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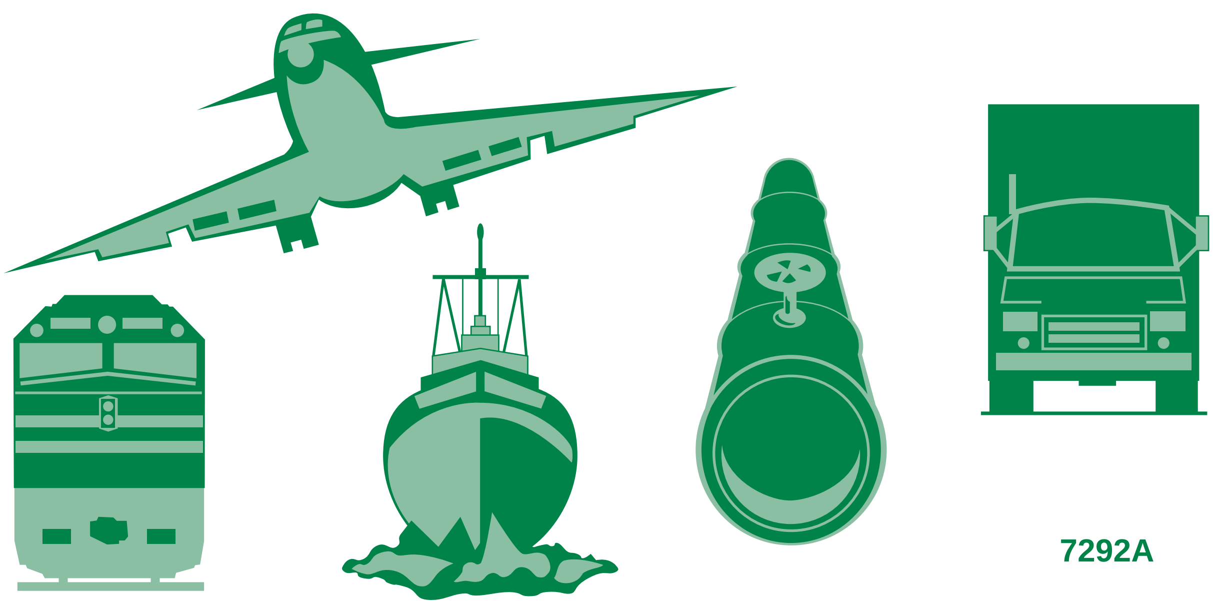
NTSB/MAR-01/02

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

MARINE ACCIDENT REPORT

FIRE ON BOARD THE U.S. PASSENGER FERRY *COLUMBIA* CHATHAM STRAIT NEAR JUNEAU, ALASKA JUNE 6, 2000



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Marine Accident Report

Fire On Board the U.S. Passenger Ferry *Columbia* Chatham Strait Near Juneau, Alaska June 6, 2000

NTSB/MAR-01/02
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Notation 7292A
Adopted September 18, 2001

National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2001. ***Fire on Board the U.S. Passenger Ferry Columbia, Chatham Strait, Near Juneau, Alaska, June 6, 2000.*** **Marine Accident Report NTSB/MAR-01/02. Washington, DC.**

Abstract: This report discusses the June 6, 2000, fire that occurred on the Alaska Marine Highway System ferry *Columbia*, while it was underway in Chatham Strait, near Juneau, Alaska. None of 498 people on board the vessel was killed or sustained serious injury; however, three passengers were transported to a shoreside hospital for medical conditions that preexisted the fire. Damages related to the accident exceeded $2 million.

From its investigation of this accident, the National Transporattion Safety Board identified safety issues in the following areas: the adequacy of inspection and maintenance procedures for electrical systems; the adequacy of management safety oversight of maintenance procedures; and the adequacy of firefighting procedures. Based on its findings, the Safety Board made recommendations to the Alaska Marine Highway System.

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Contents

Acronyms And Abbreviations

AB	able seaman
ABS	American Bureau of Shipping
AMHS	Alaska Marine Highway System
CFR	*Code of Federal Regulations*
MSO	*Marine Safety Office*
SCBA	self-contained breathing apparatus
SAR	Search and Rescue
SOLAS	*International Convention for the Safety of Life at Sea*
STCW	*International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers*

Executive Summary

About 1207, Alaskan daylight time,[1] June 6, 2000, a fire broke out in the main switchboard in the engine control room of the Alaska Marine Highway System (AMHS) ferry *Columbia*. The ferry, with 434 passengers, 1 stowaway,[2] and 63 crewmembers on board, was underway in Chatham Strait, about 30 nautical miles southwest of Juneau, Alaska, on a regularly scheduled voyage from Juneau to Sitka, Alaska. As a result of the fire, the vessel lost main propulsion and electrical power and began to drift. The crewmembers on board the *Columbia* responded to the fire first. Soon thereafter, the U.S. Coast Guard (Coast Guard) cutter *Anacapa*, on patrol nearby, sent a firefighting team to the *Columbia*. About 1425, the fire was extinguished with no resulting injuries or deaths. However, the *Columbia* remained adrift.

Three passengers were evacuated by Coast Guard helicopter because of medical conditions that preexisted the fire. The remaining passengers were safely transferred to another AMHS ferry, the *Taku*, which had rendezvoused with the drifting *Columbia*. About 2030, the *Taku* arrived at Auke Bay Ferry Terminal in Juneau, where the passengers disembarked. The *Columbia* was towed to the same terminal, arriving at 0845, on June 7. According to the AMHS, the cost of repairs to the ship was about $2 million.

The National Transportation Safety Board determines that the probable cause of the fire on the *Columbia* was the absence of an effective maintenance and inspection program for the electrical switchboards, resulting in a switchboard fire by arcing, most likely due to a faulty connection or a conductive object.

The major safety issues discussed in the report are as follows:

- Adequacy of inspection and maintenance procedures for electrical systems;
- Adequacy of management safety oversight of maintenance procedures; and
- Adequacy of firefighting procedures.

As a result of this investigation, the National Transportation Safety Board makes safety recommendations to the AMHS, the operator of the *Columbia*.

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[1] All times in this report are Alaskan Daylight Time.

[2] See "Passenger and Crew Accountability" for information concerning the stowaway.

Factual Information

Accident Synopsis

On June 6, 2000 at 0915, the 418-foot ferry *Columbia* (see figure 1) departed the AMHS's Auke Bay Terminal north of Juneau, Alaska, en route to the AMHS terminal in Sitka for a scheduled voyage of about 8 1/2 hours. (See figure 2.) On board were 434 passengers, 1 stowaway, and 63 crewmembers. About 1207, fire broke out in the main electrical switchboard[1] in the engine control room, knocking out power to the ship's electrical systems and causing the emergency generator to come on line. The ship also lost its main propulsion.

Figure 1. The *Columbia*.

Personnel on board the *Columbia* responded to the fire first. Soon thereafter, the Coast Guard Cutter *Anacapa*, on patrol nearby, sent a firefighting team to the *Columbia*. Additional resources from Coast Guard Station Juneau and the State of Alaska also responded to the emergency. About 1425, the fire was extinguished. No one was injured or killed. However, the *Columbia* remained dead in the water. Another AMHS ferry, the *Taku*, rendezvoused with the drifting *Columbia* and took on board the *Columbia*'s passengers without incident or injury. About 2030, the *Taku* arrived at Auke Bay Ferry Terminal in Juneau, where the passengers disembarked. The *Columbia* was towed to the same terminal, arriving at 0845 on June 7. Although no injuries resulted from the fire, three individuals were taken to a Juneau hospital for medical reasons.

[1] A switchboard supports and houses meters, circuit breakers, switches, indicator lights, rheostats, resistors, and fuse holders. It also contains the electrical conductors interconnecting these components.

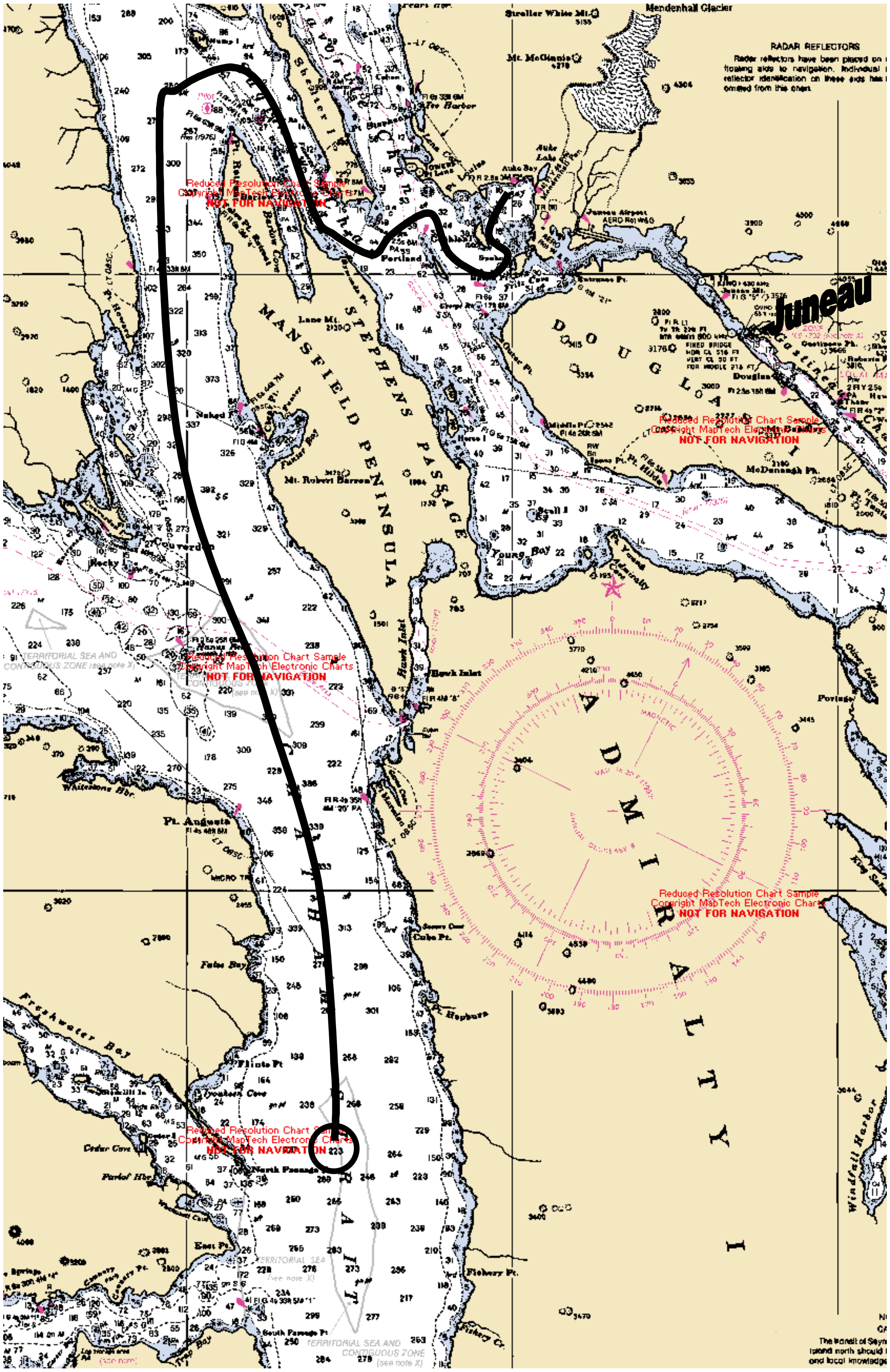

Figure 2. *Columbia*'s route to the point of the accident (circled).

Accident Narrative

Preaccident Events

According to shipboard personnel, from the time that the *Columbia* departed Juneau, at 0915, until 1130, events were routine in the engineroom. (See figure 3.) The vessel was underway at 19.4 knots with both main engines operating. Two of the ship's three auxiliary generators were operating in parallel; the third generator was shut down.

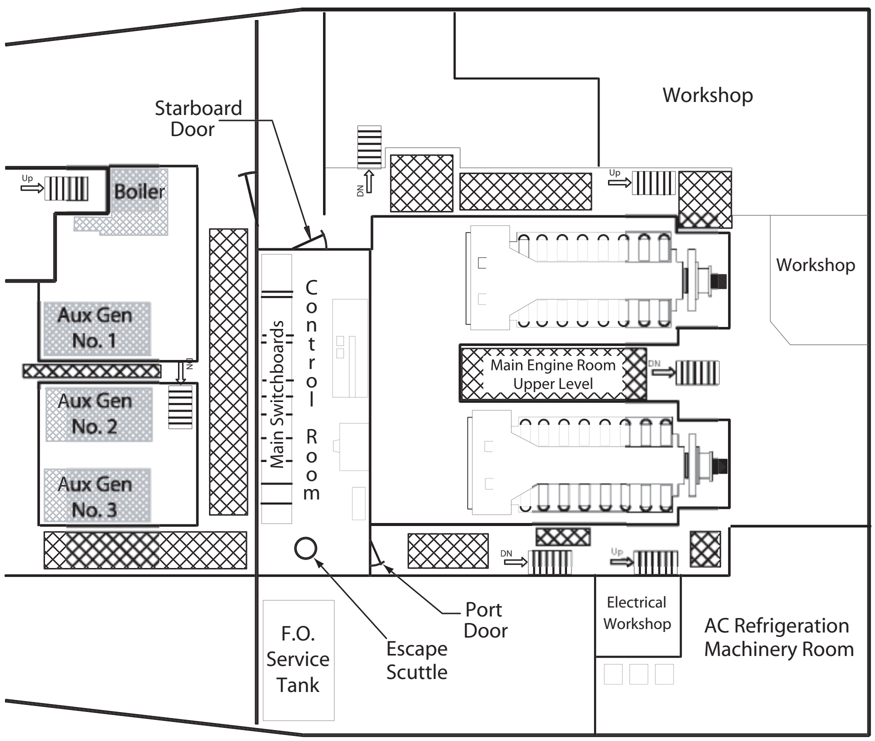

Figure 3. Schematic of engineroom.

About 1130, the engineroom watch changed. The new watch included a watch engineer, an unlicensed junior engineer, and an oiler. The junior engineer and the oiler made inspection rounds and returned to the control room. They did not note any problems during their rounds. While the watch engineer went on his rounds, the junior engineer and the oiler talked near the log desk, which was on the port side of the control room.

The Accident

The junior engineer stated that, shortly after 1200, he and the oiler heard a "disruptive sound, [a] kind of a poof" and saw a bright electrical arc[2] and sparks emerge

[2] An electric arc is a sustained luminous discharge of electricity across a gap between two conductors at different voltage levels.

from the upper portion of the main switchboard section, at its starboard end (unit 12).[3] Almost immediately, unit 10 began sparking and arcing, and the noise increased. The control room quickly filled with thick black smoke. The junior engineer and the oiler escaped through a nearby door into the engineroom, whereupon the junior engineer told the oiler to call the bridge and report the fire. The junior engineer then looked for the watch engineer to inform him of the problem. According to the engineroom alarm log printout, at 1207:48, the "Port Main Engine overspeed [alarm] tripped," signaling a loss of voltage to the overspeed protection device.[4] Within 1 minute of the first alarm, the monitoring system computer recorded about 30 fault alarms on various systems, and all engineering systems lost electrical power.

Meanwhile, the watch engineer was making an inspection round when he noticed the ship's No. 2 auxiliary generator surging and moving erratically on its foundation. (See figure 4.) He stated that the generator "would go from a slower speed to a higher speed, and it was shaking and rattling." He went to the control room to see if he could determine the cause of the erratic operation. On the way, he noticed that the lights were flickering. Upon opening the door to the control room, he "saw fire coming out of the first panel [unit] closest to the starboard door…heard a large [sic] popping sound"; he also saw what appeared to be the panels coming off the side of the breaker board. He closed the fire screen door to the control room and went to the auxiliary engineroom, where he shut down the ship's No. 2 auxiliary generator and began to stage firefighting equipment at the starboard fire screen door of the control room.

The off duty engineers were having lunch in the officers' mess when the lights began to flicker shortly after 1200. The chief engineer stated that he heard the ventilation fan motors slowing down and the diesel emergency generator start. While the other engineers headed for the engineroom to investigate the reason for the flickering lights, the first assistant engineer went to the emergency generator room, which was on the same deck as the officers' mess, to make sure that the emergency generator was running. Assured that it was, the first assistant engineer went to the engineroom to join the others.

When the day third assistant engineer[5] arrived in the engineroom, the oiler told him about the fire in the control room. The engineroom had no manual fire alarm or pull station; the only telephone in the area that could be used to call the bridge was in the control room and was inaccessible because of the fire. As a result, the day third engineer

[3] The switchboard manufacturer refers to the sections of the switchboard as units. During Safety Board interviews, the crew referred to the units as panels. Also, the crew used a different numbering system than the manufacturer. For example, unit 12, as indicated on the manufacturer's drawings, was called panel 1 by the crew. This report uses the manufacturer's designations.

[4] The engineroom automation system controls and monitors various engineering systems. When an abnormal condition occurs within a monitored system, an audible and visual alarm activates, and the time, channel identification, and alarm point condition are printed on a paper alarm log and stored in the computer's memory.

[5] The day third assistant engineer worked in the daytime only, performing maintenance work throughout the ship, and did not stand an engineering watch. For the remainder of this report, he will be referred to as the day third engineer.

Figure 4. One of the three auxiliary diesel generators.

had to climb up one deck to leave the engineroom and walk about 100 feet to call the bridge from a telephone located in the vehicle stowage area on the main deck.

When the chief engineer arrived in the engineroom, he met the watch engineer, who had already staged several CO_2 fire extinguishers near the starboard fire screen door of the control room and was stretching out the discharge hose for the semi-portable CO_2 fire extinguisher in the auxiliary machinery room. The chief engineer noticed that the ship's No. 1 auxiliary generator was operating erratically and sounded as if it were being overloaded. After feeling the fire screen door on the starboard side of the control room for heat, he opened the door and saw heavy black smoke, but no fire. He immediately closed the fire screen door and directed his and his crew's attention to checking the engineroom, starting the fire pump, and securing the fuel oil and lube oil centrifuges and the fuel oil isolation valves.

Activities on Bridge

The chief mate and the master were in the chief mate's office, working on the computer, when they saw the lights dim. They immediately ran to the bridge. Arriving in the wheelhouse at 1207, the master assumed command from the pilot on duty. Multiple alarms were sounding on the bridge. The ship had lost propulsion and regular lighting and was beginning to drift. Shortly after arriving in the wheelhouse, the chief mate got a call from the day third engineer, informing him of the fire and requesting that the fire team respond to the scene. After the chief mate relayed this information to the master, around 1208, the master ordered the chief mate to sound the general alarm and to announce an emergency to the passengers and crew. Between 1208 and 1212, the chief mate sounded the alarm and made announcements informing the passengers and crew of the fire. He instructed the passengers to muster on the upper decks and ordered the emergency squad[6]

[6] The squad consisted of 15 members of the deck department and 2 members of the engineering department, all of which were under the command of the chief mate.

to muster in its designated staging area,[7] which was on the starboard side of the main deck near the main access door to the engineroom. Immediately after these announcements were made, the public address system became inoperative. Around 1212, the chief mate, who was responsible for supervising shipboard firefighting activities, went to muster with the emergency squad. At 1216, the master requested assistance from another AMHS ferry, the *Taku*, on VHF channel 11. The master had seen the *Taku* earlier in the day and knew that it was in the area.

Meanwhile, the emergency diesel generator started, providing emergency lighting and giving the bridge steering control of the ship. When the master realized that the starboard propeller was indicating astern pitch and that both engines were slowing, he ordered the engines stopped and the rudder midships.

Fire and Rescue Response

Shipboard effort. Shortly after the fire began, the ship's emergency squad members donned personal protective equipment and brought fire extinguishers to the designated staging area. Because a car was parked in the squad's muster area, the squad was forced to assemble around the car. Shortly after his arrival at the muster location, the chief mate sent an able seaman (AB) to the engineroom to assess the situation. The first assistant engineer stated that he did not want the emergency squad to enter the control room to fight the fire; he believed that the engineers were better able to do so because of their familiarity with the control room. As a result, the first assistant engineer asked the AB to leave the engineroom.

Recognizing that the engineers were more familiar with the control room, the chief mate decided to let them fight the fire. The engineers did not don any protective clothing but they did obtain self-contained breathing apparatuses (SCBAs)[8] from the emergency squad. The emergency squad remained in the staging area and provided support as needed by changing SCBA air bottles as they became expended.

The chief engineer became concerned that the diesel emergency generator was continuing to feed electrical power to the main switchboard via the emergency switchboard; so he sent the day third engineer into the control room to open the bus tie circuit breaker between the main switchboard and the emergency switchboard. Entering the control room, the day third engineer stayed as low as possible to avoid the smoke that was accumulating near the overhead. After he had advanced about 15 feet into the room, he found that the room was so dark that he could not see the light of his own flashlight even when he aimed it at his facemask. He did not see any flames. He became concerned about his safety, withdrew from the control room, and requested that a lifeline be attached to him.

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[7] The staging area was in the vehicle stowage area and was an area on the deck that was outlined in yellow.

[8] SCBAs are protective breathing equipment that protects the face and lungs from toxic gases and high temperatures. The air supply in an open-circuit SCBA is compressed air.

At this time, the first assistant engineer donned an SCBA and joined the efforts of the day third engineer to enter the control room. Before the men entered the room, the chief engineer expressed a new concern that the ship's No. 1 auxiliary generator might still be powering the main switchboard. The chief engineer directed the two engineers to enter the control room and open the bus tie circuit breaker from the emergency switchboard as well as the circuit breakers connected to the ship's auxiliary generators.

The two engineers entered the space through the starboard fire screen door on their hands and knees. The watch engineer stated that when he reached out to open the bus tie circuit breaker, a blue electric arc knocked his hand back. The first assistant engineer then reached over the day third engineer and opened the breaker by hitting it with a flashlight. The first engineer successfully opened another breaker with the flashlight, but, according to his own account, when he attempted to open a third breaker, there was a "really big spark." At that point, the two engineers backed out of the room. They discussed the situation with the chief engineer, who then manually shut down the ship's No. 1 auxiliary generator.

The engineers attacked the fire with hand-held portable CO_2 fire extinguishers. They also unreeled a hose from a semiportable 100-pound CO_2 extinguisher in the adjacent auxiliary generator room and stretched the hose to the control room.

During this time, the chief mate kept the bridge informed of the firefighting activities. The master stated that the chief mate had difficulty getting frequent and accurate updates because when the engineers "surfaced for air, they were gasping and sweating and couldn't get time to get a report before they slapped on another bottle and ran back down there."

Around 1220, the engineers informed the chief mate that the fire was out. He passed the information on to the master. At 1225, the chief mate received permission from the master to ventilate the ship. At 1227, as a result of the fire being declared extinguished, the chief engineer, the day third engineer, and the first assistant engineer left the engineroom. Between 1225 and 1231, the chief mate opened the vehicle stowage area doors to allow natural ventilation to clear the smoke from the vessel.

Around 1240, the chief engineer reported a reflash of the fire in the main switchboard. The master ordered the crew to close all ventilation dampers and all fire screen doors. He also ordered the closing of all watertight doors, with the exception of door No. 3, which was kept open to permit the passage of the hose from the semiportable CO_2 extinguisher in the auxiliary engineroom. The master shut off all fuel to the main and auxiliary engines by remote control. Because most of the SCBA air bottles on the ship had been used during the initial firefighting operations, the *Columbia* obtained additional air bottles and SCBA units from the *Taku*.

Because a Coast Guard firefighting team from the cutter *Anacapa,* which had been operating nearby and had come to the assistance of the *Columbia,* was expected to board the *Columbia* at any time, the chief engineer instructed the ship's personnel to pull out of the engineroom and prepare to reenter with the Coast Guard team when it arrived.

Coast Guard. At 1216, the Coast Guard cutter *Anacapa* overheard the *Columbia*'s master requesting assistance from the *Taku* on VHF channel 11. The *Anacapa* notified the search and rescue (SAR) controller at the Coast Guard District 17 Rescue Coordination Center in Juneau, who had also overheard the conversation. At this time, the *Anacapa* was about 4 miles from the *Columbia*. On orders from the SAR controller, the *Anacapa* proceeded toward the *Columbia* and arrived on scene at 1230, whereupon a four-man firefighting team was dispatched in a small boat to board the *Columbia*.

At 1257, the Coast Guard team boarded the *Columbia* and met with the *Columbia*'s chief mate. He showed the Coast Guard personnel the location of fire extinguishers and went with the Coast Guard firefighters to the control room.

On orders from the *Anacapa*'s commanding officer, the senior Coast Guard firefighter evaluated the situation to determine whether it was safe to enter the control room. He asked the chief mate whether the *Columbia*'s firefighting team would assist, and the chief mate responded that the team would remain in the vehicle stowage area to help as needed. The senior Coast Guard firefighter stated that he assessed the space, opened the control room's escape hatch to vent the smoke, and stood by the control room door to oversee operations while two Coast Guard firefighters entered the control room with CO_2 extinguishers. The Coast Guard firefighters donned oxygen breathing apparatuses before entering the control room.[9]

A Coast Guard firefighter asked the chief mate whether all electrical power had been shut off to the control room. The chief mate did not know whether all of the power had been shut off, but one of the *Columbia* engineers said that it had. Upon entering the control room, around 1323, the Coast Guard firefighters noticed that some of the control console lights were lit, indicating that the space had not been completely electrically isolated. To remove all possible sources of voltage from control room equipment other than the main switchboard (power to the main switchboard had already been isolated), the chief engineer ordered the emergency generator secured about 1358. Two Coast Guard firefighters then reentered the control room and, with the assistance of the engineers, removed the switchboard panels while the other two Coast Guard firefighters stood near the door, providing backup. The Coast Guard firefighters continued to fight the fire until it was extinguished about 1425.

Because the *Columbia*'s engineers were not wearing proper protective gear, the Coast Guard firefighters asked them to stay out of the control room until the fire was extinguished. The engineers complied, except for briefly entering the area to help the Coast Guard firefighters remove the switchboard panels. The senior Coast Guard firefighter said that he could have used more help and would have asked the engineers to assist if they had been wearing personal protective equipment.

The assistance provided by the *Anacapa* was only a part of the Coast Guard's response to the fire. Shortly after dispatching the *Anacapa*, the SAR controller notified the

[9] Oxygen breathing apparatuses are closed-circuit devices that use a chemical canister to purify recirculated air.

Coast Guard Marine Safety Office (MSO) in Juneau of the situation. Over the next 4 hours, a Coast Guard helicopter made repeated trips to the scene, dropping off two firefighters from Sitka to provide medical assistance and a response team consisting of an MSO investigator, an MSO inspector, a State of Alaska fire training specialist, and an AMHS engineer. The helicopter also transported three passengers to Bartlett Memorial Hospital. (For more detailed information, see “Medical Findings.”)

Taku and Tugs. Shortly after the fire began, the *Columbia*’s master radioed a ferry that he had seen earlier, the *Taku*, to stand by for assistance. About 1400, the *Taku*’s master positioned his vessel alongside the *Columbia*’s port side in preparation to take on the passengers of the disabled ferry. The crews of the two vessels rigged a makeshift gangway of aluminum staging and 4-foot by 8-foot plywood sheets between the ferries, about 8 feet above the water. The lifejacket-clad passengers then walked over the gangway from the *Columbia* to the *Taku* while the *Taku*’s chief mate stood by in a rescue boat in case a passenger fell into the water. Six crewmembers from the *Columbia* also transferred to the *Taku* to assist with the *Columbia*’s passengers.

After completing the passenger transfer at 1523, the *Taku* towed the *Columbia* away from Admiralty Island so that the ferry would not be in danger of drifting aground. About 1630, the tugs *Banner* and *Ardie* arrived on scene and took the *Columbia* in tow. Shortly thereafter, the *Banner* began towing the *Columbia* to Auke Bay Terminal, escorted by the tug *Ardie* and the *Anacapa*. At 1640, the *Taku* departed the scene with its own passengers and crew, as well as 434 passengers, 1 stowaway, and 6 crewmembers from the *Columbia*, and 2 Coast Guard medical corpsmen from the *Anacapa*. Early the next morning, the tug *Chahoenta* relieved the *Ardie* and assisted in docking the *Columbia*.

AMHS Command Center. An emergency response team was established at the command center of the Alaskan Department of Transportation building in Juneau. The AMHS emergency response team consisted of the general manager, a safety officer, and the vessel operations manager, as well as the port captain, the assistant port captain, and the senior port engineer. The team conferred with the master throughout the emergency and participated in decision making, such as determining how to transfer passengers.

Injuries

Table 1 is based on the International Civil Aviation Organization’s injury criteria, which the Safety Board uses in accident reports for all transportation modes. Additional information about the injuries sustained by passengers appears under “Medical and Pathological.”

Table 1. Injuries Sustained in the *Columbia* Accident

Type of Injury[a]	Passengers	Crew	Total
Fatal	0	0	0
Serious	1[b]	0	1
Minor	0	0	0
None	434	63	497
Total	435[c]	63	498

a. 49 *Code of Federal Regulations* 830.2 defines fatal injury as "any injury which results in death within 30 days of the accident" and serious injury as "an injury which (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was receive; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, or tendon damage; (4) involves any internal organ; or (5) involves second or third degree burns, or any burn affecting more than 5 percent of the body surface."

b. The passenger had chest pains associated with a preexisting condition. His condition might have been aggravated by the events surrounding the fire emergency.

c. A stowaway onboard was added to the total number of paid passengers. Two of the passengers received medication for preexisting illnesses and were released from the hospital.

Damages

According to the AMHS, the cost of repairing the ship was about $2 million.

Crew Information

The *Columbia*'s crew consisted of 63 individuals, each of whom was properly licensed or certificated by the Coast Guard to serve in his/her position. All of the officers had completed the *International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers 95* (STCW) basic safety training, which included instruction on personal survival techniques, fire prevention, firefighting, first aid, personal safety, and social responsibility.

Coast Guard Firefighting Requirements for Vessel Crews

Since 1986, most applicants for an original license[10] or for a raise in grade of an existing U.S. license have been required to complete a firefighting course that has been approved by the Commandant of the Coast Guard.[11] The training must be completed on a one-time-only basis; no recurrent training is required for the original or upgraded license.

[10] Master's license for service on vessels of 200 gross tons or less in ocean service, all master or mate's licenses for over 200 gross tons; all licenses for master or mate (pilot), except apprentice mate (steersman), for towing vessels on oceans; all licenses on mobile offshore drilling units; and all engineers' licenses.

[11] This course must meet both the basic and advanced sections of International Maritime Organization Resolution A.437(XI) *Training of Crews in Fire Fighting*.

Emergency Training and Drills

The engineers and other licensed officers had taken formal firefighting training. According to the AMHS, weekly firefighting drills were held for all crewmembers who had firefighting responsibilities. These drills simulated fires in various locations of the ship. According to the AMHS, a fire drill in the engineroom had not been held within the last 2 years before the fire. The AMHS also required that crewmembers read the handbook “Fire Safety—There’s No Second Chance” and take a 20-question quiz on its contents.

Because the *Columbia* was in domestic service, it was not required to comply with the basic safety standards, including firefighting, contained in the STCW. Even though the *Columbia* did not have to comply with these standards, the AMHS decided to apply them to all of its vessels because it had to apply them to its five vessels that were operated in international waters.

Although the AMHS decided, before the fire, to require STCW basic safety training for all of its vessels, by the time of the fire, the agency had implemented basic safety training only for licensed crewmembers; it had not had the opportunity to implement it for its unlicensed crewmembers.

Vessel Information

The *Columbia* was one of nine passenger/car ferries owned by the State of Alaska Department of Transportation and Public Facilities and operated by the AMHS. The ferry was built in 1974 at Lockheed Shipbuilding, Seattle, Washington, at a cost of $22 million. The vessel was allowed to carry up to 931 passengers and 134 vehicles during the summer season (May 15 through October 15). The *Columbia* usually did not operate during the rest of the year, when tourism decreased. When the ferry operated during the off-season, it was limited to 527 passengers. The vessel had 91 staterooms.

The *Columbia*’s principal characteristics follow:

Length	418.0 feet
Beam	85.1 feet
Depth	24.0 feet
Draft	17.4 feet (summer)
Gross tons	3,946
Displacement tons	7,745
Horsepower	12,340

The *Columbia* was built of all-welded-steel construction, in accordance with the rules of the American Bureau of Shipping (ABS), a classification society. The ABS had given the *Columbia* the highest rating for hull and machinery. The vessel had been maintained in class ever since it was built.

The *Columbia* also met Federal regulations (46 CFR Parts 70-89) for domestic passenger vessels. The Coast Guard completed an annual inspection of the *Columbia* in May 2000. The inspection included an examination of the hull, machinery, and safety and lifesaving equipment. The inspection did not include an examination of the main switchboard, therefore the problems incidental to this accident would not have been detected. A Coast Guard Certificate of Inspection was issued to the *Columbia* on May 22, 2000, upon departing the Alaska Ship and Drydock, Ketchikan, Alaska. The certificate of inspection was issued with no major deficiencies and was valid for 1 year after the date of issuance.

The *Columbia*'s Coast Guard Certificate of Inspection stated that the "route permitted and condition of operation" is lakes, bays, and sounds—the sheltered waters of the west coast of North America as defined in 46 CFR 42.03-35, not international waters. Its operating route included Bellingham, Washington, to Ketchikan, Wrangell, Petersburg, Juneau, Sitka, Haines, and Skagway, Alaska. As the *Columbia* was certified for the domestic coastwise trade, the vessel was exempt from the *International Convention for Safety Of Life At Sea* (SOLAS) 1974 and its protocol, the STCW.

The *Columbia* had seven decks, four of which were passenger decks containing cabins, lounges, a children's play area, and exercise facilities. Two enclosed decks were used for roll-on/roll-off vehicular stowage. The bridge, with an enclosed pilothouse, was at the forward end of the vessel on the uppermost deck.

The *Columbia* had two 16-cylinder diesel main engines, one for each shaft, driving a variable pitch propeller. The ship's three auxiliary generators supplied all electrical power for the vessel. An emergency generator, located on the cabin deck, supplied backup electric power for vital loads.

The main switchboard, located in the control room, consisted of 12 units. (See figure 5.) The starboard-most unit was identified as unit 12 and consisted of three rows of circuit breakers. Each row had four circuit breaker locations. Of the 12 locations, only 10 had circuit breakers. Units 8 and 10 of the main switchboard each had two rows of circuit breaker locations. Units 8 and 10 had 8 circuit breakers installed. Units 9 and 11 were ventilation spaces and had no circuit breakers. The three main generator circuit breakers were in units 2, 3, and 4.

The vessel had two 450-volt alternating current dead front[12] switchboards—a main switchboard and an emergency switchboard. The main switchboard was in the control room, and the emergency switchboard was in the emergency diesel generator room on the cabin deck. The location of the equipment on the switchboard was such that all components requiring monitoring, adjusting, or manual setting could be operated from the

[12] A type of electrical construction, usually a switchboard or panel board, where energized parts are not exposed to a person on the operating side of the equipment.

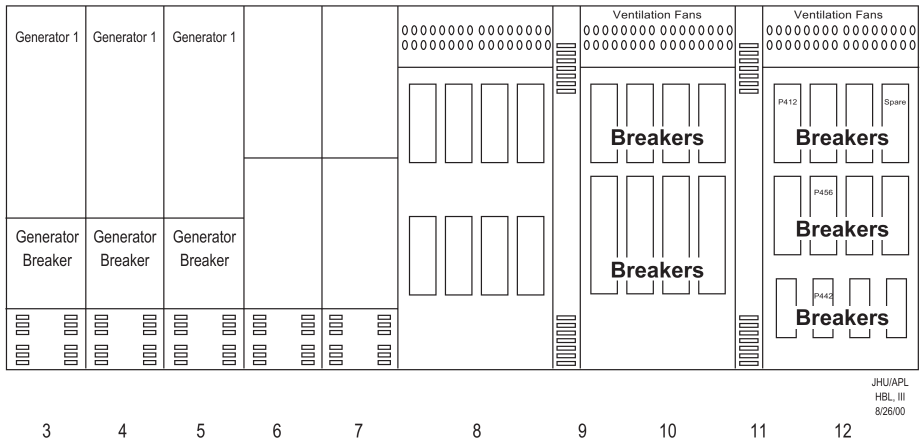

Figure 5. Outline view of main switchboard showing arrangement of units 3 through 12.

front of the switchboard without opening the hinged panels. All other components were mounted within the switchboard. The main switchboard contained the devices for the control and protection of the ship's three auxiliary generators. The main switchboard and the emergency switchboard were interconnected with an automatic bus tie circuit breaker. During normal operation, the emergency switchboard was supplied with electrical power from the main switchboard through the automatic bus tie circuit breaker, and the emergency diesel generator was in standby. Upon loss of voltage at the main switchboard, the automatic bus tie circuit breaker opened, the emergency diesel generator started, and the emergency diesel generator circuit breaker closed, thus supplying electrical power to the emergency switchboard. The Federal Pacific Electric Company of New Jersey had manufactured the main and emergency switchboards, including the breakers installed on the switchboards. The company is no longer in business.

The fire alarm system consisted of 20 manual pull stations distributed throughout the vessel and one smoke detector in the paint locker. Each station and detector activated audible and visual alarms on the supervisory panel in the wheelhouse. Heat detectors were distributed throughout the ship, covering public spaces, galleys, lockers and storerooms. The phone system consisted of four independent sound-powered systems;[13] the phone stations were installed in the main operating and crew spaces. The four systems were designated as 1JV (six stations for vessel maneuvering, including one in the control room and one on the bridge), 2JV (six stations for senior engineering officers' quarters and engineering spaces), 3JV (15 stations for senior officers' quarters and other spaces), and 4JV (nine stations for the chief steward's quarters and for public spaces), for a total of 36 stations.

[13] A sound-powered telephone system is one in which the operating power is derived from the speech input only. The four systems on the *Columbia* were independent in the sense that the stations in one circuit could not communicate with the stations in another circuit. For example, the stations in the 1JV circuit could not talk with the stations in the 3JV circuit.

AMHS Maintenance Policy

According to the AMHS's ship operations manual, the engineering department on each vessel in its fleet was required to develop a maintenance program for its equipment and to retain maintenance records. While a vessel's maintenance program was often discussed with the port engineer and modified according to the engineer's recommendations, each vessel's engineering department was responsible for determining the nature and timing of its maintenance activities, including those that focused on the main and emergency switchboards. Maintenance tasks were coordinated with the ABS and the Coast Guard through periodic inspections and tests of the equipment and systems.

The manufacturer's technical manual for the *Columbia*'s main switchboard recommends that operators "physically check the tightness of all electrical connections and parts" and "ascertain that no tools or extraneous materials are adrift" and that operators do so either annually or during shipyard overhaul, whichever occurred first. According to the chief engineer, the *Columbia*'s crew had not done any maintenance or repair work within the main switchboard or the ship's auxiliary generators before the accident. The AMHS management had reduced the size of the vessel crew during the lay-up period, leaving the chief engineer with limited crew resources to perform such work. The chief engineer did not know when the main switchboard had last been inspected or cleaned, but he thought it was in 1995 (there were no machinery history records). He was also unsure of when the switchboard had last been checked for loose connections. He added that immediately before the accident, the *Columbia* had not had any operational difficulties with the switchboard.

The chief engineer stated that the vessel's maintenance program included an infrared thermographic inspection to identify existing or potential problems in electrical circuitry, such as poor physical contact, overload, or load imbalances. Once a year, a contractor boarded the vessel and inspected the distribution panels and motor controllers. A review of the last inspection report showed that the inspection did not cover the main switchboard or its bus bars.[14] On this point, the chief engineer said:

> No, they typically don't do the main switchboard, due to the fact that, when they do their survey, we're usually underway and it's too hard.…we open up the panels down there that are on hinges and that he can get to and can look at, but that's mainly just the gauges and stuff; it's not the main switchboard itself.

The main switchboard was mounted against the forward bulkhead of the control room and, consequently, did not have access covers on its rear side. Therefore, infrared thermographic imaging of the rear side of the bus bars was not possible. Neither Coast Guard regulations nor ABS rules require that switchboards be accessible from the rear if they are fully serviceable from the front side.

[14] A bus bar is a solid aluminum or copper alloy bar that carries current to the branch or feeder devices in a power panel board or switchboard. There is at least one bus bar for each phase of the incoming electrical service.

Prior Shipyard Work on Main Switchboard

Before the accident, Alaska Ship and Drydock electrical workers had worked on the main switchboard during the winter lay-up period. The installation of rescue boats required modifying the main switchboard so it could supply electrical power to the electric motors and controls on the boat winches. The Coast Guard approved the modifications to the ship's electrical drawings,[15] and a Coast Guard inspector visually examined the completed work to ensure the modifications complied with the drawings and found the work satisfactory. Shipyard electricians entered the main switchboard enclosure[16] on three separate occasions to complete the work. A shipyard electrical foreman supervised the work done in the switchboard. After the first time that shipyard electricians worked on the switchboard, the AMHS port engineer overseeing the project looked into the energized switchboard to verify whether the connections to the new breaker had been properly made. Following the subsequent two times that electricians worked on the switchboard, no representatives of the AMHS or crewmembers of the *Columbia* inspected the work while it was in progress or when it was completed.

Waterway Information

The Columbia's usual route to Sitka began at the AMHS terminal at Auke Bay, northwest of Juneau, and proceeded through Stephen's Passage, Saginaw Channel, and then south following Chatham Strait to Peril Strait, then through Neva Strait, Olga Strait and Sitka Sound to the AMHS Sitka terminal. The trip typically took 8 1/2 hours. The accident occurred less than 3 hours into the trip, when the ship was abeam of North Passage Point in Chatham Strait. The width of the strait is about 8 nautical miles.

Meteorology Information

At the time of the accident, the weather was as follows: winds–light airs; seas–1 foot; visibility–0.5 nautical miles in fog and light rain. At 1200 on June 6, the height of the tide was approximately 0 feet and the tidal current was approximately 1 knot in an east-southeast direction at North Passage Point at the entrance to Freshwater Bay. At 1245, when the *Taku* arrived on scene, the observed weather was wind from the southeast at less than 5 knots, calm seas, cloudy skies, and visibility about 10 miles.

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[15] Coast Guard letter dated March 13, 2000, Serial: E2-0000682.

[16] A constructed case to protect personnel against contact with the enclosed equipment and to protect the enclosed equipment against environmental conditions.

Medical And Pathological

Medical Findings

The Coast Guard transported three passengers to shore in Juneau, where they were taken to Bartlett Memorial Hospital. One passenger, an 80-year old man, had chest pains associated with a preexisting illness, was admitted to the hospital on June 6, and released on June 9. The other two passengers, a 73-year-old woman and a 45-year-old woman, had left medications on the *Columbia* that needed to be replaced; the women, however, did not suffer any injuries as a result of the fire.

Toxicological Testing

On June 6, while the *Columbia* was being towed to Juneau, 13 *Columbia* crewmembers who were identified as essential personnel were tested for drugs and alcohol between 1800 and 2000, or within 6 hours of the fire. Table 2 shows the results of the tests performed on the members of the on-watch control room and the bridge watch.

Table 2. Postaccident Drug and Alcohol Testing Results of *Columbia* Crewmembers.

POSITION	LOCATION/DUTY	ALCOHOL TESTED (BREATH)	DRUG TESTED (URINE)	RESULTS (All Tests)
Master	Bridge	X	X	Negative
Chief Mate	Fire Team Lead	X	X	Negative
Third Mate	Bridge Watch		X	Negative
Pilot	Bridge Watch	X	X	Negative
AB	Fire Response		X	Negative
AB	Helm		X	Negative
Chief Purser	Pass. Evacuation		X	Negative
Chief Engineer	Fire Response	X	X	Negative
l/A Engineer	Fire Response	X	X	Negative
3/A Engineer	Fire Response		X	Negative
3/A Engineer	Engine Watch		X	Negative
Junior Engineer	Engine Control Room - Watch	X	X	Negative
Oiler	Engine Control Room - Watch	X	X	Negative

Wreckage

Damage to the *Columbia* was limited to the control room. A thin film of soot covered nearly all the surfaces within the room, and a video monitor used for surveillance was partially melted, as was a plastic light diffuser on one of the fluorescent light fixtures above unit 10 of the main switchboard. The main switchboard itself suffered the most serious and extensive damage. Most of the damage occurred in units 9, 10, 11, and 12 (all closest to the starboard end of the switchboard). (See figure 6.) Units 1 through 8 did not exhibit any evidence of electrical arcing and had minimal fire damage other than the sooting mentioned above.

Figure 6. Units 8, 9, 10, 11, and 12 of the main switchboard. The Safety Board investigator is examining unit 12.

Units 9 and 11

Each unit was separated by a void. Each void was designated by a number. The space between unit 10 and unit 12 was void and was designated unit 11. Similarly, the space between unit 10 and unit 8 was void and was designated unit 9. The surface of the framing for unit 11 was heavily damaged. Its paint was blistered to a powdery consistency in places, and paint around the vent in the unit's cover was burned away. The remaining paint on the cover of unit 11 was discolored and powdery in consistency. Unit 9 exhibited less damage, with some burned and soot-covered paint on the framing and the cover, and limited paint blistering around the vent in the unit's cover.

Unit 12

The interior side of the unit was covered with soot, heavy at the top and moderate toward the bottom. (See figure 7.) The top two-thirds of the interior had burned and blistered paint on the framing and the sides.

Figure 7. Unit 12. Photograph courtesy of the AMHS.

In addition, there was a 9-inch-high by 4-inch-wide spot of localized heating, where the paint was missing. (See figure 8.) On the exterior right side of the unit, a spot of localized heating measured 6 inches by 6 inches, and the paint was white and powdery. The feed and load wires for the entire unit were intact, with only heat damage to the insulation. The insulation on the wires that went to the lower row of breakers was sooted and showed no evidence of heat damage. The unit's cover was burned and paint was missing in places on the interior. The exterior of the cover had no significant damage.

At the top of the unit was an indicator board with 39 lights. Each of the lights was serviced by 110-volt wires. All of the light bulbs were melted out of the panel. The insulation on the wires was melted and charred, but the wires were otherwise intact. The wires showed no evidence of arcing.

Unit 12 was made up of three rows of breakers. The top row had three breakers and one blank. The left and center breakers were tripped but otherwise intact. The right breaker was pulled down during the firefighting effort but was otherwise intact. The bus bars and bus bar supports in the top row were also intact.

Figure 8. Closeup of heat damage to unit 12.
Photograph courtesy of the U.S. Coast Guard.

The middle row had four breakers. The bus bar connectors were melted except for the bottom left stab-loc connector for the far left breaker. The wire insulation for the relay of that breaker was melted, but the wires were intact and not damaged. The insulated bus bar supports toward the front of the panel were delaminated, but the ones in the back were intact. The support was fractured on the right side. The bottom row had a blank in the far left breaker position. The breakers, bus bars, and supports were intact.

Investigators found a 3/8-inch diameter by 1 1/4-inch long steel bolt with an oversized flat washer and a lock washer lying on an angle support bracket on the lower portion of the unit. Arcing, melting, or spatter marks were present on the bolt and on both washers, and the bolt and washers appeared to have melted together.

The deck below unit 12 was swept and then vacuumed to collect small pieces of debris. Among the items found were two pieces of plastic wiring banding material. None of the collected material exhibited evidence of heat or fire damage. The investigators did not find any discernable foreign objects in the debris.

Unit 10

The top two-thirds of the unit framing was burned and heavily sooted; the paint was missing. (See figure 9.) The lower third was sooted but otherwise undamaged. The compartment above the unit was warped.

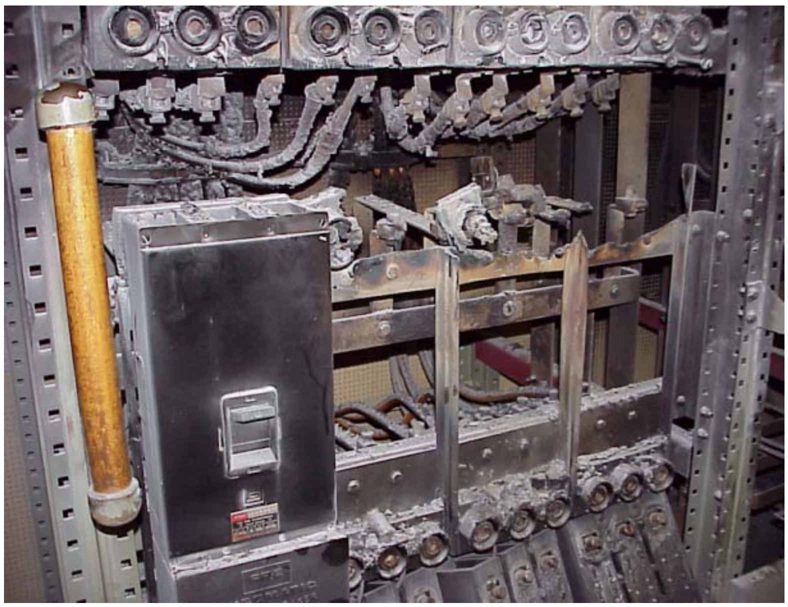

Figure 9. Unit 10. Photograph courtesy of the U.S. Coast Guard.

At the top of the unit was a light indicator board with 40 lights, each of which was serviced by 110-volt wires. All of the light bulbs were melted out of the panel. The insulation on the wires was melted, but the wires were intact. There was no evidence of arcing on the wires. There was a 34-inch long by 3.5-inch wide hole in the 1/8-inch steel plate that separated this area from the breaker area of the unit. (See figure 10.) The edges were smooth. Investigators found no evidence of material drip-down on the components below. The steel was discolored from tan to gray in some areas and to black in others.

The unit was made up of two rows of breakers. The top row had four breakers. Four tulip-clip connectors were intact—three on the left and one fourth from the right. The rest of the bus bars were melted; both bus bar supports were delaminated in the front, and the breakers were not intact. (See figure 11.) The wires servicing this row were intact, but heat had heavily damaged the insulation.[17]

[17] The bus bar ended in a male tulip connector. It was through these connectors that the circuit breakers were attached. There were six tulip connectors for every circuit breaker.

Figure 10. Closeup of hole in steel plate in unit 10. Photograph courtesy of the U.S. Coast Guard.

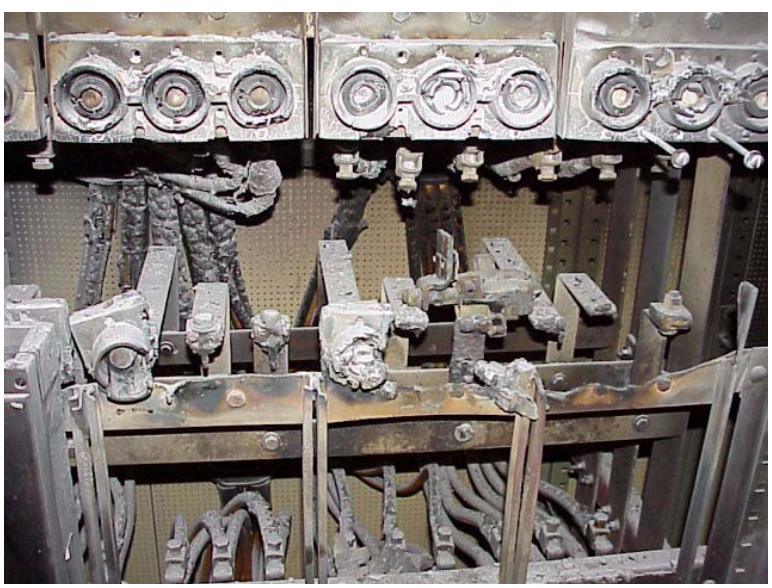

Figure 11. Damage to bus bars in unit 10.

The bottom row had four breakers. The three bus bar connectors on the top were all melted except for one. All the bottom connectors were intact. The top edge of the bus bar was melted down to half its width in places. Insulated bus bar supports were delaminated toward the front of the panel but were intact in the back. The wires servicing this row had damaged insulation but were otherwise intact.

The deck underneath unit 10 was swept and then vacuumed to collect small pieces of debris. Several pieces of wiring banding material were found. The investigators did not find any discernable foreign objects in the debris.

Survival Factors

Muster/Evacuation

The chief purser was in charge of mustering passengers. The *Columbia* had three muster stations—the forward lounge, the snack bar, and the dining room, all located on the boat deck. The emergency squad was directed to muster at the emergency locker in the vehicle stowage area, one level above the engineroom, to obtain firefighting equipment.

The chief steward directed the stewards to search passenger staterooms and put towels on the doorknobs or at the bottom of the doors to indicate that the staterooms had been searched. The chief steward then briefed the chief purser on the status of the search. According to the master, after 1210, he tried to use the public address system on the bridge; but, to his surprise, it did not work. Because he could not use either the main or the emergency public address system, he relied on hand-held VHF radio units to communicate directly with his crew. He used one VHF channel to communicate with the chief mate who was in charge of fire operations. He used another channel to coordinate the evacuation efforts, directing the pilot to relay information to and from the chief purser, the chief steward, and the second steward, all of whom were managing the muster and evacuation of the passengers. The master stated that using separate channels for radio communication was a new procedure, and it worked well. Through the use of the VHF units, the master was also able to send messages through his staff to the passengers. To help ensure that passengers were kept informed, various crewmembers walked around relaying instructions in loud voices; no loud hailer or similar equipment was available. The chief steward said that some passengers complained about not being able to hear and some passengers were confused about what to do. Other passengers were calm. The muster was completed at 1222, after which the crew distributed lifejackets to the passengers.

The *Columbia*'s master coordinated the transfer of passengers and crew with the *Taku*'s master, the *Anacapa*'s captain, the Coast Guard SAR controller, and the AMHS's general manager. The master of the *Columbia* obtained permission on his cellular telephone from the AMHS's general manger to bring the *Taku* alongside his vessel for the transfer. The master allowed the passengers to go to their staterooms and vehicles to obtain personal belongings and then instructed them to don their lifejackets and proceed to the transfer point via the forward stairwell. The passenger transfer began at 1419 and was completed by 1523. Crewmembers were positioned along the stairwell and on the *Taku* to assist the passengers.

Passenger Questionnaires

The Safety Board mailed 327 questionnaires to passengers who, according to company records, were on board the *Columbia* at the time of the accident. Eighty-one passengers responded. Overall, passengers said that the evacuation and transfer to the *Taku* went well. Fifty-three passengers stated that they heard the announcement describing what to do in an emergency. Twenty-four stated that they did not hear the safety announcement; some commented that they boarded late and did not recall whether such an announcement was made. The majority of the respondents noticed the placards posted throughout the vessel providing safety information.

Fifty-two passengers stated that the vessel’s crewmembers gave directions during the emergency and were well trained, helpful, professional, easily identified, and responsive to questions. Forty-two smelled an odor in the dining room and on different decks that seemed to be electrical in nature (like burning rubber or wires). Passengers obtained lifejackets from their staterooms, the crewmembers, or the storage bins. Forty-three passengers stated that they had difficulty hearing announcements once the public address system became inoperable, despite the crew’s efforts to provide information verbally as they walked through the ship.

Lifesaving Equipment

The *Columbia* had enough lifeboats and inflatable rafts to accommodate all of the people on board, 1,054 adult-size lifejackets, 98 child-size lifejackets, 12 ring buoys, and an emergency position indicating radio beacon.

Firefighting Equipment

The *Columbia* had fire hoses, fire axes, fire pumps, and a wide range of firefighting apparatus, including fixed extinguishing systems in the main engineroom, the auxiliary engineroom, the emergency generator room, the paint locker, the cafeteria, the vehicle stowage area, and the dining salon. More than 60 portable and semiportable fire extinguishers were located throughout the ferry. According to an AMHS general manager, at the time of the fire, the vessel carried seven firemen’s outfits, each consisting of pants, a coat, boots, gloves, a helmet, and an SCBA.

Firefighting Procedures

According to the *Columbia*’s muster list, which indicated the assignments for crewmembers during emergencies, the emergency squad was designated to fight fires on board the vessel. Shipboard references contained no procedures for fighting an electrical fire in the control room or how the emergency squad and the engineers should coordinate their firefighting efforts.

Emergency Procedures

According to the *Columbia*'s muster list, the master had overall command of the evacuation. The chief purser was in charge of the upper deck evacuation, the chief steward was in charge of the boat deck evacuation, and the second steward was in charge of the cabin deck evacuation. All three of these individuals were responsible for coordinating the muster and evacuation of passengers and crew and reporting to the master.

Placards that provided safety information on emergency signals and lifejacket locations were posted throughout the ship and in each stateroom. Signs with arrows posted throughout the passenger decks identified the most direct routes to the liferafts. After passengers boarded the *Columbia,* they were told over the public address system what to do in an emergency. The briefing covered locating and donning lifejackets, the safety announcements that would be provided over the public address system, and the emergency signal for mustering passengers and crew.

Coast Guard Firefighting Policy

The Coast Guard's *Marine Safety Manual*[18] stipulates the actions of the agency in preventing marine casualties and incidents. Volume VI, Chapter 8, "Coast Guard Fire Fighting Activities," states the following, under <u>Policy</u>:

> Although the Coast Guard clearly has an interest in fires involving vessels or waterfront facilities, local authorities are principally responsible for maintaining the necessary fire fighting capabilities within U.S. ports and harbors. Additionally, a vessel/facility's owner and/or operator is ultimately responsible for the overall safety of vessels/facilities under their control, including ensuring adequate fire fighting protection.

Chapter 8, under <u>Restrictions</u>, states:

> Generally, Coast Guard personnel shall not directly engage in fire fighting activities on other than Coast Guard units except when necessary to save a life or when possible to avert a significant threat with minimal risk to Coast Guard personnel.

In fighting fires on vessels other than its own, the Coast Guard usually limits itself activities to certain activities, including the following: conducting preliminary assessments of the incident, evaluating the magnitude of the threat, developing a response plan, monitoring response actions, contacting the owner, providing assistance as available, and giving any necessary first aid.

Passenger and Crew Accountability

Based on the advanced reservations made by passengers and the number of tickets purchased before the departure from Juneau, the total number of paid passengers on board the *Columbia* at the time of the fire was known. To verify that all of the passengers were

[18] Commandant Instruction M16000.11.

accounted for, an Alaska State trooper who happened to be on board worked with the chief purser and second mate to account for passengers during the transfer to the *Taku*. The State trooper took the names of the passengers as they left the *Columbia*, and the second mate had a counter to help confirm the numbers. The number of passengers listed on the manifest did not match the number of passengers counted during the transfer. The manifest listed 434 passengers, but the actual count was 435. It was at this point that it became known that the vessel had a stowaway. The master provided an accurate count of the transfer to the Coast Guard, 435 passengers and 6 crewmembers.

Tests And Research

Johns Hopkins University-Applied Physics Laboratory Report

The Safety Board contracted an expert on arcing faults[19] in marine switchboards to assist in the investigation. The contractor was an employee of the Johns Hopkins University-Applied Physics Laboratory and had been contracted to investigate a number of U.S. Navy switchboard fires while under contract to the U.S. Navy.

The contractor, with the assistance of party representatives, thoroughly examined the switchboard and all of its components. During the investigation a steel bolt was found in unit 12 that was fused to two washers (mentioned earlier in the section on fire damage). (See figure 12.)

In his report, dated July 27, 2000, the contractor concluded that the most likely origin of the fire was in the vicinity of the port steering gear breaker in switchboard unit 12. The report also concluded that the most likely cause of the fire was either a faulty connection of the switchboard bus bars or the loose bolt found during the examination of the switchboard. Because of the bolt's location, its appearance and other factors, the contractor concluded that that the bolt was probably the initiator of the arcing fault that spread through the two sections of the switchboard.

[19] A high impedance connection, such as an arc through air or across insulation, between two conductors.

Figure 12. Bolt found on front (aft side) framework of switchboard.

Safety Board Materials Laboratory Testing Report

The Safety Board's Office of Research and Engineering Materials Laboratory tested the bolt found within the switchboard to determine the nature of the deposits on the bolt and the manner in which the two washers had bonded to the bolt. In addition, technicians tested two other bolts as controls. The first control bolt had been removed from the bus connection to a main switchboard breaker. This bolt was nearly intact and identical in size and washer arrangement to the loose bolt found in the switchboard. The second control bolt was similar in design to the bolts from the switchboard. Before testing the second control bolt, technicians intentionally arced it by placing it across two copper bus bar conductors and subjecting it to 240 volts direct current.

During metallurgical tests, the three bolts and their washers were sectioned longitudinally and polished. The cross-sections were examined using optical microscopy and scanning electron microscopy. The cross-sections of the subject bolt and washers were also examined using energy dispersive x-ray spectroscopy. Technicians determined that the material creating the bond between the subject bolt and the washer was copper. The profiles of the bolt and washers at the points of contact were not deformed by melting. In contrast, the intentionally arced bolt was fused to the washer at the junction between them, and no copper material was found within the fused area.

Other Information

Infrared Thermographic Inspection

Infrared thermographic inspection of electrical equipment can be used to detect electrical overloads and poor electrical connections. It has gained increasing acceptance as a valuable tool in the preventive maintenance of electrical equipment and is used by a number of vessel owners as part of the condition-based preventive maintenance program.

The Coast Guard has used infrared thermography as part of its Reliability Centered Maintenance program aboard its newest ice-breaking cutter, the *Healy*. The use of infrared thermograpy was discussed in a paper published in the Society of Naval Architects and Marine Engineers journal *Marine Technology*.[20] In a 1999 Merchant Note Guidance, the United Kingdom's Coast Guard advised ship owners, masters, and ships officers:

> In order to identify potential overheating situations in electrical equipment, owners are advised to consider the use of thermal-imaging techniques as a means of verifying the security of electrical connections and pinpoint problem areas at an early stage.[21]

Emergency Team Muster Location

The emergency squad muster location was a deck space painted yellow in the vehicle stowage area; however, during the fire, a car was parked in the space, and the fire team had to assemble around the car. Since the accident, the space has been designated a fire lane, and cars are no longer allowed to park there. Similar areas on other AMHS vessels have also been designated as fire lanes.

Public Address System

As a result of the accident, the AMHS purchased portable battery-powered public address systems for all of its vessels as backups for the installed public address systems.

[20] US Coast Guard, C *Healy* (WAGB 20), "A Case Study for Implementing Reliability Centered Maintenance." *Marine Technology*, Vol. 37, No. 1, January 2000, pp. 50-56.

[21] Maritime and Coast Guard Agency Merchant Guidance Note 132 (M+F), December 1999.

Survey of Equipment

At the Safety Board's request, the Columbia's engineering staff made a survey of all motor controllers and voltage transformers. The crewmembers found no problems that could be related to the switchboard fire.

Equipment Repair and Upgrading of Columbia *Systems*

The damage to the main switchboard was such that the vessel could not be operated without extensive and lengthy repairs. The owner removed the vessel from service. During the lay-up period, repairs to the switchboard and modifications to other systems were made by a shipyard facility in Ketchikan. The vessel returned to service in July 2001. Work performed during the shipyard repair period included the following:

- Replacing the switchboard, including repairing or replacing load cables within the switchboard;
- Installing a new dial phone system (existing sound-powered system is to remain on board);
- Replacing the public address system (According to an AMHS letter, as part of the already scheduled $l0 million+ Federally funded modernization project, the ship is getting an entirely new state-of-the-art, SOLAS-conforming public address and telephone system); and
- Inspecting the electrical system.

In June 2000, the AMHS issued Engineering Policy 034, which reads, in part:

> Due to the recent switchboard fire onboard the *Columbia*, all vessels are directed to include switchboard maintenance in their maintenance planning systems….As a fleet policy, cleaning and tightening fastenings of main and emergency switchboard should be done during the overhaul period at least every other year. On alternate years, all the electrical distribution boards should be maintained by cleaning and tightening fastenings. This maintenance work will normally be done by the crew.

In an April 5, 2001, letter to the Safety Board, the AMHS stated that it is installing a computer maintenance planning system, which will present the maintenance planning tasks in a uniform method throughout the fleet. With this program, the AMHS will have the ability to monitor the maintenance efforts of the engineering department on board all ships. As of the date of this report, the system has not been implemented and the AMHS could not provide an accurate timetable for implementation.

Analysis

General

This analysis first identifies factors that can be readily eliminated as causal or contributory to the fire and determines how the fire started. The report then discusses the following major safety issues, which were identified during the investigation:

- Adequacy of inspection and maintenance procedures for electrical systems;
- Adequacy of management safety oversight of maintenance procedures; and
- Adequacy of firefighting procedures.

Exclusions

The weather was mild and the seas were calm throughout the fire emergency and did not affect the emergency response. The officers and crew were properly licensed and certified by the Coast Guard and were fully qualified to serve in their respective positions. Postaccident drug and alcohol screening was done in a timely manner, given the circumstances, and the results were uniformly negative. Consequently, the Safety Board concludes that the conditions of the weather and the sea, the qualifications of the officers and crewmembers, and the use of drugs or alcohol were not factors in this accident.

Cause and Origin of Fire

In its investigation of the accident, the Safety Board considered whether a fault in one of the three areas of the electrical system (the load section, the distribution section, and the generation section) could have caused the fire. Because the damage to the switchboard was extensive, it is possible that important evidence might have been consumed or altered as a result of the fire or the firefighting efforts. Nevertheless, the Safety Board's investigation of the electrical system provided important information that the Board used to assess the probable cause of the fire. The investigation considered five scenarios that focused on the main switchboard and its protective devices, the auxiliary generators and their controls, and the electrical system equipment powered by the main switchboard. The hypothetical situations or conditions presented in the first three scenarios probably did not cause the fire; these situations are, therefore, discounted. The conditions in the last two scenarios are the most likely causes of the fire.

System Load Components

According to the first scenario, a malfunction occurred in one of the system load components. Such electrical system components include voltage transformers, motors or their controllers, and interconnecting wiring. A malfunction, such as a short circuit, in a connected component might have caused an increase in current flow that, in turn, might have resulted in temperatures high enough to damage the copper conductors or their insulation. An arc fault could have then developed and spread throughout the two switchboard units that were damaged in the fire.

The physical evidence does not support this scenario. After the accident, an examination of all motor controllers and transformers did not find any abnormal conditions that were related to the fire. Had there been a fault, evidence of its occurrence would have been visible. Such evidence could include visibly burned or melted insulation on wires, burned contacts in motor controllers, or damaged windings in electric motors. In addition, an excessively high current in any of the load cables connected to the output side of the breakers in the main switchboard would have discolored the copper conductors in the affected cable. An inspection of those cables revealed no discoloration. The Safety Board concludes that the fire was probably not caused by a fault in an electrical system component that was powered by the main switchboard.

Failure of Main Switchboard Breakers

According to the second scenario, a failure occurred in one of the main switchboard's breakers. For example, a breakdown in the electrical insulation between the electrical phases of the breaker might have initiated an arcing fault that could have spread to other areas of the switchboard bus bars. The physical evidence collected does not support this scenario. According to the vessel's chief engineer, most of the breakers had been installed at the time of the vessel's construction (1974) and had been largely trouble free. He stated that the breakers had been inspected periodically; however, the vessel operator did not maintain complete records of the work performed on the main switchboard breakers. The Safety Board, therefore, has no way of verifying the accuracy of the chief engineer's statement. Furthermore, because the manufacturer of the switchboard and the breakers is no longer in business, the Safety Board could not obtain the manufacturer's information on product reliability. Nevertheless, an inspection of the exterior and interior of all of the breakers in the main switchboard did not reveal any evidence of electrical arcing. The Safety Board concludes that the fire was probably not caused by a breaker fault.

Abnormal Condition in Electrical Generation System

According to the third scenario, an abnormal condition in the electrical system on the main switchboard's input side resulted in extremely high voltage or current. This could be caused, for example, by a malfunction of a generator or one of its control devices—the governor (speed controller), a load sharing device, or the voltage regulator. At the time of the accident, two generators were operating in parallel. If the voltage regulator on one of the generators malfunctioned, the generator might have become unstable or have reached an abnormal level of excitation, possibly resulting in an abnormally high voltage output from the generator or, if the compensation circuit was inoperative, an abnormal reactive current flow (cross currents) between the two generators. The development of high cross currents, however, would have required the simultaneous failure of at least two control devices (the voltage regulator or the governor and the compensation circuit), which is unlikely. In addition, because one of the generators became unstable first and the second generator became unstable only after the first was shutdown, an abnormal condition in the voltage regulators or governors probably was not responsible. If the voltage regulator or the governor controlling one of the generators had failed, the corresponding control device on the other generator would have acted in the opposite direction to maintain system voltage or frequency at a set point. Moreover, because a fuse protected the voltage regulator's current output to the exciter, only a limited level of excitation could occur. Consequently, the generator probably could not have developed the extremely high voltage needed to cause a current to arc through the air between adjacent phases (a spark jumping the gap).[22] Even without a fuse, a transient voltage spike of sufficient magnitude to create an arc that could jump the gap probably could not have been created. The generator's maximum output level was only slightly above 450 volts, and an output level in excess of 10,000 volts would be required to create an arc that could jump the gap.

Finally, if a high voltage condition had developed in the electrical system on the input side of the switchboard, electrical equipment breakdowns would have occurred in vessel areas away from the main switchboard. However, a postfire examination of the *Columbia*'s electrical equipment found no such breakdowns. The damage was limited to the main switchboard. The Safety Board concludes that the fire was probably not caused by an abnormal condition on the input side of the electrical system.

Electrical Connection in Switchboard

According to the fourth scenario, a faulty electrical connection within the main switchboard initiated an arc fault that grew and spread throughout two units of the main switchboard. Such a faulty connection could have resulted from a loose or corroded joint within the bus bars or circuit breaker tulip clips. A faulty electrical connection might have generated a high level of resistance that would have impeded current flow, causing the temperature to rise to the conductor's melting point. As the conductor melts, physical separation occurs within the conductor of one phase. At the moment of separation, an arc will develop, in a manner similar to the arc that occurs when a switch is opened while current is flowing in a circuit. If current flow is high enough, a plasma cloud[23] that develops as a result of the arc can expand to create a conductive path to an adjacent conductor of a different phase. The arc then becomes a phase-to-phase high impedance short circuit because the conductive path between the two phases is the plasma cloud, which has significant resistance. As the plasma cloud expands further, it can envelop other adjacent conductors, which can then become involved in the event.

[22] This voltage level, known as the dielectric breakdown strength of air, is empirically known and can be theoretically calculated using Paschen's Law.

[23] A plasma cloud is a collection of ionized atoms exhibiting some properties of a gas but differing from a gas in being a good conductor of electricity and in being affected by a magnetic field. A plasma cloud is the conductive medium through which an arc's electron flow occurs.

During postaccident examination, Safety Board investigators did not find any loose or faulty connections within the switchboard. However, an electrical arc, such as the type described above, probably would have destroyed the conductors in a faulty connection. The examination revealed that the connections in the *Columbia*'s switchboard were badly melted, precluding Safety Board investigators from identifying whether faulty connections existed before the fire. Despite the lack of conclusive evidence, the Safety Board is of the opinion that a faulty connection or connections likely caused the fire for several reasons.

That mechanical vibrations and thermal cycling gradually loosen electrical connections is well known. However, investigators found no evidence that the integrity of the switchboard's electrical connections had been inspected during the last 5 years, despite the switchboard manufacturer's recommendation that an inspection be done, at a minimum, every year or during vessel overhauls. In addition, although vessel crewmembers had used an infrared thermographic inspection program to detect faulty electrical connections, they had never used the program to inspect the switchboard's internal electrical connections. Therefore, a faulty connection within the switchboard could have developed and remained undetected for a considerable period of time.

Before the accident, during a shipyard overhaul, the *Columbia*'s main switchboard was modified to support the installation of new rescue boats. The work required that shipyard workers open the switchboard to add electrical connections and, in the process, disturb the connections that were already in place. The AMHS representative did not supervise this work or inspect it upon its completion. In addition, the ship's crew did not check the integrity of the electrical connections, either manually or thermographically. The modification work, therefore, could have created a faulty connection that would not have been detected by the owner's representative or the vessel's crew. The Safety Board, therefore, concludes that the fire might have been caused by a faulty connection within the main switchboard that initiated an arc fault, which spread within the two switchboard units and damaged them.

Conductive Object

According to the fifth scenario, a conducting object caused a short circuit connection between two phases in the distribution section of the electrical system. Any conductive object, such as a metal tool or a bolt, as well as a conductive liquid, such as seawater, could have created a conductive path. The arc would have grown and spread in the same way as the arc described in the fourth scenario.

The Safety Board materials laboratory performed metallurgical testing on the bolt found in unit 12 to evaluate whether it might have caused the arcing fault that swept through the switchboard. Of particular interest was how the washers were bonded to the bolt. If electrical current had passed through the bolt and washers, the high temperature would have fused them, much like welding, resulting in a layer of porous, molten steel between the component pieces. However, the metallurgical examination revealed that a layer of copper bonded the bolt and washers. The molten copper probably was deposited on the junction between the bolt and washer after the arc fault began and could have dripped down onto the bolt and washers from a unit that was higher in the switchboard. Safety Board technicians compared a bolt that they had intentionally arced to the bolt found in the switchboard. Although some external features of the two bolts appeared similar, the cross sections of the bolts differed.

For the bolt found in the switchboard, the copper that accumulated in the threads and between the washers and the bolt had little porosity and appeared to be consistent with molten flow. The edges of the washer and the threads were intact where the copper had accumulated. In contrast, the beaded areas in the intentionally arced bolt were porous and composed of molten steel. Also, the edges of the washer and the bolt's thread peaks were missing in locations where the molton material had accumulated, and there was an area of contact between the washer and the bolt. Because the damage to the subject bolt and washers was consistent with exposure to molten material, primarily copper, and did not appear consistent with arc damage, the Safety Board concludes that the bolt found in the switchboard was probably not the cause of the fire.

Whether or not this particular bolt caused the fire does not eliminate the possibility that the fire might have been caused by a conductive object falling on the bus bars. Electricians possibly inadvertently left a metallic object inside the switchboard during the last shipyard overhaul. Such a mistake would not have been detected because the owner's representative did not inspect the electricians' work. It is also possible that a conductive object had been left in the switchboard during some previous work period and remained undetected. Despite the fact that the investigation did not discover any conductive objects in the switchboard that could be definitely identified as causing a short circuit, this scenario cannot be ruled out because the conductive object might have been destroyed or altered beyond recognition as a result of the arcing and/or fire. The Safety Board, therefore, concludes that the fire might have been caused by a conductive object falling onto the switchboard bus bars.

Inspection and Maintenance Procedures For Electrical Systems

Preventive Maintenance Plan

Several preventive measures can be taken to discover or prevent faulty connections before they result in a fire. For example, faulty electrical connections in a switchboard often can be located and tightened during periodic maintenance inspections. A valuable addition to these inspections is the use of infrared thermographic imaging equipment that can uncover faulty connections that might not be visible to the naked eye. The *Columbia*'s main switchboard had not been inspected either manually or thermographically during the past 5 years. The chief engineer recognized the importance of inspecting and maintaining the switchboard, and placed the tasks on his annual winter lay-up worklist. Such tasks, however, were not given high priority and, therefore, were not completed. According to the chief engineer's best recollection, the last switchboard inspection had been performed in 1995, but he was not certain whether it was done even then.

Infrared thermographic inspection of electrical equipment is recognized as an important tool in locating improper connections and preventing switchboard fires. Infrared imaging of the *Columbia*'s switchboard could not be readily performed because its design arrangement prevented a full view of the electrical connections in the switchboard. Full views of the internal connections possibly could be obtained by installing access panels on the rear side of the switchboard. The Safety Board concludes that the use of suitably located access panels on the *Columbia*'s switchboards would facilitate infrared thermographic inspections and, therefore, help detect faulty electrical connections.

After the accident, the AMHS issued an engineering policy letter directing the crews of all vessels in its fleet to clean and tighten the electrical connections in the main and emergency switchboards not less than every other year. The switchboard manufacturer had recommended that such cleaning and tightening be performed, at a minimum, every year or during vessel overhauls. The Safety Board recognizes that the manufacturer's recommended inspection interval might be based on operating time and that the *Columbia* typically operates about 6 months a year. This means that it would take the ferry 2 calendar years to attain 1 year of operating time.

During half of the year, however, the *Columbia* is taken out of service, which affords the AMHS ample time and opportunity to perform switchboard maintenance. The Safety Board, therefore, considers an annual examination consistent not only with the manufacturer's recommended inspection interval but also the ferry's operation.

In spite of the manufacturer's recommending an annual inspection, the AMHS had not cleaned or tightened the switchboard connections during the 5 years before this accident. Had the switchboard had faulty connections, they would have remained undetected until they became apparent through an equipment malfunction or fire. Thus, it is apparent that thorough and timely inspection of electrical switchboards is necessary for continued safe operations. The Safety Board concludes that had the main switchboard been subjected to thorough and timely inspections as part of an effective preventive maintenance program, any faulty connections or conductive objects would have likely been identified and corrected, and the fire might have been avoided. Therefore, the Safety Board believes that the AMHS should develop an annual switchboard inspection program that includes a thorough infrared thermographic inspection and physical examination of components. In addition, the AMHS is in the process of implementing a computer-based maintenance program that could address the problem of loose connections in the switchboards. In the Safety Board's opinion, the maintenance of switchboards should be included in this computer-based program. The Safety Board, therefore, believes that the AMHS should include an annual switchboard inspection program in its computer-based maintenance planning system.

Quality Assurance Program

Quality assurance is the planned and systematic pattern of actions, including inspections, performed by the vessel owner to determine whether a contractor has fulfilled contract obligations pertaining to the quality and quantity of work.[24] The AMHS included general quality assurance requirements in its agreements with contractors; the agency clarified the nature of the general requirements through individual specifications associated with each work item. Because the main switchboard is the central point for receiving and distributing all electrical power throughout a vessel, it is critical to the vessel's operation. Therefore, any contract work on the switchboard should be subjected to quality assurance inspections. However, for unknown reasons, the AMHS did not include switchboard inspections in its contract with the shipyard. The AMHS had not required the shipyard to present the switchboard for inspection or required the vessel's crew or the agency's port engineering staff to inspect the work before the switchboard was returned to service. The shipyard's electrical foreman stated that he inspected his subordinates' work upon completion; however, he did not do so at the direction of the AMHS. The Safety Board concludes that a thorough inspection of the interior of the switchboard by the AMHS and the port engineering staff before it was returned to service might have detected the presence of faulty connections and/or foreign objects and led to their correction and/or removal. Consequently, the Safety Board believes that the AMHS should revise its procedures for accepting completed shipboard maintenance and repair performed by outside contractors to verify that the work has been done properly.

Firefighting Procedures

Actions of the Columbia's *Crew*

Upon discovering the fire, the on-scene engineers rapidly accounted for crewmembers in the engineroom and notified the master. They also obtained, staged, and used the CO_2 extinguishers, secured the ventilation, and isolated the smoke and fire by closing the control room's fire screen door. The Safety Board concludes that the initial response to the fire by the shipboard engineers was appropriate. However appropriate the engineers' initial actions were in this accident, the Safety Board is concerned that the crew's subsequent actions were somewhat haphazard and improvised as they went along. The crew's actions did not reflect the type of performance that would be expected from properly planning, training, and drilling for a fire in the control room.

The emergency response organizational structure for the *Columbia* was provided in the crew muster list, which showed each crewmember by position and identified his/her station and duty assignment during a fire or other emergency. Generally speaking, a muster list summarizes a crewmember's duties and responsibilities in one line of text and is designed to provide officers and other crewmembers with a quick guide to the emergency duty assignments. A muster list does not go into any depth on individual roles and responsibilities or give details about policies, procedures, and plans for responding to shipboard fires. A prefire plan, on the other hand, provides such vital information; however, prefire plans are not required by regulation, and not all vessels have developed such plans. The *Columbia* had a prefire plan, but it was not comprehensive. The *Columbia*'s fire plan merely provided a brief description of the vessel's firefighting resources and listed the locations of access doors and fire stations. The plan did not

[24] Adapted from the quality assurance definition at 48 CFR 46.101, "Federal Acquisition Regulations."

describe the vessel's firefighting organization or specify the crewmembers' firefighting roles and responsibilities. Moreover, the plan did not describe in detail how to fight fires in specific parts of the vessel.

A properly developed comprehensive prefire plan describes various fire scenarios in different spaces on the ship and how to fight the fire in each situation. The plan fully describes the roles and responsibilities of the emergency responders and establishes the chain of command for firefighting operations. Responsibility for strategic and tactical command is made clear and unambiguous for all foreseeable situations, including fires on the decks and in the engineroom. If necessary, separate and distinct organizations are created to respond to fires on deck and fires in the engineroom. In addition, the prefire plan contains checklists for emergency actions, procedures for shutting down the electrical power and closing the ventilation to the various ship areas, as well as instructions for establishing fire boundaries and for maintaining watertight integrity. With a prefire plan, predetermined actions for responding to a fire in a given space or compartment are developed in a nonurgent atmosphere, where one is more likely to exercise good judgment. Then, if a fire develops, the officers in charge can refer to the plan and take appropriate action. However, as noted by one authority,[25] "The most comprehensive and well-designed prefire plans are of little value if they are not used for training and they are even less valuable if they are not used when a fire actually occurs."

The *Columbia*'s muster list designated the master as the person in charge from the bridge and the chief mate as the person in charge of the emergency squad on scene, but the list did not elaborate on their respective duties and responsibilities. The list indicated that the emergency squad consisted of unlicensed deck crewmembers on two hose teams and other unlicensed personnel providing backup and support. The list did not indicate that a separate emergency squad was to respond to engineroom fires or that engineroom personnel were assigned to hose teams. Further, the *Columbia* had not held a training drill featuring a response to an engineroom fire during the 2 years before the fire.

The muster list designated the chief engineer to be "in charge" of the engineroom and to supervise the release of the CO_2 system protecting the engineroom should such release be necessary. However, his role in responding to an engineroom fire was not spelled out in any detail. The other engineering officers were variously designated to tend bilge and fire pumps, operate sprinkler systems, and shut down ventilation systems, but were not listed as having any specific firefighting responsibility. The off-watch third assistant engineer and the off-watch junior engineer were the only engineering officers detailed to work with the emergency squad, and their roles were limited to bringing tools to the emergency locker.

According to the muster list, the emergency squad, under the command of the chief mate, should have fought the *Columbia*'s fire. However, the emergency squad was made up mainly of deck department personnel who were unfamiliar with the engineroom and who had never participated in a fire training drill in the control room. The lack of lighting

[25] *Marine Fire Fighting*, First Edition, International Fire Service Training Association, Copyright 2000 by the Board of Regents, Oklahoma State University, pp 261.

and the presence of large quantities of black smoke, which reduced visibility in the control room to nearly zero, complicated their firefighting efforts. The engineers, on the other hand, were very familiar with the layout of the control room. They, logically, should have assumed the lead in fighting this fire. However, the lack of a comprehensive prefire plan detailing firefighting roles and responsibilities, coupled with the lack of a squad trained to fight engineroom fires, reduced the crew's capability to fight the fire effectively.

In response to the fire, the chief engineer sent the day third engineer without a lifeline into the control room to open the bus tie circuit breaker between the main switchboard and the emergency switchboard. Upon encountering difficult conditions, the day third engineer backed out in order to get a lifeline. He and the first assistant engineer then entered the control room to open the circuit breaker between the main and emergency switchboards and the circuit breakers between the ship's auxiliary generators and the main switchboard. Both men wore SCBAs borrowed from the emergency squad, but neither wore protective clothing. In the Safety Board's opinion, sending crewmembers who were not properly clothed in protective gear into an active fire scene needlessly exposed them to serious injury and demonstrated poor decisionmaking on the part of the chief engineer.

The first assistant engineer opened two circuit breakers by hitting them with his flashlight, which was an imprudent action. Considering the electrical arcing activity and the fire in the switchboard, the poor visibility within the control room, and his choice of tool for the job, only happenstance prevented his being seriously injured. In the Safety Board's opinion, the actions of the first assistant engineer indicated a lack of proper training in fighting a switchboard fire.

After the first assistant opened a third circuit breaker, he and the day third engineer backed out of the control room, and the chief engineer decided to manually shut down the No. 1 auxiliary generator, which was still powering the switchboard. In the Safety Board's view, manually shutting down the generator to remove electrical input to the switchboard was the course of action that should have been taken in the first place. Manually shutting down the generator is much safer than sending a person into a dark, smoke-filled room to open a bus tie circuit breaker.

Once the engineers had notified the bridge of the fire and the general alarm had been sounded, a firefighting team that was trained in the techniques of combating an electrical fire should have led the response to the fire in the control room. Such a team probably would have extinguished the fire more quickly and with minimum risk. This accident demonstrates that, because engineers have the specialized knowledge and expertise needed to effectively fight engineroom fires, they should be an integral part of a vessel's firefighting team.

In the Safety Board's opinion, if the *Columbia* had had a comprehensive prefire plan that included procedures for fighting a control room fire and if the crewmembers had been properly trained and drilled in the execution of the plan, they would have known exactly what to do from the outset. If the firefighting roles and responsibilities of the various crewmembers had been predetermined and drilled, the main switchboard would have been electrically isolated quickly and completely, and the engineers would not have been sent into the control room without proper gear. The danger to firefighters would, thereby, have been diminished; and the fire might well have been extinguished sooner. The Safety Board concludes that the ability of the *Columbia*'s crew to respond to the fire was less than adequate for the following reasons: the AMHS had not developed a comprehensive prefire plan that included procedures for fighting engineroom fires, and the AMHS, during the past 2 years, had not required that crewmembers train and drill for an engineroom fire. Therefore, the Safety Board believes that the AMHS should develop comprehensive prefire plans for the vessels in its fleet that include procedures for fighting an engineroom fire and require the ships' crews to be thoroughly drilled in using the plans.

Coast Guard Actions

One of the primary reasons why the *Columbia*'s crewmembers were required to complete firefighting training and drills was so that they could control and extinguish an onboard fire in the absence of outside help. This ability is critical to all passenger ship crews because, when underway, such vessels might be too far from shore or other vessels to receive outside firefighting assistance.

The Coast Guard cutter *Anacapa* just happened to be in the area and its crew not only rendered assistance, but also extinguished the reflash of the fire.

The Coast Guard firefighters were well organized and well prepared. They were properly equipped with protective clothing and oxygen breathing apparatuses. Furthermore, they assessed the fire before entering the control room, planned how they would approach the fire, rotated fire teams to reduce each individual's exposure and fatigue, and maintained two firefighters at the control room door to monitor the safety of those inside. Because the engineers were not properly outfitted with protective clothing and gear, the Coast Guard firefighters did not allow them to remain in the control room. The Safety Board concludes that the Coast Guard's actions in responding to the fire were timely and effective.

Firefighters' Staging Area

When firefighters assembled on the car deck, one deck above the engineroom, a car was parked in their staging area. Before this accident, the AMHS had not designated the space as a fire lane and had no policy precluding cars from parking in the space. After the accident, the AMHS designated the area as a fire lane and established a policy prohibiting cars from parking in the space. According to an AMHS representative, the problem of allowing cars to park in the emergency squad staging area existed on other AMHS vessels, but has since been rectified in the same manner. The Safety Board concludes that the actions taken by the AMHS after the fire to ensure that emergency squad muster areas were kept clear for use in an emergency were appropriate.

Means of Communication in Engineroom

When fire and smoke forced the oiler and junior engineer to evacuate the control room, they were unable to alert the bridge immediately because the only telephone in the engineroom was in the control room and no manual fire alarms were in the engineroom.

Fortunately, the oiler and the junior engineer were able to escape from the engineroom. Subsequently, the day third engineer was able to call the bridge from the car deck. In the Safety Board's opinion, having a single telephone with which to communicate from the engineroom to the bridge is inadequate to ensure communications during an emergency. Even though the telephone system on board the *Columbia* has since been upgraded, the main engineroom still has no means of communication outside of the control room. The Safety Board concludes that the means of contacting the bridge from the engineroom was less than adequate once the telephone in the control room became inaccessible. The Safety Board believes that the AMHS should install a means of alerting the bridge of an emergency from the *Columbia*'s engineroom in case the telephone in the control room is inaccessible.

Passenger and Crew Muster

Because the passengers were given a safety briefing after boarding the *Columbia*, they knew how to locate and don their lifejackets and how to report to their muster stations if the general alarm was sounded. Passengers were also provided with safety information on placards posted throughout the ship. The muster of passengers and crewmembers was performed in accordance with emergency procedures. Because the passengers were well briefed on the procedures, muster leaders were able to assemble the passengers in an orderly fashion. The master was in command of mustering operations, and the chief purser accounted for passengers and crewmembers in accordance with her responsibilities as indicated on the muster list. The chief steward carried out his duties by ensuring that the cabin stewards searched cabins. Because a separate radio frequency was used to muster the passengers and the crew, the master was able to relay information through the pilot to the chief purser and chief steward without interfering with firefighting operations. The Safety Board concludes that the passenger and crew muster was well coordinated.

Passenger and Crew Communication

The public address system became inoperable after the *Columbia* lost power, forcing crewmembers to provide information to the passengers by walking through the muster stations and speaking loudly. The crewmembers did not use any portable equipment to amplify their voices. In postaccident surveys, 43 passengers stated that they had had difficulty hearing the crewmembers' announcements. Following this accident, the AMHS supplied all its vessels with portable battery-powered public address systems as backup for the main address system.

Before the *Columbia*'s fire, the AMHS had scheduled the replacement of the older public address systems in its fleet as part of its SOLAS 2000 upgrade. After the accident, the older public address system on the *Columbia* was removed and replaced with a new system. The Safety Board is satisfied that this action will probably eliminate future public address problems during shipboard emergencies.

Emergency Response

An emergency response team led by the AMHS general manager assisted the *Columbia*'s master, the *Taku*'s master, and the Coast Guard's SAR controller in developing a method of safely conducting and coordinating the transfer of passengers and crew from the *Columbia* to the *Taku*. The *Columbia*'s crewmembers constructed a ramp between the ships. Both sides of the ramp had safety lines, and passengers and crewmembers were required to don lifejackets before walking over the ramp. Crewmembers assisted passengers during the transfer. As an added safety precaution, the *Taku*'s chief mate stationed himself in a small boat beneath the ramp to be in a position to help if anyone fell into the water. The procedures worked well, as evidenced by the fact that all passengers and crewmembers were transferred quickly and without injury. The Safety Board concludes that the transfer of passengers between the *Columbia* and the *Taku* was executed in a timely and effective manner and was well coordinated with shoreside management.

Conclusions

Findings

1. The conditions of the weather and the sea, the qualifications of the officers and the crewmembers, and the use of drugs or alcohol were not factors in this accident.
2. The fire was probably not caused by a fault in an electrical system component that was powered by the main switchboard.
3. The fire was probably not caused by a breaker fault.
4. The fire was probably not caused by an abnormal condition on the input side of the electrical system.
5. The fire might have been caused by a faulty connection within the main switchboard that initiated an arc fault, which spread within the two switchboard units and damaged them.
6. The bolt found in the switchboard was probably not the cause of the fire.
7. The fire might have been caused by a conductive object falling onto the switchboard bus bars.
8. The use of suitably located access panels on the *Columbia*'s switchboards would facilitate infrared thermographic inspections and, therefore, help detect faulty electrical connections.
9. Had the main switchboard been subjected to thorough and timely inspections as part of an effective preventive maintenance program, any faulty connections or conductive objects would have likely been identified and corrected, and the fire might have been avoided.
10. A thorough inspection by the Alaska Marine Highway System and the port engineering staff of the interior of the switchboard before it was returned to service might have detected the presence of faulty connections and/or foreign objects and led to their correction and/or removal.
11. The initial response to the fire by the shipboard engineers was appropriate.
12. The ability of the *Columbia*'s crew to respond to the fire was less than adequate for the following reasons: the Alaska Marine Highway System (AMHS) had not developed a comprehensive prefire plan that included procedures for fighting engineroom fires, and the AMHS, during the past 2 years, had not required that crewmembers train and drill for an engineroom fire.
13. The Coast Guard's actions in responding to the fire were timely and effective.

14. The actions taken by the Alaska Marine Highway System after the fire to ensure that emergency squad muster areas were kept clear for use in an emergency were appropriate.
15. The means of contacting the bridge from the engineroom was less than adequate once the telephone in the control room became inaccessible.
16. The passenger and crew muster was well coordinated.
17. The transfer of passengers between the *Columbia* and the *Taku* was executed in a timely and effective manner and was well coordinated with shoreside management.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the fire on the *Columbia* was the absence of an effective maintenance and inspection program for the electrical switchboards, resulting in a switchboard fire by arcing, most likely due to a faulty connection or a conductive object.

Recommendations

As a result of its investigation of this accident, the National Transportation Safety Board makes the following recommendations:

To the Alaska Marine Highway System:

Develop an annual switchboard inspection program that includes a thorough infrared thermographic inspection and physical examination of components. (M-01-19)

Include an annual switchboard inspection program in your computer-based maintenance planning system. (M-01-20)

Revise your procedures for accepting completed shipboard maintenance and repair work performed by outside contractors to verify that work has been done properly. (M-01-21)

Develop comprehensive prefire plans for the vessels in your fleet that include procedures for fighting an engineroom fire and require the ships' crews to be thoroughly drilled in using the plans. (M-01-22)

Install a means of alerting the bridge of an emergency from the *Columbia*'s engineroom in case the telephone in the control room is inaccessible. (M-01-23)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

CAROL J. CARMODY
Acting Chairman

JOHN A. HAMMERSCHMIDT
Member

JOHN J. GOGLIA
Member

GEORGE W. BLACK, JR.
Member

Adopted: September 18, 2001

Appendix A

Investigation

The National Transportation Safety Board was notified of this accident at 1245 on June 7, 2000, and launched a 9-person team that arrived in Juneau, Alaska, at 0700 on June 8. The investigative team consisted of an investigator-in-charge, an operational specialist, a marine engineer, a fire science specialist, a human performance specialist, a survival factors specialist, and a family affairs specialist. Also present were a public affairs specialist and an observer from the Office of General Counsel. The on-scene investigation was conducted between June 8 and 20, 2000. No Board Member participated in the on-scene phase of the investigation. Assisting the Board with the investigation were an investigator from the Anchorage Office of the Bureau of Alcohol, Tobacco and Firearms, a fire marshall from the Alaska Department of Public Safety, and a research engineer from Johns Hopkins University Applied Physics Laboratory who was under contract to the Board.

The Safety Board investigated the accident under the authority of the Independent Safety Board Act of 1997 and according to Safety Board rules. The designated parties to the Safety Board's on-scene investigation were the Coast Guard, the Alaska Department of Transportation and Facilities, the Alaska Department of Public Safety (Division of Fire Prevention), and the Alaska Ship and Drydock Company.

The team viewed the damage on the *Columbia* and conducted over 30 interviews in Juneau and Ketchikan, Alaska. The witnesses included the management of the AMHS and the Alaska Ship and Drydock Company and the officers and crew of the *Columbia, Taku,* and *Anacapa*.