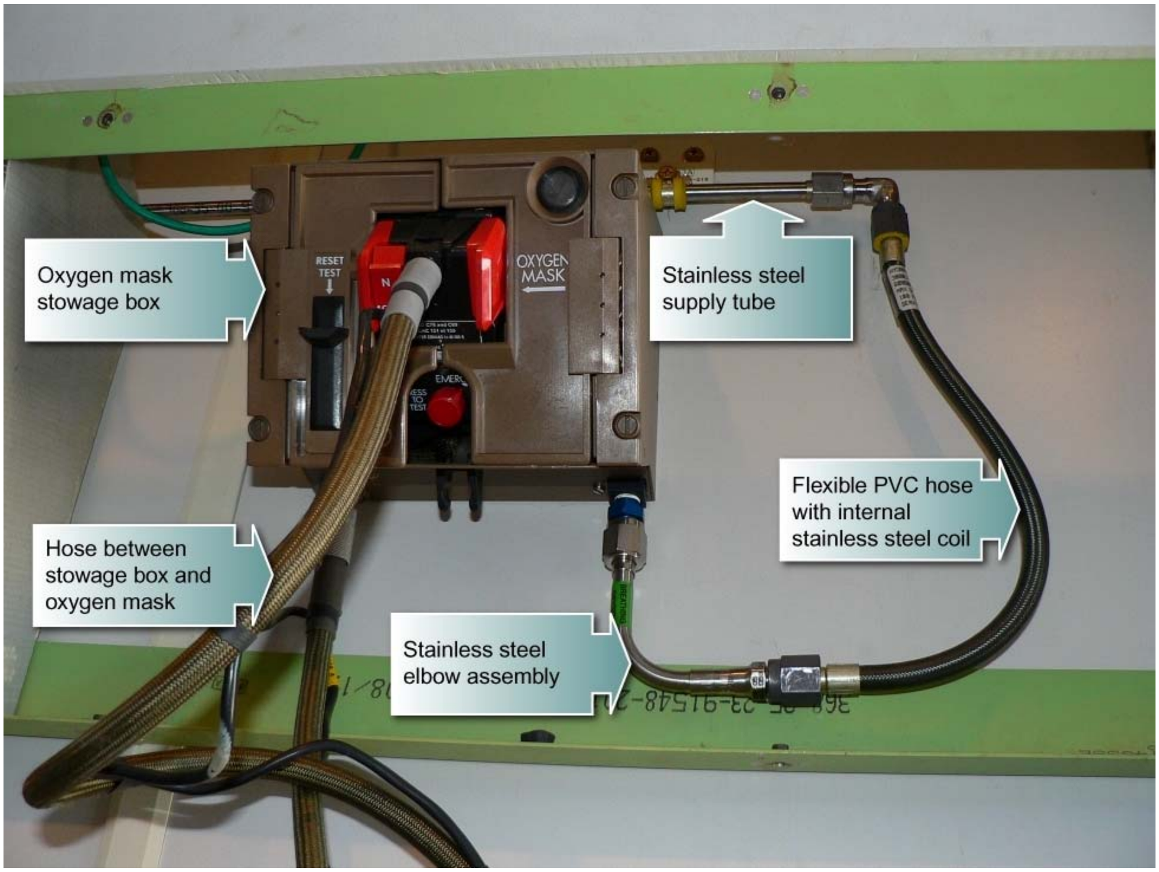

Figure 3. Oxygen System Components in Supernumerary Compartment

Note: The oxygen system components shown in the figure were not from the accident airplane but were instead from another 767 airplane in ABX Air's fleet.

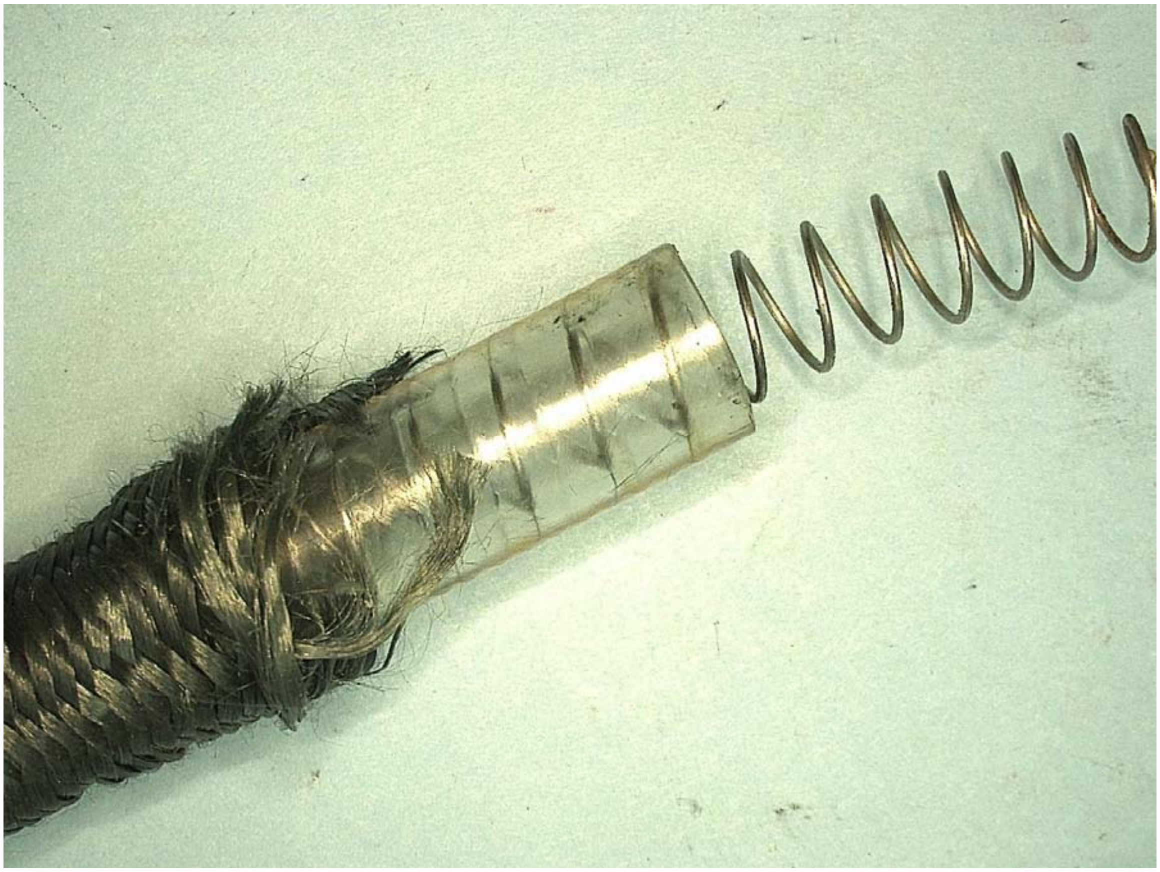

Figure 4. Stainless Steel Coil Spring Within Flexible Oxygen Hose

Note: The flexible oxygen hose shown in the figure was not from the accident airplane but was instead from the NTSB's oxygen hose tests, as explained in this section.

The National Transportation Safety Board (NTSB) performed tests on PVC flexible oxygen hose assemblies that had been removed from the accident airplane and other ABX Air 767 airplanes to evaluate whether electrically energized hoses could cause a fire. The hoses were pressurized with oxygen, and a 120-volt AC electrical current[15] was passed through the internal stainless steel coil spring by attaching electrical conductors to the aluminum fittings at each end of the hose assemblies, which resulted in the hoses becoming part of an electrical circuit. Discrete tests at various energy levels evaluated the hose assemblies' response to becoming electrically energized. (These energy levels were consistent with those that were available on the airplane in the areas where the oxygen system components were routed.) At low energy levels, the heating of the internal spring by the electrical current passing through it (known as resistance heating) caused the PVC hose material to heat enough to soften and allowed the oxygen pressure to rupture the hose. At higher energy levels, the internal spring could be heated until it became an ignition energy source, causing the flexible oxygen hose to ignite and sustain a fire. The time to failure during the tests ranged from 6 to 180 seconds depending on the amount of energy supplied to the internal spring.

[15] One test was conducted with a 28-volt DC electrical current.

Each hose ignition that resulted from heating the internal spring was preceded by a loud pop sound (similar to that of a firecracker) that resulted from the combustion of the PVC hose interior wall along with the oxygen within the hose. (The combustion within the hose generated internal pressure and burst the hose.) The sustained burning of the pressurized flexible hose was accompanied by a loud hissing sound. When ignition occurred, the fire would progress upstream toward the source of oxygen. When the ignition took place near the upstream (supply) end of the flexible hose, the resulting fire would extinguish quickly once it consumed the PVC hose material upstream of the failure location. When the ignition took place near the downstream end, the resulting fire would steadily burn until either the oxygen was manually shut off or all of the PVC hose material was consumed.

Additional tests involved igniting a pressurized PVC flexible oxygen hose with an external heat source; specifically, a wire was wrapped around the hose, and electrical current was applied to the wire. These tests demonstrated the ignition and sustained combustion of a pressurized PVC hose as a result of an external ignition source. During these tests, the oxygen hose did not ignite with a loud pop sound, but a loud hissing sound was heard, and an intense fire resulted from the burning of the PVC hose material.

The NTSB concludes that the pop and hissing sounds heard by the flight crew immediately before the fire was discovered were consistent with the ignition of an oxygen hose by an internal rather than external heat source. The NTSB further concludes that the design of the oxygen hose assembly allowed the internal spring to become a source of ignition when it was electrically energized, the PVC hose material to act as a fuel, and the oxygen within the hose to promote burning.

In addition, the two portions of a partially melted 90° stainless steel elbow assembly (a connector tube) were found near the right supernumerary occupant seat. The portions had been separated by melting that severed the middle of the tube. Also, aluminum fittings were found attached to the stainless steel fittings at the ends of the two elbow assembly portions. (The upstream aluminum fitting had been part of the oxygen hose, and the downstream aluminum fitting had been part of the oxygen mask stowage box assembly.) The aluminum fittings showed signs of incipient melting (that is, the beginning stages of melting) and slight deformation but otherwise remained in place, even though the melting temperature of aluminum is less than one-half of the melting temperature of stainless steel.[16] Thus, the elbow assembly melting occurred in a highly localized manner before the heat could conduct and affect the aluminum fittings on the ends.[17]

The only way to cause melting of the stainless steel elbow assembly is an oxygen-fuel flame because temperatures that are attained in ordinary fires are not sufficient to melt stainless

[16] The average melting point of aluminum is 1,200° F, and the average melting point of stainless steel is 2,500° F.

[17] When an exemplar elbow assembly was exposed to the burning end of a pressurized oxygen hose, the elbow did not melt, but the heat-affected zone was concentrated to an area that was about the same size as the melted area on the portions of the elbow assembly that were recovered from the airplane.

steel. The source of oxygen to allow for this melting would have had to be located closely to the melted stainless steel elbow assembly; thus, the source of oxygen was the flexible oxygen hose connected to that particular elbow assembly.

During the inspections of other ABX Air 767 airplanes, electrical wiring was found in contact with or routed near the stainless steel oxygen supply tubing, as shown in figure 5. A short circuit from this close-contact wiring would be the most likely source to provide electrical energy to the spring. No direct evidence of a short circuit (that is, no beading on wires or arc marks on the oxygen supply tubing) was found, but most of the wiring near the supply tubing and portions of the tubing were missing.

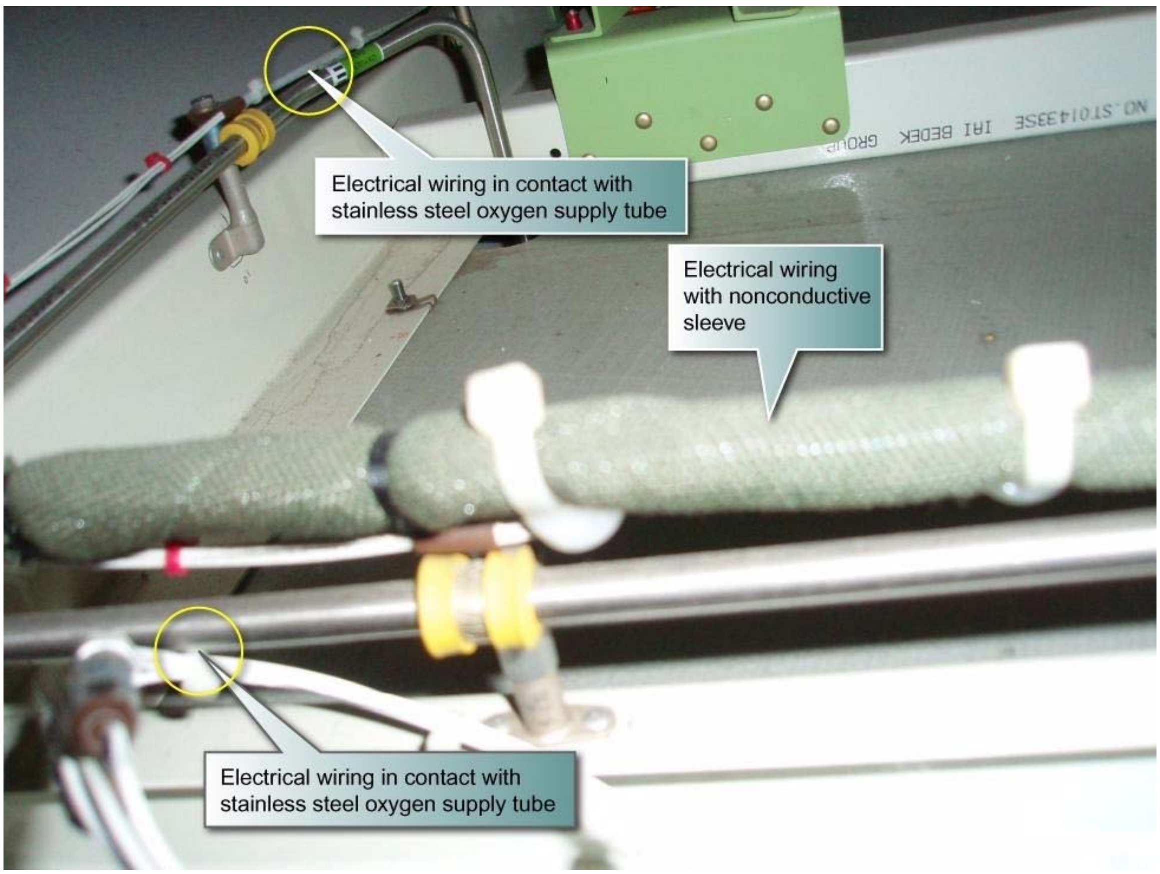

Figure 5. Proximity of Electrical Wiring to Oxygen System Tubing

Note: The wiring and tubing shown in the figure were not from the accident airplane but were instead from another 767 airplane in ABX Air's fleet.

It is important to note that Boeing had received previous reports of electrical energy causing leaks in oxygen hoses. Specifically, Boeing had received a report from a 737 operator (the date of which is unknown) and from a 757 operator (in August 1997) indicating that cockpit flexible oxygen hoses had developed leaks after an electrical current had shorted and heated the internal coil spring, causing the PVC hose material to melt and rupture. [Boeing's and the Federal Aviation Administration's (FAA) response to these reports are discussed in section 3.1.]

On the basis of these reports, as well as the results of the oxygen hose tests, the pop and hissing sounds heard by the flight crew, and the lack of highly combustible materials and ignition sources in the area, the NTSB concludes that the fire aboard the ABX Air airplane most likely began when a combustible and electrically conductive oxygen hose in the supernumerary compartment became energized by a short circuit, which caused the hose to ignite and burn through, and that the release of oxygen from the hose caused adjacent materials to ignite and burn at an accelerated rate.

The damaged areas in the cockpit and the main deck cargo compartment were the result of the fire spreading into those areas from the supernumerary compartment. Specifically, evidence indicated that the fire entered the cockpit from an aft location and worked its way forward and downward as the bulkhead separating the supernumerary compartment and the cockpit (along which flight control cables were vertically routed) was consumed. The evidence also indicated that the fire entered the main deck cargo compartment after the fire melted the aluminum strips that held together the smoke barrier wall above the supernumerary occupant seats.

2.2 Oxygen System Leaks

Maintenance records for the accident airplane showed that, between January 2007 and June 2008, the oxygen system was serviced 50 times for routine maintenance of the oxygen system and for reported discrepancies. During that time, maintenance personnel found the following four oxygen leaks:

- On September 27, 2007, a regulator for an oxygen bottle was leaking.[18] To resolve this issue, the regulator was replaced.
- On November 8, 2007, a hose fitting above a supernumerary occupant seat was leaking. To resolve this issue, the fitting was reset.
- On March 4, 2008, a fitting downstream of a pressure regulator was leaking. To resolve this issue, the fitting was tightened.
- On June 25, 2008, the adaptor from an oxygen bottle to a regulator was leaking. To resolve this issue, the adaptor was tightened.

Most of the 50 oxygen services occurred after the airplane's last C check on July 23, 2007, and maintenance records showed that the oxygen bottles needed frequent refills after that time. The NTSB was unable to determine from the available evidence whether any maintenance performed on or near the oxygen system during the C check disturbed the system's

[18] Maintenance records showed that ABX Air did not consistently distinguish between the cockpit and the supernumerary oxygen bottles as well as which bottle was the top and the bottom one. (The supernumerary bottle was positioned above the cockpit bottle.) After the accident, ABX Air installed placards on the bottles, and maintenance personnel were instructed to note the specific bottle that was being serviced.

components.[19] However, the repetitive servicing of the oxygen system and the amount of oxygen bottle refills after the C check indicated that the airplane most likely had a chronic oxygen leak, yet the location of an oxygen system leak was detected in only four system services. In addition, interviews with some company maintenance personnel indicated that they did not always record oxygen system servicing in the maintenance logbooks,[20] which was not in compliance with company procedures and further precluded the company from being completely aware of the maintenance performed on the system. The NTSB concludes that, although no evidence was found to indicate that previous oxygen system leaks contributed directly to the fire in the supernumerary compartment, oxygen leaks are a safety hazard because of their potential to facilitate a fire. ABX Air indicated that, since the time of the accident, oxygen system leaks have been fully documented, corrected, and tracked. However, ABX Air had a continuing analysis and surveillance program (CASP) that did not adequately resolve chronic discrepancies, including oxygen system leaks.[21] The company's CASP is discussed further in section 3.8.

2.3 Emergency Response

According to an emergency response event chronology created by SFO,[22] ARFF was notified of the ground fire about 2212:27, when the ground controller issued an Alert 3.[23] Twenty-two ARFF personnel from three airport firehouses responded to the accident, and one firefighter reported to a staging area where mutual aid firefighters from the city of San Francisco and San Mateo County responded.

The first ARFF vehicle (Rescue 49) arrived on scene by 2215:14 and was initially positioned at the nose of the airplane. A firefighter from this vehicle entered the cockpit (using the stairs that had been positioned at the left cockpit window during the captain's evacuation of the airplane), conducted an interior search of the cockpit, and located the fire in the supernumerary compartment. However, ARFF personnel could not immediately access the fire

[19] During the C check, the supplemental oxygen system was tested, and the mask regulators and hoses in the cockpit and supernumerary compartment were replaced, according to standard operating procedures. Maintenance records showed that the system check was normal and that no discrepancies resulted from this work. Also during the C check, galley light electrical wiring was changed, and a galley light modification was subsequently installed in March 2008. Galley light electrical wiring is run near oxygen system components, but no evidence indicated that galley light wiring contributed to this accident.

[20] One of these instances occurred during the predeparture check of the accident airplane, when a mechanic removed the supernumerary oxygen supply bottle from the airplane (because the pressure was reportedly between about 1,220 and 1,230 psig) and then reinstalled it after determining that no additional oxygen could be added to the bottle. According to the mechanic, the oxygen servicing bottle had the same pressure, so no additional oxygen could be transferred to the supply bottle. The mechanic stated that he did not enter this discrepancy into the maintenance logbook because no maintenance was conducted. Besides not entering this pertinent maintenance information, the mechanic should have checked the servicing bottle to make sure that it had usable oxygen available.

[21] Title 14 CFR 121.373 states that each certificate holder is to establish and maintain a system for the continuing analysis and surveillance of the performance and effectiveness of its inspection and maintenance programs. ABX Air's CASP is similar to other air carriers' continuing analysis and surveillance system programs.

[22] CVR transcript and SFO chronology times were not correlated.

[23] Alert 3 indicates that an aircraft has been involved in an accident on or near the airport.

because they were unable to open the L1 and R1 doors as a result of fire damage to the mechanisms that allowed the doors to travel upward.

Rescue 49 had a high-reach extendable turret (HRET) with a skin-penetrating nozzle (SPN). The HRET/SPN was visually positioned by the driver using controls in the cab of the vehicle.

The driver of Rescue 49 reported that he tried to insert the SPN through the right cockpit window but that the extinguishing agent had sprayed outside, rather than inside, the airplane. The firefighter also reported that he was unaware of this situation until other firefighters told him.

Once Rescue 49 was repositioned near the L1 door,[24] the driver used the SPN to apply extinguishing agent onto the fire through the burn-through areas above the supernumerary compartment. The SFO event chronology indicated that the fire was contained about 2241:04, about 25 minutes after the first ARFF vehicle had arrived. Once the fire was contained, ARFF personnel cut a hole in the fuselage and gained entry into the supernumerary compartment. The fire was extinguished about 2258:03, about 43 minutes after the first ARFF vehicle had arrived. The NTSB concludes that ARFF personnel extinguished the fire in a timely manner. The NTSB further concludes that the SPN was an effective tool in extinguishing the fire, especially because the forward doors were rendered inoperable by the fire and could not be used to gain access to the fire.

In its report on the February 7, 2006, United Parcel Service flight 1307 accident in Philadelphia, Pennsylvania, the NTSB stated that ARFF personnel who used the HRET/SPN during the emergency response experienced problems penetrating the fuselage with the device and had to reposition the tip of the SPN a few times before successfully piercing the airplane's fuselage.[25] The NTSB also stated that the FAA and the International Fire Service Training Association[26] had acknowledged the importance of HRET/SPN training but that the FAA's Advisory Circular (AC) 150/5210-17A, "Programs for Training of Aircraft Rescue and Firefighting Personnel," did not specifically address this training. The NTSB concluded that some ARFF personnel were not adequately trained on the use of this device, which reduced its

[24] Rescue 49 had been repositioned aft near the tail (for undetermined reasons) and then at the L1 door after the driver was notified by a firefighter that the vehicle was needed at that location.

[25] The NTSB's investigation found that ARFF personnel responding to a runway overrun accident in Teterboro, New Jersey, experienced similar problems. For more information, see National Transportation Safety Board, *Runway Overrun and Collision, Platinum Jet Management, LLC, Bombardier Challenger CL-600-1A11, N370V, Teterboro, New Jersey, February 2, 2005*, Aircraft Accident Report NTSB/AAR-06/04 (Washington, DC: NTSB, 2006).

[26] According to its website, this association identifies needed training materials for the fire service and related areas and fosters the development and validation of such training materials.

effectiveness in fighting interior aircraft fires.[27] As a result, on December 17, 2007, the NTSB issued Safety Recommendation A-07-100, which asked the FAA to do the following:

> Provide guidance to aircraft rescue and firefighting personnel on the best training methods to obtain and maintain proficiency with the high-reach extendable turret with skin-penetrating nozzle.

On September 8, 2008, the FAA stated that, in July 2008, it had issued a CertAlert[28] to all airport certification and safety inspectors and operators of Part 139 airports. According to the FAA, the CertAlert highlighted the availability of airport improvement program funding for training aids that would allow ARFF personnel to practice piercing an aircraft structure with an HRET/SPN. The FAA also stated that it would revise AC 150/5210-17A to highlight the importance of this training for ARFF personnel. The FAA expected to complete the revision by September 30, 2008. On February 4, 2009, the NTSB classified this recommendation "Open—Acceptable Response" pending the issuance of the revised AC.

The intent of Safety Recommendation A-07-100 was for the FAA to determine the best methods for ARFF personnel to train and maintain proficiency with the HRET/SPN. The FAA's response to this recommendation indicated that the best method would be training that allowed ARFF personnel to use the SPN to pierce an airplane structure. However, in March 2009, the FAA indicated that the AC recommending this training might be issued in August 2009, which is almost 1 year later than initially planned.

The driver of Rescue 49 stated that he received familiarization training on the use of the HRET/SPN when the vehicle was delivered to SFO (about 14 years before the accident occurred). He stated that he practiced using the SPN on cars and vans, indicating that the SPN required "lots of practice." Although the driver of Rescue 49 had an initial problem using the SPN, he was then able to successfully use the device to penetrate the fuselage skin near the burn-through area and extinguish the fire. However, it is important for firefighters to receive training that will enable them to quickly and successfully use the SPN in an emergency response. The NTSB concludes the type of training that the driver of Rescue 49 received on the operation of the HRET/SPN was not sufficient to allow him to successfully insert extinguishing agent into the cockpit on his initial attempts. The NTSB further concludes that ARFF personnel who are not sufficiently trained on the HRET/SPN may not be able to use the device effectively when fighting aircraft fires. Therefore, the NTSB reiterates Safety Recommendation A-07-100.

[27] National Transportation Safety Board, *Inflight Cargo Fire, United Parcel Service Company Flight 1307, McDonnell Douglas DC-8-71F, N748UP, Philadelphia, Pennsylvania, February 7, 2006*, Aircraft Accident Report NTSB/AAR-07/07 (Washington, DC: NTSB, 2007).

[28] According to the FAA's website, a CertAlert allows the FAA airports safety and operations division to quickly provide additional guidance on Part 139 certification and related issues to FAA inspectors and staff.

3. Safety Issues

3.1 Conductivity of Oxygen Hoses

After receiving reports that electrical energy (in one case, from a short circuit) had caused leaks in oxygen hoses installed on its airplanes, Boeing changed the design requirement for flexible hose assemblies and began installing nonconductive hoses on new-production airplanes. The nonconductive hoses included insulators that were installed between the internal coil spring and the fitting at each hose end. According to Boeing, the new hoses were designed to help prevent damage if they were subjected to an electrical current. The first 767 (the accident airplane model) with the new hose design was delivered in August 1999.

In addition, Boeing issued alert service bulletins (SBs) to operators of its 737, 747, 757, and 767 airplanes to replace existing oxygen hoses in the cockpit with the new nonconductive hoses. The SB for the accident airplane model, 767-35A0034, was issued in September 1999.[29] However, the FAA did not mandate compliance with the SBs, as discussed further in section 3.2. Although SB 767-35A0034 was not initially accomplished on the accident airplane,[30] after the accident, ABX Air accomplished the SB on all of its 767 airplanes. In addition, ABX Air replaced the oxygen hoses in the airplanes' supernumerary compartment with nonconductive hoses.

The manufacturer of the flexible oxygen hoses noted that the general hose design was based on military standards but that the lengths, diameters, and other features were established by the airplane manufacturer. The hose manufacturer also noted that, in addition to Boeing, conductive hoses were installed on airplanes manufactured by Bombardier, Douglas, Cessna, Gulfstream, Hawker, Embraer, and others.[31] The NTSB examined the conductive hoses in some of those airplane models and verified that the hose design was similar to that of Boeing.

The NTSB recognizes the logistical challenge of replacing all of the conductive oxygen hoses that are currently installed on airplanes. However, Boeing has already made nonconductive hoses available for its airplanes, and similar action by other airplane manufacturers would help prevent the circumstances of this accident from recurring. The NTSB's oxygen system hose tests demonstrated that the internal coil spring in the flexible hose assembly became an ignition source when the spring was electrically energized, causing it to heat up, and that the PVC hose material,

[29] Boeing SB 737-35A1053, 747-35A2101, and 757-35A0015 were issued for the other affected airplane models.

[30] Even though maintenance records showed that the SB had not been accomplished on the accident airplane, the NTSB found that three of the four oxygen hoses in the cockpit were the nonconductive hose type.

[31] Airbus had used conductive hoses from the same manufacturer but has since changed to a different hose design that replaces PVC with a material that is less permeable, thus eliminating PVC hose material that could act as a fuel.

when heated by the spring, would generate combustible gases as a result of a process known as pyrolysis.[32] As a result, the NTSB concludes that combustible oxygen hoses with an electrically nonconductive design would prevent the internal coil spring from becoming electrically energized, mitigating the possibility that the hoses would melt and ignite. Therefore, the NTSB recommends that the FAA require operators to replace electrically conductive combustible oxygen hoses with electrically nonconductive hoses so that the internal hose spring cannot be energized. Because Boeing continues to stock conductive hoses (they are still a certified part) and provide them to customers who request the original part number for the hose, and because other manufacturers may have the same practice, the NTSB further recommends that the FAA prohibit the use of electrically conductive combustible oxygen hoses unless the conductivity of the hose is an intentional and approved parameter in the design.

3.2 Airworthiness Directive Process

After manufacturers provide draft SBs to the FAA for approval, the FAA routinely uses the opportunity to create airworthiness directives (ADs) that require implementation of the SBs as a means for removing parts from service when those previously approved parts are found to be no longer airworthy. According to the FAA, ADs are legally enforceable rules to correct an unsafe condition in an aircraft, engine, propeller, or appliance.[33] However, the FAA's review of Boeing's SBs (recommending the replacement of conductive cockpit oxygen hoses with nonconductive ones) missed the importance of this safety issue for undetermined reasons and thus did not result in the issuance of ADs.

After the ABX Air accident, the FAA recognized the significance of this safety issue and began its rulemaking process. In June 2009, the FAA began issuing notices of proposed rulemaking for ADs that would require the use of nonconductive hoses in the cockpit for each of the affected Boeing airplane models in production.

Because the intent of an FAA AD and a manufacturer's SB is frequently the same, many ADs simply instruct airplane operators to comply with the provisions of a specific SB. As a result, this instruction would only address specific uses of an unsafe part. For example, the FAA's expected ADs on conductive oxygen hoses will only address specific part numbers in specific applications that Boeing cited in its SBs. However, the expected ADs will not likely address the same part numbers used in other applications, including a supplemental type certificate for a postmanufacture modification (as was the case with the accident airplane). Also, because the FAA planned to issue ADs for Boeing 737, 747, 757, and 767 models only, the ADs

[32] According to a guide for fire and explosion investigations by the National Fire Protection Association, pyrolysis is the chemical decomposition by heat of a compound into one or more other substances. In this case, the PVC had pyrolized, generating gaseous fuel inside the hose, which, when combined with the oxygen and the heated internal hose spring, resulted in a fire.

[33] According to 14 CFR 1.1, "General Definitions," an appliance is "any instrument, mechanism, equipment, part, apparatus, appurtenance, or accessory, including communications equipment, that is used or intended to be used in operating or controlling an aircraft in flight, is installed in or attached to the aircraft, and is not part of an airframe, engine, or propeller."

will not address oxygen hoses from the same hose manufacturer that have a similar electrically conductive design but are used by other airplane manufacturers and may have different part numbers.

Although Boeing's SB specified the replacement of the oxygen hoses only in the cockpit, this accident demonstrates that electrically conductive oxygen hoses in any airplane installation are a safety hazard. Because the design of the hose originated with a military specification that could be used by any manufacturer, and this hose manufacturer provides similar hoses to numerous airplane manufacturers, the problem with conductive hoses is not restricted to Boeing or even this particular hose manufacturer.

The hoses are examples of a part (that is, appliance) that is used by more than one airplane manufacturer. If the FAA can determine which airplane models include the part, multiple ADs can be issued against each of the airplane models at the same time. If the FAA were uncertain about the specific airplane models that might include the part, the FAA could then issue an AD citing the part manufacturer or the base model identifier from that manufacturer. For example, AD 94-06-04, which was an appliance AD issued against oxygen mask regulators, stated that the mask regulators were "installed on but not limited to" a list of multiple airplane models. The AD described the general series for the part along with empty brackets ("EROS series MF10-[ ]-[ ] full face quick donning mask regulators") to represent the various part numbers used by the different airplane manufacturers. In either case, the most effective way for the FAA to have parts that are no longer airworthy removed from service is to ensure that the AD process coordinates with part manufacturers as well as airplane manufacturers.

The accident airplane was approved to be converted from a passenger to a cargo configuration, and Israel Aerospace Industries (IAI) modified the accident airplane in 2004.[34] For this modification, IAI used a design that adapted original Boeing-numbered parts,[35] including the flexible hoses for the supernumerary supplemental oxygen system.[36] Because IAI is not a Boeing operator, it was not aware of Boeing's SB regarding the replacement of conductive oxygen hoses in the cockpit. Even if IAI had been so aware, the SB addressed only Boeing installations, and the supernumerary compartment had been a postmanufacture design

[34] In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the State of Israel, Ministry of Transport, Aviation Incidents and Accidents Investigation, participated in this investigation as the representative of the State of Design and Manufacture (Aircraft Modification). IAI participated in the investigation as a technical advisor to Israel's Aviation Incidents and Accidents Investigation office, as provided in Annex 13. Comments from Israel's Aviation Incidents and Accidents Investigation office on a draft of this report appear in appendix B.

[35] A review of ABX Air and IAI job cards related to the airplane conversion revealed no discrepancies. Because of the fire damage to the area, the NTSB could not determine whether the supernumerary compartment and its oxygen system were properly installed according to the job cards.

[36] Boeing records showed the sale of conductive hoses to IAI in 2003. IAI's search of purchasing records revealed that the last receipts for conductive-style hoses were from 2005, but these hoses might have been received directly from the hose manufacturer.

created by IAI.[37] However, airplane modifiers, including IAI, review pertinent ADs to ensure the airworthiness of all parts used in a postmanufacture modification. As a result, the NTSB concludes that it is likely that the modifier of the accident airplane would have recognized the use of a part that was potentially combustible before releasing the airplane to the operator if the FAA had issued an appliance AD that cited the part manufacturer as well as the airplane model. Therefore, the NTSB recommends that the FAA formalize the AD process so that, when an aircraft manufacturer or other source identifies an airworthiness issue with an appliance, coordination with the appliance manufacturer occurs to ensure that the possible safety risks to all products using the appliance are evaluated and addressed.

3.3 Proximity of Oxygen System Components to Electrical Wiring

Boeing guidance stated that oxygen installations should include a minimum of 2 inches between oxygen lines (that is, hoses and tubing) and electrical wiring. The guidance also advised securing the wiring so that it could not reach oxygen lines and installing the wiring beneath oxygen lines in case the wiring sagged over time. During postaccident inspections of other ABX Air 767 airplanes that were modified by IAI, some installations were found to have electrical wiring in proximity to the stainless steel oxygen supply tubing. Other installations (both in the cockpit and supernumerary compartment) were found to have electrical wiring that was routed above and in direct contact with the oxygen tubing, even though the supplemental type certificate provided for positive separation. This routing created the potential for electrical short circuits to reach the flexible oxygen hoses. (Figure 5 in section 2.1 shows electrical wiring in contact with the supply tubing located just above the ceiling in the supernumerary compartment.) The investigation of the fire aboard the accident airplane found that a short circuit from electrical wiring was the most likely source to energize the coil spring inside a supernumerary oxygen system hose, causing the hose material to ignite.

On January 15, 1998, the NTSB issued Safety Recommendations A-98-1 and -2 to the FAA as a result of an April 1997 in-flight fire aboard a Cessna Citation 650 airplane. The investigation found that the fire was caused by arcing between electrical wiring and a hydraulic tube, and postaccident inspections found wiring that interfered with oxygen hoses. Safety Recommendations A-98-1 and 2 asked the FAA to do the following:

> Review the design, manufacturing, and inspection procedures of aircraft manufacturers, and require revisions, as necessary, to ensure that adequate clearance is specified around electrical wiring, in accordance with published FAA guidelines. (A-98-1)

[37] After the accident, IAI representatives indicated that the company would be installing nonconductive hoses in future 767 conversions. Also, in September 2008, IAI issued SB 368-35-094, which recommended replacing conductive-style hoses in airplanes that IAI had previously modified. (ABX Air owned 18 of the 30 IAI-modified airplanes.)

> Review the existing designs of all transport-category airplanes to determine if adequate clearance is provided around electrical wiring, in accordance with published FAA guidelines. If deviations are found, require that modifications be made to ensure adequate clearance. (A-98-2)

The published FAA guidelines referred to in the recommendations were AC 43.13-1A, "Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair," and AC 65-15, "Airframe and Powerplant Mechanics Airframe Handbook." These guidelines stated that no electrical wire should be located within 1/2 inch of any combustible fluid or oxygen line and that, if the separation was less than 2 inches, back-to-back clamps or a polyethylene sleeve should be installed to ensure positive separation. On June 28, 2002, the NTSB stated that the FAA's actions fully addressed the recommendations.[38] As a result, the NTSB classified Safety Recommendations A-98-1 and -2 "Closed—Acceptable Action." However, these actions did not prevent the wiring problems that were found on the ABX Air airplanes. The NTSB was unable to determine whether the wiring problems were the result of the IAI design or ABX Air's maintenance.

The involvement of oxygen in a fire can significantly expedite its growth and severity. In its report on the May 11, 1996, accident involving Valujet Airlines flight 592, the NTSB determined that the accident was the result of an in-flight fire that began with the actuation of oxygen generators, which were being improperly carried as cargo. The NTSB's report on this accident stated, "the oxygen generators would have initially fed the fire with an abundance of oxygen … resulting in a very rapidly developing fire," which prevented the airplane from returning safely to land on the runway from which it had departed about 10 minutes earlier.[39] Also, in its report on the September 2, 1998, accident involving Swissair flight 111, which crashed into water while the pilots were attempting an emergency landing after detecting an in-flight fire, the Transportation Safety Board of Canada (TSB) found that an aluminum cap assembly used on an oxygen tube above the cockpit ceiling was susceptible to leaking or fracturing when exposed to the fire-related temperatures that were likely occurring in that area

[38] On April 3, 2002, the FAA stated that it conducted audits on wire separation installation practices used at Cessna, Boeing, Raytheon, and Learjet and did not find any systemic wire separation problems that would warrant review of existing designs of all transport-category airplanes. The FAA also stated that it produced two training aids to increase awareness of wire installation and separation requirements and address wiring maintenance practices. In addition, the FAA stated that it published a policy statement in the *Federal Register* that addressed wire installation drawings, safety analyses of wiring and wire bundles, and continued airworthiness considerations for wiring. The FAA further stated that it had initiated a program to enhance wire system safety through better design, inspection, maintenance, and training. Last, the FAA indicated that it was proposing improved wire separation design and instructions for continuing airworthiness requirements.

[39] National Transportation Safety Board, *In-Flight Fire and Impact With Terrain, Valujet Airlines Flight 592, DC-9-32, N904VJ, Everglades, Near Miami, Florida, May 11, 1996,* Aircraft Accident Report NTSB/AAR-97-06 (Washington, DC: NTSB, 1997).

during the last few minutes of the flight. The TSB stated that it could not determine whether leaking or fracturing had occurred but that such a failure would have exacerbated the fire.[40]

The energy in a short circuit could perforate the rigid stainless steel supply tubing and become an ignition energy source or allow oxygen to reach other fuel and ignition sources. The NTSB concludes that protecting oxygen system tubing from inadvertent short circuits is important because of the proximity between the tubing and electrical wiring in a compressed area as well as the potential severity of a fire involving oxygen. Because the general wire routing guidelines in AC 43.13-1A and AC 65-15 were advisory only and specific installations can deviate from airplane manufacturer wiring guidance, the NTSB recommends that the FAA require airplane manufacturers, modifiers, and maintenance personnel to provide positive separation between electrical wiring and oxygen system tubing according to, at a minimum, the guidance in AC 43.13-1A and AC 65-15. The NTSB further recommends that the FAA require airplane manufacturers and operators to ensure that oxygen system tubing in proximity to electrical wiring is made of, sleeved with, or coated with nonconductive material or that the tubing is otherwise physically isolated from potential electrical sources.

3.4 Electrical Grounding of Oxygen System

Examination of the supplemental oxygen system found that it was supported by rubber clamps so that the system was grounded to the airplane structure through the PVC flexible hoses and a stainless steel convoluted oxygen hose[41] that was routed to an overpressure port. Although the convoluted oxygen hose and its fittings were metal, they were not designed or evaluated to be a potential ground path for the electrical wiring that was routed nearby. However, the investigation determined that the path of least resistance between the supplemental oxygen system and the airplane structure was through the hoses.

Title 14 CFR 25.1441, "Oxygen Equipment and Supply," paragraph (b), states that an oxygen system must be free from hazards in itself. However, the existing method of grounding the oxygen system could allow inadvertent contact from adjacent electrical wiring to energize oxygen system components.

Specific electrical grounding requirements would ensure that an electrical current has a path for reaching airplane structure without energizing oxygen system components. These requirements could include the use of electrical ground straps, which generally consist of a braided wire with an eyelet at each end; one eyelet is connected to a system component, and the other is connected to the airplane structure. (These straps are commonly used to electrically bond numerous flight control and fuel control system components to an airplane structure.) Ground straps would also provide redundancy in case the method used to physically isolate electrical and

[40] Transportation Safety Board of Canada, *In-Flight Fire Leading to Collision with Water, Swissair Transport Limited, McDonnell Douglas MD-11, HB-IWF, Peggy's Cove, Nova Scotia 5 nm SW, 2 September 1998*, Aviation Investigation Report A98H0003 (Quebec, Canada: TSB, 2003).

[41] Convoluted hoses have ridges or folds (similar to a vacuum cleaner hose).

oxygen system components experiences a fault or if the design requirements for the isolation of oxygen system components become compromised after in-service modifications and maintenance.

No electrical ground straps were found in the cockpit and the supernumerary compartment oxygen system installations and near the oxygen supply bottles (below the cockpit) on the ABX Air 767 airplanes that were examined. (It is important to note that the cockpit was an original airplane installation and was not part of the airplane's modification to a cargo configuration.) If ground straps had been installed on the accident airplane, the short circuit that energized the supernumerary oxygen hose internal spring might have been directed away from the spring. Because undesirable potential electrical ground paths exist with the current grounding method for the 767 oxygen system components, electrical ground straps or another method of electrical grounding would help protect system components. Other Boeing airplane models and other manufacturers' airplanes may have similar undesirable potential electrical ground paths because the design of their oxygen system is similar to that of the Boeing 767 oxygen system.

The NTSB concludes that an effective method of electrically grounding the supplemental oxygen system to the airframe would help ensure that oxygen system components are protected from short circuits. Therefore, the NTSB recommends that the FAA develop minimum electrical grounding requirements for oxygen system components and include these requirements as part of the certification process for new airplanes and approved supplemental type certificate modifications to existing airplanes. The NTSB further recommends that, once electrical grounding requirements for oxygen system components are developed, as requested in Safety Recommendation A-09-48, the FAA require airplane operators and modifiers to inspect their airplanes for compliance with these criteria and modify those airplanes not in compliance accordingly.

3.5 Aging Oxygen Hoses

The investigation of this accident determined that no life limits were established for supplemental oxygen system hoses and that some hoses had been in service for more than 40 years. The hoses on the accident airplane were consumed by the fire, so no evidence was available to show whether an aging hose contributed to the fire. Examination of supplemental oxygen system hoses on other ABX Air 767 airplanes found that older hoses were stiffer than newer ones. It is likely that the older and stiffer hoses would be more prone to cracking than the newer and more flexible hoses. Also, cracked hoses can lead to oxygen leaks.

Because the hoses are common to several airplane manufacturer models, it is possible for an operator to remove an aging hose from an older in-service airplane and install the hose on a newer airplane, including one that has been newly delivered. However, oxygen system hoses are inspected only as part of general maintenance inspections; there are no detailed hose inspections or tests for plastic parts that have been in service for long periods. Oxygen hose inspections are also important because the PVC hose material can be degraded over time by pressure, temperature, light, and some chemicals used in normal airplane maintenance and operations (including cleaning agents, hydraulic fluid, oils, and greases).

The NTSB concludes that, because aging PVC flexible hoses are more likely than newer hoses to be cracked or otherwise degraded, aging hoses are more likely to leak oxygen, which, along with an ignition source, could result in a fire. As a result, the NTSB recommends that the FAA develop inspection criteria or service life limits for flexible oxygen hoses to ensure that they meet current certification and design standards. The NTSB further recommends that, once inspection criteria or service life limits for flexible oxygen hoses have been developed, as requested in Safety Recommendation A-09-50, the FAA require airplane operators to replace those hoses that do not meet the inspection criteria or that exceed the service life limits.

3.6 Potential for Reading Lights to Become Ignition Source

Passenger service unit (PSU) assemblies were installed in the supernumerary compartment of ABX Air's 767 airplanes. The PSU assemblies included reading lights and their electrical push-button switches,[42] which were typically installed near the supplemental oxygen system.[43]

During the investigation of this accident, ABX Air found that the sockets containing the reading lights could be rotated so that the grounded socket housings could touch the electrical contacts for the switches. To prevent such contact from occurring, the manufacturer of the lights provided rubber boots for the switch assembly and the lighting socket assembly. These boots isolated the electrical parts of the light assembly. However, many of the rubber boots were missing from the ABX Air 767 airplanes that were examined as part of this investigation. The rubber boots are reportedly difficult to install, so it is possible that the boots were not put on the assemblies during the cargo conversion or that the boots were taken off but not properly put back on the assemblies during maintenance.

A PSU reading light without rubber boot protection has the potential to short circuit, causing sparks. In fact, during this investigation, ABX Air personnel demonstrated that visible sparks could be produced when the electrical components of the light assembly contacted each other.[44] Such a spark could ignite a combustible material, such as lint accumulations or, with minor oxygen leakage, the PVC material of a supplemental oxygen system hose.

The PSU reading lights can be eliminated as a possible cause for the fire aboard the accident airplane for two reasons. First, the first officer had turned off the PSU lights, thus eliminating a potential ignition source. Second, the flight crew heard a loud popping noise before

[42] The PSU assemblies also included a gasper (fresh air vent) assembly.

[43] Many transport-category passenger airplanes have oxygen generators, so the electrical parts of the PSU assembly are not installed near a source of gaseous oxygen.

[44] In other installations, it is also possible for the lights to be rotated until their electrical components contact grounded structure.

discovering the fire, and the NTSB's oxygen hose tests (see section 2.1) showed that an external ignition source, which would include a spark from a PSU light, did not produce a popping sound once the hose was ignited, as did the internal ignition source. However, any spark in the enclosure above the supernumerary occupant seats, whether the result of an internal or external ignition source, could be generated in an oxygen-rich environment if a concurrent oxygen leak existed, creating a safety hazard.

Both IAI and ABX Air took action to correct the lack of rubber boots for the PSU reading lights. The companies' efforts focused initially on inspections to ensure that the boots were in place. However, in February 2009, IAI issued SB 368-25-025 to allow operators the option of using common heat-shrinkable tubing to cover the electrical contacts.

Although the PSU reading light assemblies on the ABX Air airplanes had a specific part number from the PSU manufacturer, the light assemblies were similar to those that are found in the passenger cabin of some transport-category airplanes or the supernumerary compartment of other cargo airplanes. The NTSB concludes that PSU reading lights with exposed electrical contacts have the potential to move to positions that create inadvertent short circuits and produce sparks near combustible materials. Therefore, the NTSB recommends that the FAA require transport-category airplane operators to (1) perform a one-time inspection of all PSU reading lights installed on their airplanes to ensure that they include rubber boots or use other means to isolate the electrical parts of the assembly and (2) include, in maintenance manuals or other maintenance documentation, information about the importance of this electrical protection.

3.7 Smoke Detection System

No smoke detection system was present in, or required for, the supernumerary compartment. Given that the flight crew was alerted to the fire by the loud pop and hissing sounds, the rate at which the fire developed, and the intensity of the fire, a smoke detector would not have helped prevent the fire damage that occurred during this accident. However, in other situations, a smoke detector could alert flight crewmembers of a fire and allow them to address it while the fire was still at a stage at which it could be suppressed. For example, smoke detectors would alert a flight crew to a smoldering fire, which would produce smoke for a prolonged period of time before generating flames. This type of fire could originate in electrical devices, such as a coffee maker, within the supernumerary compartment.

Passenger cabins are regularly occupied areas that do not have smoke detectors. As such, flight crewmembers of these transport-category airplanes rely on the passengers and flight attendants to report any smoke in the cabin. For transport-category cargo airplanes, smoke detectors were required in the lavatory and the cargo compartments.[45] However, because the

[45] See 14 CFR 25.854, "Lavatory Fire Protection," and 14 CFR 25.858, "Cargo or Baggage Compartment Smoke or Fire Detection Systems."

supernumerary compartment is not a regularly occupied area, a smoke detector in the compartment would provide additional safety for cargo operations.

Even though a smoke detector was required for the lavatory, the door to the lavatory is usually closed. As a result, the detection of smoke emanating from elsewhere in the supernumerary compartment would be delayed, especially if no one were occupying the supernumerary seats (as was the case with this accident). The NTSB recognizes the possibility for a smoke detector to produce a false alarm. However, if this situation were to occur and the supernumerary compartment were unoccupied, the false alarm could easily be detected by the nonflying pilot.

In its report on the Swissair flight 111 accident, the TSB concluded that the fire started above the ceiling on the right side of the cockpit near the cockpit rear wall and that the fire "spread and intensified rapidly to the extent that it degraded aircraft systems and the cockpit environment, and ultimately led to the loss of control of the aircraft." The report also concluded, in part, that no built-in smoke detection devices were in the area where the fire started and that the lack of such devices delayed the identification of the existence of the fire.[46] However, unlike the Swissair pilots, who could not access the location where the fire initiated, pilots of cargo airplanes can access the supernumerary compartment; as a result, they could detect and extinguish a smoldering-type fire if they were provided with a warning of the fire's existence.

After the accident, ABX Air initiated efforts to install a smoke detector in the supernumerary compartment of its airplanes. (The project is still ongoing.) The NTSB concludes that installing smoke detectors in supernumerary compartments would help flight crews identify the existence of a fire in an accessible, possibly unoccupied space and initiate suppression of the fire before it could propagate and become uncontrollable. Some cargo airplanes have an area between the cockpit and the main deck cargo compartment that is similar to the one in the accident airplane but is not specifically referred to as a supernumerary compartment by the operator. Therefore, the NTSB recommends that the FAA require operators of transport-category cargo airplanes to install smoke detectors in the supernumerary or similar compartment of their airplanes.

3.8 ABX Air's Continuing Analysis and Surveillance Program

ABX Air's CASP provided surveillance and analysis of the company's continuous airworthiness maintenance program (CAMP). The CASP had two program components: quality assurance and reliability. The reliability program component included trend analysis. As part of this program, ABX Air's reliability department issued company advisory notices, via e-mail, to alert maintenance control personnel of repetitive airplane discrepancies. These notices were

[46] According to the Swissair flight 111 report, after the accident, Swissair and its maintenance provider performed a study that focused on minimizing the vulnerability of the MD-11 to an in-flight fire by developing an early warning smoke detection system. The study resulted in a modification program that installed smoke detectors in the avionics compartment, the cockpit overhead area, and the first-class galley overhead zone of the MD-11.

generated when three defects were noted within 15 days, five defects were found within 30 days, or one or more defects were found within 2 days of a notice's closing date. Maintenance records showed that four company advisory notices were issued—in September and November 2007 and February and April 2008—for the accident airplane's oxygen system.

To resolve repetitive aircraft discrepancies identified by advisory notices, ABX Air's reliability department held weekly meetings with other company aircraft maintenance departments and usually a member of the FAA principal maintenance inspector's (PMI) staff. At these meetings, personnel reviewed the notices; discussed previous and current corrective actions; and, if warranted, identified a more in-depth action plan to correct a chronic discrepancy. A review of the notes from the meetings during which the four advisory notices were discussed revealed that the oxygen system discrepancies on the accident airplane were being tracked and discussed but that some discrepancies listed no specific action items to resolve them. The NTSB is concerned that, even with four advisory notices within 7 months for the accident airplane's oxygen system, ABX Air did not develop a specific action plan for fully resolving repetitive maintenance issues on the accident airplane.

As part of the reliability department's weekly meetings, ABX Air would determine if any chronic issues were affecting the airplanes in its fleet based on the advisory notices that had been issued during a rolling 3-month period. This approach, however, did not allow ABX Air to adequately track all of the oxygen-related discrepancies on the accident airplane because the advisory notices issued in September and November 2007 were not considered with the advisory notices issued in February and April 2008. Although the September and November 2007 advisory notices were reviewed as part of the same rolling 3-month review period, as were the February and April 2008 advisory notices, the number of discrepancies considered during those separate reviews did not result in the airplane being taken out of service because of a chronic problem. However, it is possible that ABX Air could have recognized a chronic problem with the oxygen system if the company had considered the total number of discrepancies that had accumulated, and the number of advisory notices that were issued, during the 7-month period from September 2007 to April 2008.

On June 25, 1990, the NTSB issued Safety Recommendations A-90-98 and -99 after an October 1989 ground fire aboard Delta Air Lines flight 1558, a Boeing 727 that had been parked at the gate at Salt Lake City International Airport, Salt Lake City, Utah. At the time of the fire, a mechanic had been servicing the passenger oxygen system. Safety Recommendations A-90-98 and -99 asked the FAA to do the following:

> Review airline maintenance-related trend-analysis programs to verify that such programs can detect leaking oxygen systems. (A-90-98)

> Require air carriers to perform a one-time inspection of the oxygen systems on their airplanes and promptly repair all leaks. (A-90-99)

On August 17, 1992, the FAA stated that it issued Notice 8300.85, "Servicing and Maintaining Oxygen Systems on Air Carrier Aircraft While Passengers Are Aboard." The notice asked PMIs to ensure that each operator had structured its maintenance program so that the program is able to detect leaks in aircraft oxygen systems. The notice also called for the time between oxygen system inspection intervals to be decreased or for the performance of a one-time inspection of oxygen systems. In addition, the notice required PMIs to ensure that each operator's FAA-approved CAMP was structured to detect and repair leaking oxygen systems on a continuing rather than a singular basis. On March 4, 1993, the NTSB classified Safety Recommendation A-90-98 "Closed—Acceptable Action" and Safety Recommendation A-90-99 "Closed—Acceptable Alternate Action."

FAA Notice 8300.85 expired after 1 year. Nevertheless, an air carrier's CAMP should continuously detect and repair leaks on airplane oxygen systems, and a carrier's continuing analysis and surveillance system program should effectively analyze maintenance trends to ensure, among other things, that repetitive oxygen leaks are not occurring. However, the procedures in place for ABX Air's CASP at the time of the accident recognized only those maintenance problems that had recurred within a specific 3-month period. ABX Air stated that it now reviews 12 months, rather than 3 months, of discrepancies to determine if any chronic issues are affecting the airplanes in its fleet.

ABX Air had 42 Boeing 767 airplanes (including the accident airplane) in its fleet, 16 of which needed oxygen system servicing (for routine maintenance of the oxygen system and for reported discrepancies) during the 6-month period from January to June 2008. A review of the maintenance records for each of these 16 airplanes showed that the accident airplane had about three times more oxygen system service discrepancies than the airplane with the next highest amount (23 versus 8, respectively). The NTSB concludes that the number of reported discrepancies regarding the accident airplane's oxygen system was excessive and indicative of a chronic problem with the system, yet ABX Air's CASP did not include adequate actions for resolving the discrepancies and preventing additional oxygen leaks from occurring. Therefore, the NTSB recommends that ABX Air modify its CASP so that all identified chronic discrepancies, such as those affecting the oxygen system on the accident airplane, are effectively resolved.

4. Conclusions

4.1 Findings

1. The pop and hissing sounds heard by the flight crew immediately before the fire was discovered were consistent with the ignition of an oxygen hose by an internal rather than external heat source.

2. The design of the oxygen hose assembly allowed the internal spring to become a source of ignition when it was electrically energized, the polyvinyl chloride hose material to act as a fuel, and the oxygen within the hose to promote burning.

3. The fire aboard the ABX Air airplane most likely began when a combustible and electrically conductive oxygen hose in the supernumerary compartment became energized by a short circuit, which caused the hose to ignite and burn through, and the release of oxygen from the hose caused adjacent materials to ignite and burn at an accelerated rate.

4. Although no evidence was found to indicate that previous oxygen system leaks contributed directly to the fire in the supernumerary compartment, oxygen leaks are a safety hazard because of their potential to facilitate a fire.

5. Aircraft rescue and firefighting personnel extinguished the fire in a timely manner.

6. The skin-penetrating nozzle was an effective tool in extinguishing the fire, especially because the forward doors were rendered inoperable by the fire and could not be used to gain access to the fire.

7. The type of training that the driver of Rescue 49 received on the operation of the high-reach extendable turret with skin-penetrating nozzle was not sufficient to allow him to successfully insert extinguishing agent into the cockpit on his initial attempts.

8. Aircraft rescue and firefighting personnel who are not sufficiently trained on the high-reach extendable turret with skin-penetrating nozzle may not be able to use the device effectively when fighting aircraft fires.

9. Combustible oxygen hoses with an electrically nonconductive design would prevent the internal coil spring from becoming electrically energized, mitigating the possibility that the hoses would melt and ignite.

10. It is likely that the modifier of the accident airplane would have recognized the use of a part that was potentially combustible before releasing the airplane to the operator if the Federal Aviation Administration had issued an appliance airworthiness directive that cited the part manufacturer as well as the airplane model.

11. Protecting oxygen system tubing from inadvertent short circuits is important because of the proximity between the tubing and electrical wiring in a compressed area as well as the potential severity of a fire involving oxygen.

12. An effective method of electrically grounding the supplemental oxygen system to the airframe would help ensure that oxygen system components are protected from short circuits.

13. Because aging polyvinyl chloride flexible hoses are more likely than newer hoses to be cracked or otherwise degraded, aging hoses are more likely to leak oxygen, which, along with an ignition source, could result in a fire.

14. Passenger service unit reading lights with exposed electrical contacts have the potential to move to positions that create inadvertent short circuits and produce sparks near combustible materials.

15. Installing smoke detectors in supernumerary compartments would help flight crews identify the existence of a fire in an accessible, possibly unoccupied space and initiate suppression of the fire before it could propagate and become uncontrollable.

16. The number of reported discrepancies regarding the accident airplane's oxygen system was excessive and indicative of a chronic problem with the system, yet ABX Air's continuing analysis and surveillance program did not include adequate actions for resolving the discrepancies and preventing additional oxygen leaks from occurring.

4.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the design of the supplemental oxygen system hoses and the lack of positive separation between electrical wiring and electrically conductive oxygen system components. The lack of positive separation allowed a short circuit to breach a combustible oxygen hose, release oxygen, and initiate a fire in the supernumerary compartment that rapidly spread to other areas. Contributing to this accident was the Federal Aviation Administration's failure to require the installation of nonconductive oxygen hoses after the safety issue concerning conductive hoses was initially identified by Boeing.

5. Recommendations

5.1 New Recommendations

As a result of the investigation of this accident, the National Transportation Safety Board recommends the following:

To the Federal Aviation Administration:

Require operators to replace electrically conductive combustible oxygen hoses with electrically nonconductive hoses so that the internal hose spring cannot be energized. (A-09-43)

Prohibit the use of electrically conductive combustible oxygen hoses unless the conductivity of the hose is an intentional and approved parameter in the design. (A-09-44)

Formalize the airworthiness directive process so that, when an aircraft manufacturer or other source identifies an airworthiness issue with an appliance, coordination with the appliance manufacturer occurs to ensure that the possible safety risks to all products using the appliance are evaluated and addressed. (A-09-45)

Require airplane manufacturers, modifiers, and maintenance personnel to provide positive separation between electrical wiring and oxygen system tubing according to, at a minimum, the guidance in Advisory Circular (AC) 43.13-1A, "Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair," and AC 65-15, "Airframe and Powerplant Mechanics Airframe Handbook." (A-09-46)

Require airplane manufacturers and operators to ensure that oxygen system tubing in proximity to electrical wiring is made of, sleeved with, or coated with nonconductive material or that the tubing is otherwise physically isolated from potential electrical sources. (A-09-47)

Develop minimum electrical grounding requirements for oxygen system components and include these requirements as part of the certification process for new airplanes and approved supplemental type certificate modifications to existing airplanes. (A-09-48)

> Once electrical grounding requirements for oxygen system components are developed, as requested in Safety Recommendation A-09-48, require airplane operators and modifiers to inspect their airplanes for compliance with these criteria and modify those airplanes not in compliance accordingly. (A-09-49)

> Develop inspection criteria or service life limits for flexible oxygen hoses to ensure that they meet current certification and design standards. (A-09-50)

> Once inspection criteria or service life limits for flexible oxygen hoses have been developed, as requested in Safety Recommendation A-09-50, require airplane operators to replace those hoses that do not meet the inspection criteria or that exceed the service life limits. (A-09-51)

> Require transport-category airplane operators to (1) perform a one-time inspection of all passenger service unit reading lights installed on their airplanes to ensure that they include rubber boots or use other means to isolate the electrical parts of the assembly and (2) include, in maintenance manuals or other maintenance documentation, information about the importance of this electrical protection. (A-09-52)

> Require operators of transport-category cargo airplanes to install smoke detectors in the supernumerary or similar compartment of their airplanes. (A-09-53)

To ABX Air:

> Modify your continuing analysis and surveillance program so that all identified chronic discrepancies, such as those affecting the oxygen system on the accident airplane, are effectively resolved. (A-09-54)

5.2 Previously Issued Recommendation Reiterated in This Report

The National Transportation Safety Board reiterates the following recommendation to the Federal Aviation Administration:

> Provide guidance to aircraft rescue and firefighting personnel on the best training methods to obtain and maintain proficiency with the high-reach extendable turret with skin-penetrating nozzle. (A-07-100)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

MARK V. ROSENKER
Acting Chairman

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Member

DEBORAH A. P. HERSMAN
Member

ROBERT L. SUMWALT
Member

Adopted: June 30, 2009

6. Appendixes

Appendix A

Cockpit Voice Recorder

The following is the transcript of the L-3 Communications FA2100-1020 cockpit voice recorder, serial number 000204038, installed on ABX Air flight 1611, a Boeing 767-200, N799AX, which experienced a ground fire before engine startup at San Francisco International Airport, San Francisco, California, on June 28, 2008:

LEGEND

CAM	Cockpit area microphone voice or sound source
CLD	Radio transmission from the San Francisco clearance delivery
HOT	Flight crew audio panel voice or sound source
RDO	Radio transmissions from N799AX
GND	Radio transmission from the San Francisco ground controller
-1	Voice identified as the captain (CAPT)
-2	Voice identified as the first officer (FO)
-3	Voice identified as a ground crew person
-4	Voice identified as a ground crew person
-?	Voice unidentified
*	Unintelligible word
#	Expletive
@	Non-pertinent word

( )	Questionable insertion
[ ]	Editorial insertion

Note 1: Times are expressed in pacific daylight time (PDT).

Note 2: Generally, only radio transmissions to and from the accident aircraft were transcribed.

Note 3: Words shown with excess vowels, letters, or drawn out syllables are a phonetic representation of the words as spoken.

Note 4: A non-pertinent word, where noted, refers to a word not directly related to the operation, control or condition of the aircraft.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
20:07:17.0	[start of recording]		
21:02:25.4	[start of transcript]		
21:02:25.4 **CAM-3**	no paperwork (yet)?		
21:02:27.5 **CAM-4**	yeah I got it already.		
21:02:29.6 **CAM-3**	* * * * * downstairs?		
21:02:31.6 **CAM-4**	(yup).		
21:02:38.1 **CAM-4**	(yeah) they got it [sound similar to throat clearing].		
21:02:53.8 **CAM-3**	oh #, look at that.		
21:02:57.8 **CAM-4**	what.		
21:02:58.4 **CAM-3**	look at the oxygen.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
21:02:59.8 **CAM-4**	oh on the passengers?		
21:03:01.0 **CAM-3**	yeah.		
21:03:03.6 **CAM-4**	* like (reading) like nine hundred or something.		
21:03:06.3 **CAM-3**	it's eleven something.		
21:03:08.2 **CAM-4**	on ah, I pulled out the MEL on that.		
21:03:11.6 **CAM-3**	pull it out?		
21:03:24.2 **CAM-3**	like eleven ten, I can't believe they didn't # get that this morning.		
21:03:34.9 **CAM-3**	I mean I can pull it and service it you have a key to that, service shed over there?		
21:03:42.8 **CAM-4**	(on the ah).		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
21:03:56.6 **CAM-4**	where do you get that figure?		
21:04:04.7 **CAM-3**	'cause I know the service check * * it's low it's too (low).		
21:04:07.4 **CAM-4**	well the service check is higher than, the dispatch.		
21:04:12.5 **CAM-3**	yeah but it should have been done if there was a service check.		
21:04:14.7 **CAM-4**	why I I agree but.		
21:04:20.4 **CAM-3**	I don't know you think we should chance it or you think I should just service it?		
21:04:28.0 **CAM-4**	you think they're gonna *?		
21:04:29.4 **CAM-3**	yeah * *.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
21:04:30.1 **CAM-4**	'cause I heard 'em say before that if it's (in) I mean like nine hundred or somethin'. but.		
21:04:37.7 **CAM-4**	I'm a crew using oxygen I mean it's.		
21:04:43.5 **CAM-4**	post flyin' was operative.		
21:04:47.2 **CAM-4**	I mean as low as look at that it can even be much lower if you assume if you assume six crew members at fifty degrees Centigrade nine hundred and thirty nine and that's that's the most that's the highest requirement.		
21:05:03.4 **CAM-3**	yeah I just know per the service check it's too low.		
21:05:08.5 **CAM-4**	yeah 'cause they're not ga- they want you to get (it) well above that.		
21:05:15.7 **CAM-3**	it's up to you if wanna do it.		
21:05:20.9 **CAM-4**	[unintelligible vocalizations].		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
21:05:30.6 **CAM-3**	I'm gonna service it you have a key to that shed though?		
21:05:34.5 **CAM-4**	(I think it's) on the ah.		
21:19:04.2 **CAM-?**	* * (good).		
21:19:20.0 **HOT**	[electronic transient].		
21:20:47.1 **CAM**	[sound similar to electronic warning siren].		
21:20:57.5 **CAM-?**	[unintelligible vocalizations].		
21:44:48.3 **CAM-2**	kid sittin' out there on the tug said that he was under the impression that we make ah we only work three days a week.		
21:44:56.9 **CAM-1**	what?		
21:44:57.8 **CAM-2**	yup.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
21:45:00.5 **CAM-2**	he he had the salary basically right.		
21:45:06.6 **CAM-1**	hah.		
21:45:06.8 **CAM-2**	yeah he and he said your first year you probably make eighty grand, right?		
21:45:10.4 **CAM-2**	I said no your first year most places you make between twenty six and thirty four.		
21:45:17.5 **CAM-2**	and ah he, couldn't believe that.		
21:45:20.5 **CAM-1**	ah huh.		
21:45:23.7 **CAM-2**	said well believe it.		
21:45:33.9 **CAM-2**	do you have these in align? * * *.		
21:45:35.7 **CAM-1**	no no no I want 'em, there.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
21:45:36.9 **CAM-2**	oh okay.		
21:45:37.8 **CAM-1**	ahh it's I tried do a quick align and now it's not takin' the ah I guess I have to actu- oh okay I guess I have to put it in here where this is plot eleven here isn't it? * plot eleven or twelve?		
21:45:49.7 **CAM-2**	ah I believe yeah yeah.		
21:45:50.7 **CAM-1**	I think it's eleven.		
21:45:52.1 **CAM-2**	* *.		
21:45:52.4 **CAM-1**	you know if we're off.		
21:45:53.4 **CAM-2**	it is it is eleven.		
21:45:54.6 **CAM-1**	ah okay.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
21:45:57.3 **CAM**	glide slope pull up wind shear wind shear wind shear terrain ahead pull up [electronic voice].		
21:46:11.4 **CAM-1**	there we go.		
21:46:22.4 **CAM**	[sound similar to stick shaker].		
21:46:42.5 **CAM-2**	you want water @?		
21:46:44.0 **CAM-1**	yeah put it on thanks.		
21:47:01.5 **CAM-2**	* * * flight kit.		
21:47:03.8 **CAM-1**	thank you.		
21:47:04.6 **CAM-2**	* * * on.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
21:47:13.4 **CAM-1**	well you know these guys are jealous from their perspective they're bustin' their #. you know sweatin' loadin' this airplane and they see us sittin' up here in our shirt and tie.		
21:47:21.5 **CAM-2**	sure.		
21:47:22.1 **CAM-1**	readin' the paper and drinkin coffee.		
21:47:23.9 **CAM-2**	yeah.		
21:47:28.0 **CAM-2**	heck yeah.		
21:47:32.8 **CAM-1**	laying around all day in luxurious hotels.		
21:47:35.1 **CAM-2**	oh yeah.		
21:47:35.9 **CAM-1**	yeah and I would say and your point is?		
21:47:37.6 **CAM-2**	ah hah hah that's right.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
21:47:40.0 **CAM-1**	got that part right.		
21:47:43.4 **CAM-1**	(I know) * * * *.		
21:47:46.1 **CAM-2**	ah * it depends on the hotel.		
21:47:47.6 **CAM-1**	ah well this one's not bad.		
21:47:51.5 **CAM-1**	I've seen worse.		
21:48:01.0 **CAM**	San Francisco International Airport information Quebec zero three five six Zulu wind two niner zero at one zero visibility one zero few clouds at one thousand ceiling one five thousand broken temperature one four dew point one one altimeter three zero zero zero simultaneous charted visual flight procedures in use arrivals expect runways two eight left two eight right departing runways one left one right read back of all runway holding instructions is required advise on initial contact you have information Quebec.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
21:49:01.7 **CAM**	[unintelligible voices].		
21:50:47.2 **HOT**	[sound similar to fire warning test bell].		
21:51:45.1 **CAM**	TCAS systems test okay [electronic voice].		
		21:53:10.3 **RDO-1**	clearance ABEX ah sixteen eleven heavy to Wilmington Ohio with Quebec.
		21:53:18.2 **CLD**	ABEX sixteen eleven heavy San Francisco clearance good evening cleared to the Wilmington airport the Quiet Two departure ah Linden transition direct PEONS intersection direct INSLO intersection as filed maintain one five thousand expect flight level three seven zero ten minutes after departure, departure frequency will be one three five point one squawk three two five seven.
		21:53:47.3 **RDO-1**	okay ABEX sixteen eleven heavy cleared to Wilmington Quiet Two Linden PEONS INSLO as filed maintain one five thousand expect three seven oh in ten minutes one three five decimal one squawk three two five seven.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		21:53:59.6 **CLD**	ABEX sixteen eleven heavy your readback correct good night.
		21:54:03.5 **RDO-1**	*.
21:54:08.9 **CAM-1**	alright.		
21:54:24.3 **CAM-1**	okay we can figure one left.		
21:54:48.0 **CAM-?**	* * *.		
21:55:52.7 **CAM-2**	want me to build you a route two for the single engine out procedure while you do route one?		
21:55:57.9 **CAM-1**	oh thanks that'll help expedite things.		
21:59:48.3 **CAM-1**	I didn't activate it yet so let me know when it looks good to you.		
21:59:49.1 **CAM-2**	looks good to me.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:00:07.4 **HOT-2**	[sound similar to oxygen mask test].		
22:01:45.6 **CAM-1**	just in case we got a big map shift even though this is not an RNAV SID I'll ah get the lat longs here from the runway and we can plug it in if we have do a quick alignment (north) thirty seven thirty six point six West one twenty two point two nine. I'll leave that under the ah takeoff ah card there so if you need it you can just pull it out there * * quicker.		
22:01:53.8 **CAM-2**	* * *.		
22:02:29.0 **CAM-2**	in route two all I did was build ah San Francisco to San Francisco the San Francisco VFR ah VOR's anchored and that represents the zero eight zero at six point five DME.		
22:02:40.5 **CAM-1**	okay.		
22:02:41.2 **CAM-2**	that is ah how we get there is aat two DME a fifteen degree climbing right turn to hundred thirty heading.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:02:42.1 **CAM-1**	* it.		
22:02:49.1 **CAM-1**	okay.		
22:02:50.8 **CAM-2**	basically out over the water.		
22:02:54.6 **CAM-1**	fifteen degree climbing right turn at two DME to a magnetic heading of one thirty intercept track outbound San Francisco zero eight zero, okay, so that is the that first waypoint is the zero eight ah zero at six point five D- okay alright. very good, thank you. * * (need it).		
22:03:11.3 **CAM-2**	correct.		
22:03:14.5 **CAM-2**	*. and hopefully we won't.		
22:03:18.6 **CAM-?**	* * *.		
22:03:21.6 **CAM-1**	finish up few thing here get the # out.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:03:24.1 **CAM-2**	mask check		
22:03:24.2 **CAM-3**	and this is their copy I believe.		
22:03:27.5 **CAM-2**	yes.		
22:03:28.3 **CAM-1**	yeah doesn't matter.		
22:03:40.0 **CAM-1**	see they're projecting us at two ninety five. okay.		
22:03:43.9 **CAM-?**	* *.		
22:03:44.6 **CAM-2**	and we're comin' in a two eighty.		
22:03:46.0 **CAM-1**	yup. good.		
22:03:50.4 **CAM-2**	derate one region A.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:03:52.9 **CAM-1**	okay.		
22:03:57.5 **CAM-1**	thirty thirty three thirty seven.		
22:04:14.5 **CAM-1**	do you ah do you have the numbers already?		
22:04:16.1 **CAM-2**	I do have ah most of them I have not entered anything into the FMC.		
22:04:19.7 **CAM-1**	okay okay.		
22:04:20.9 **CAM-1**	ah FMC zero fuel weight is two one eight decimal eight.		
22:04:29.5 **CAM-1**	and I guess you got the takeoff weight CG and everything else right?		
22:04:31.8 **CAM-2**	yes.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:04:32.1 **CAM-1**	okay very good okay. let's see seventy eight * two eighteen.		
22:04:45.7 **CAM-1**	and ah * *.		
22:04:56.3 **CAM-1**	alright I'm ready whenever you are for the ah cross check.		
22:05:00.2 **CAM-3**	* * * compartment ten one two four six five compartment nine two six four eight zero compartment eight two six two one four compartment seven two five five seven five compartment six two seven (two) seven nine compartment five two four one eight five compartment four two three zero five zero compartment three two five seven zero five compartment two two three one five five compartment one two two five nine five belly one seven nine nine belly two seven nine seven belly three three zero six six belly four five (two) seven belly five six seven three fuel sixty (thousand) zero pax cargo secure * * * * * *.		
22:06:02.5 **CAM-1**	okay that looks good time is zero five zero six.		

INTRA-COCKPIT COMMUNICATION		**AIR-GROUND COMMUNICATION**	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:06:10.1 **CAM-3**	(we) are.		
22:06:11.6 **CAM-1**	we have a few few things to do up here we'll probably be out in seven or eight minutes.		
22:06:18.9 **CAM-1**	okay I can I guess let's just do the checklist when you hav- when you can get to it and then and then we'll close the door so.		
22:06:26.4 **CAM-2**	alright.		
22:06:28.3 **CAM-2**	before start checklist, logbook manuals?		
22:06:31.4 **CAM-1**	seven nine nine check.		
22:06:33.0 **CAM-2**	gear pins checked?		
22:06:33.8 **CAM-1**	checked.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:06:34.2 **CAM-2**	accessory panel checked circuit breaker checked IRS?		
22:06:37.0 **CAM-1**	NAV.		
22:06:37.4 **CAM-2**	ignition start selectors?		
22:06:38.9 **CAM-1**	one auto.		
22:06:39.5 **CAM-2**	fuel quantity?		
22:06:40.3 **CAM-1**	sixty thousand eight hundred pounds.		
22:06:41.8 **CAM-2**	sixty thousand pounds, planned pressurization?		
22:06:43.8 **CAM-1**	set.		
22:06:44.1 **CAM-2**	oxygen checks?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:06:44.9 **CAM-1**	checks.		
22:06:45.3 **CAM-2**	altimeters flight instruments three zero zero zero. set crosscheck.		
22:06:48.3 **CAM-1**	three triple zero set crosscheck.		
22:06:50.1 **CAM-2**	GPWS override.		
22:06:51.1 **CAM-1**	normal.		
22:06:51.4 **CAM-2**	EICAS.		
22:06:51.9 **CAM-1**	set.		
22:06:52.1 **CAM-2**	FMC?		
22:06:52.9 **CAM-1**	programmed.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:06:53.1 **CAM-2**	verified radar checked off.		
22:06:54.4 **CAM-1**	checked off.		
22:06:54.9 **CAM-2**	parking brake pressure?		
22:06:56.0 **CAM-1**	set check.		
22:06:56.5 **CAM-2**	fuel control switches.		
22:06:57.6 **CAM-1**	cutoff.		
22:06:58.0 **CAM-2**	before start checklist complete.		
22:07:32.1 **CAM**	[sound similar to cockpit door being closed].		
22:07:37.0 **CAM-1**	I guess we can L-NAV this one it's got the headings and everything in it so I'll just call L-NAV four hundred feet.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:07:42.1 **CAM-2**	good.		
22:07:42.6 **CAM-1**	this'll be a ah derate one, ah flaps fifteen takeoff two hundred eighty thousand pounds speeds are V-one one thirty rotate one thirty three V-two one thirty seven the ah Quiet Two departure as previously mentioned heading select to four hundred feet and ah fly out on the zero one one degree radial of ah San Francisco to the four DME that's off of SASLY intersection and ah then turn left heading three two zero to intercept the San Francisco ah three twenty I'm sorry that's ah three forty two so see how that works out probably you can just extend me off of REBUS maybe or if he gives us a heading to intercept whatever we can just extend off of REBUS .		
22:08:25.8 **CAM-2**	okay.		
22:08:26.6 **CAM-1**	and ah we are cleared to one five thousand we're going to three seven oh as a final if we have to come back we will ah declare an emergency we'll get out the book do whatever we have to do and come back get vectors for an ILS to runway ah probably two eight left.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:08:43.8 **CAM-2**	alright. *.		
22:09:24.2 **HOT-2**	oh @ in the past ah the only hiccups that I've ever had that I just my experience ah right around this area if they're busy for some reason.		
22:09:33.5 **CAM-1**	yeah.		
22:09:34.1 **HOT-2**	I've done a couple loopty-loops around Bravo one into Bravo two back out Q One every once in a while they'll they'll sequence us in here if there's traffic the other (way).		
22:09:43.0 **CAM-1**	yeah this time of night unlikely but thanks for the heads up.		
22:09:46.1 **HOT-2**	you bet.		
22:09:47.6 **CAM-1**	okay so we're gonna be yeah they'll probably take us on Bravo all the way around hopefully Bravo takes us there.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:09:54.6 **HOT-2**	roger.		
22:09:55.3 **CAM-1**	I know it can get confusing right in the middle of the airport. * * *.		
22:10:00.2 **HOT-2**	you bet.		
22:10:01.4 **CAM-1**	alright. ah oh I don't know if I put the departure frequency in there, squawk wanna make sure we're all set up ah what the # did I do with that? Quiet Bridge, #. where did I write the clearance?		
22:10:27.9 **HOT-2**	hey there's something going on in the back.		
22:10:29.7 **CAM**	[sound of increased variable amplitude wideband background noise].		
22:10:32.7 **CAM-1**	uh oh.		
22:10:38.8 **CAM-2**	we got a fire.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:10:40.6 **CAM-2**	got a big fire.		
22:10:40.9 **CAM**	[sound similar to cockpit door closing].		
22:10:42.4 **CAM-1**	* * #.		
22:10:43.6 **CAM-2**	whoa.		
22:10:44.2 **CAM**	[sound similar to direct-vision window being cranked open].		
22:10:49.2 **CAM-2**	declare an er- or a #.		
22:10:56.5 **CAM-1**	alright.		
22:10:56.9 **CAM**	[sound similar to lavatory smoke detector alarm].		
22:10:57.2 **CAM**	[sound of electronic alarm in background].		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:11:00.1 **CAM-2**	want me to call ground roll the equipment?		
22:11:01.4 **CAM-1**	yeah absolutely.		
		22:11:04.3 **RDO-2**	San Francisco ground San Francisco ground ABEX sixteen eleven.
22:11:06.2 **CAM**	[sound similar to fire warning bell].		
		22:11:08.7 **GND**	ABEX sixteen eleven San Francis ground.
		22:11:11.4 **RDO-2**	yes sir we need a ah CFR over here at ah spot eleven a cargo aircraft fire.
22:11:16.5 **CAM**	[sound similar to fire warning bell].		
		22:11:18.9 **GND**	ABEX sixteen eleven you're you're reportin' aircraft fire?
		22:11:22.1 **RDO-2**	yes sir.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
22:11:22.1 **CAM-1**	yup.		
		22:11:23.5 **GND**	okay we're gonna roll the trucks right now.
		22:11:25.5 **RDO-2**	thank you.
22:11:26.3 **CAM-1**	okay parking brake set APU engine fire pu- override and pull and rotate.		
22:11:26.5 **CAM**	[sound similar to fire warning bell].		
22:11:34.1 **CAM-2**	I gonna * * for ya.		
22:11:35.1 **CAM-1**	go ahead.		
22:11:36.8	[end of transcript]		
22:11:37.9	[end of recording]		

Appendix B

Comments from the State of Israel, Ministry of Transport, Aviation Incidents and Accidents Investigation

STATE OF ISRAEL
MINISTRY OF TRANSPORT
AVIATION **I**NCIDENTS & **A**CCIDENTS **I**NVESTIGATION

משרד התחבורה
והבטיחות בדרכים

20 May 2009
04599509

Dear Lorenda,

Samuel and I have thoroughly reviewed the final Aircraft Accident Summary Report.

We find the report is very comprehensive and complete, and professionally presented.

I was continuously kept up-to-date by Sam, throughout all the stages of the investigation. I received feedback from him telling me that the cooperation of the Team was excellent.

We have received some comments regarding the Report from IAI's Technical Team (Engineers & Team Leaders). I have personally checked their comments, and selected a few of them, regarding which I wish to offer the following minor remarks, provided herein for your consideration.

Comment 1

On page 7 of the Executive Summary the following wording is used:

"**The probable cause of accident was the design of the supplemental oxygen system**".

Since this is an Executive Summary, persons that would not read the complete report may understand that this is a unique problem with the specific design detail of the supernumerary system installation, where the actual finding is that the hazard of proximity of wiring and oxygen tubes exists in other "non-modified" locations as well and the corrective action and recommendations may apply to general design standards as well as to manufacturing and inspection procedures (existing Standards Practice).

Therefore we propose the following phrasing of page 7, lines 9 through 16:

The National Transportation Safety Board determines that the probable cause of this accident was insufficient positive separation between electrical wiring and oxygen system components resulting in a contact between electrical wiring and an element of the supplemental oxygen system, and causing an electrically induced heat in a conductive oxygen hose, causing failure and ignition of the hose and allowing a fire to initiate in the supernumerary compartment and rapidly spread to other areas. Contributing to this accident was the Federal Aviation Administration's (FAA) failure to require the replacement of conductive oxygen hoses after this safety issue was initially identified by Boeing.

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STATE OF ISRAEL
MINISTRY OF TRANSPORT
AVIATION INCIDENTS & ACCIDENTS INVESTIGATION

משרד התחבורה והבטיחות בדרכים

Comment 2

Section 3.3 discusses the proximity of electrical wiring to oxygen system components. It is noted within the description of the findings (Page 32 line 19 and on) that wiring was found on some airplanes above and in direct contact with oxygen tubes (both in cockpit and supernumerary areas).

Considering that the cockpit area is unmodified by the cargo conversion, the problem does not seem to be a result of an approved design for the Supplemental Type Certificate only, but more of a general industry lack of implementation of the recommended standard practice for installation and inspection of electrical wiring installations.

We believe that the following section (Lines 2 through 6 of Page 34) should be changed as follows to reflect the general nature of the problem:

"However, these actions did not prevent the wiring problems that were found on the ABX Air airplanes because the proximity between oxygen system tubing and electrical wiring within a compressed area indicates that the standard practices for separation of wiring and oxygen system components were not always followed."

It may be worthwhile to mention (either here and/or in the Recommendations in paragraph 5 of the report) the new rule of FAR 26.11 (EWIS) which, if implemented correctly, will provide better instructions for continued airworthiness of wiring hazards.

We are attaching herein, for your information, an FAA presentation on this subject.

You can also propose to the FAA (at their discretion) to update the following document (attached herein) to include also the routing (protection) of electrical wiring in the vicinity of oxygen tubing:

Docket No.: FAA-2004-18379;

Amendment Nos. 1-60, 21-90, 25-123, 26-0, 91-297, 121- 336, 125-53, 129-43

RIN 2120-AI31

"Enhanced Airworthiness Program for Airplane Systems/Fuel Tank Safety (EAPAS/FTS)"

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Comment 3

On page 36 line number 6 the method of grounding is common to the existing main oxygen system and to the supplemental oxygen system. Therefore we recommend removing the word "supplemental" and word the section to identify the hazard as a general oxygen systems design practice issue (Reference: page 37 line 1 and on).

"Title 14 CFR 25.1441, "Oxygen Equipment and Supply," paragraph (b), states that an oxygen system must be free from hazards in itself. However, the existing method of grounding the oxygen system could allow inadvertent contact from adjacent electrical wiring to energize oxygen system components."

Comment 4:

Page 36 line 19 discusses the lack of bonding straps. As the cockpit system is an original airplane installation, unmodified by the conversion, we propose the following clarification note to be added:

"No electrical ground straps were found on the ABX Air 767 airplanes that were examined (both in the cockpit and supernumerary compartment). It is to be noted that the cockpit installation is not part of the freighter modification but an original airplane installation. If ground straps had been installed on the accident airplane, the ……"

Comment 5

On page 37 recommendations line 9 we propose to add the words "and modifiers" as follows, in order to implement the same standards on all future STCs as well:

"The Safety Board concludes that an effective method of electrically grounding of the supplemental oxygen system to the airframe would help ensure that oxygen system components are protected from short circuits. [Conclusion] Therefore, the Safety Board believes that the FAA should require (1) airplane manufacturers to develop minimum electrical grounding requirements for oxygen system components and (2) airplane modifiers and operators to comply with these requirements. [Recommendation]"

This will also match the recommendation of page 46 line 10:

"Require airplane manufacturers and modifiers to provide positive separation between electrical wiring and oxygen hoses and tubing. (A-09-XX)".

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Comment 6

Page 45, line 15, we propose the following change similar to our comment 1 above:

"The National Transportation Safety Board determines that the probable cause of this accident was a failure to ensure positive separation between electrical wiring and oxygen system components, allowing a fire to initiate in the supernumerary compartment and rapidly spread to other areas. Contributing to this accident was the Federal Aviation Administration's failure to require the replacement of conductive oxygen hoses after this safety issue was initially identified by Boeing."

Again, I was delighted to be able to read a really professional document.

My compliments, on a professionally conducted investigation, and my best personal wishes to you.

Sincerely,

ITZHAK RAZ (RAZCHIK), ADV.
CHIEF INVESTIGATOR

c.c.

Mr. S. Ifergan, Senior Director Quality Assurance
Bedek Aviation Group, Israel Aerospace Industries Ltd.

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