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National Transportation Safety Board
Washington, DC

Engineering Group Chairman's
Factual Report

National Transportation Safety Board
Office of Marine Safety
Washington, DC 20594-0003

February 6, 2001

Engineering Group Chairman's Factual Report

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A. Accident Information

Location:	Juneau, Alaska
Date:	June 6, 2000
Time:	1207 Alaska daylight time (ADT)
Vessel:	*M/V Columbia*
Case number:	DCA-MM-00-030

B. Engineering Group

Group Chairman

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C. Summary

About 1207 local time, while underway from Juneau, AK, to Sitka, AK, the passenger vessel *M/V Columbia* experienced a fire in the main electrical switchboard located in the engine room. On watch in the engine room were a third engineer, an unlicensed junior engineer, and an oiler. The unlicensed junior engineer and the oiler were in the control room at the port side of the switchboard when the fire broke out on the starboard side of the switchboard. The third assistant engineer was on the lower level of the engine room making an inspection round of the engine room machinery. The fault in the main switchboard developed very quickly, and control room filled with thick black smoke. Fortunately, the unlicensed junior engineer and the oiler were able to escape through a nearby door without injury. The smoke was mostly contained within the control room by the smoke-tight integrity of the engine control room space. Because of the fire, the vessel immediately lost propulsion and normal lighting, and began to drift. The steering gear units were powered from the emergency switchboard so power was restored to them as soon as the emergency diesel generator started. Upon reduction of voltage at the main switchboard, the ship's emergency generator started and began to provide power to critical loads connected to the emergency switchboard, including communication equipment and a limited amount of lighting throughout the vessel.

With the assistance of four firefighters from a nearby Coast Guard cutter that responded to the M/V Columbia's distress call, the ship's crew was able to extinguish the fire within a short period of time. The fire was contained within of the main switchboard by its steel enclosure, and the fire damage to the control room was minor in extent. However, the smoke damage to all equipment located within the engine control room was extensive.

Passengers from the *M/V Columbia* were transferred at sea to the *M/V Taku* and were returned to Juneau by the *M/V Taku*. The tug *Banner* took the *M/V Columbia* under tow at 1630, and they arrived in Juneau about 0845 the next day.

D. Details of the Investigation

1. Accident Events

1.1. Activities of the engineering watch crew before the fire. According to statements made by engine room watch personnel during interviews conducted by investigators on scene after the accident, the following is a summary of the activities of the personnel on watch in the engine room at the start of the fire (the third assistant engineer, the unlicensed junior engineer, and the oiler). Some time before the watch was relieved at noon, the third engineer on watch engine room heard a rattling noise in the main switchboard near units 10 and 12. He investigated the source of the noise, but could not determine its source. In interviews after the fire, the chief engineer discounted the relevance of the noise to the cause of the fire because there are often rattle noises in the machinery space that were normal and of no significance, and because the third engineer was new to the vessel he would not have been attuned to the normal rattles in the machinery space. The engine room watch had been relieved just before noon, around 11:30 am. The vessel was underway at sea speed with both main engines in operation. Both the number 1 and number 2 ships diesel generators where in operating in electrical parallel, and the number 3 auxiliary diesel generator was shut down. After relieving the watch in the engine control room, the unlicensed junior engineer made an inspection round of the MSD (marine sanitation device) in the crew quarters, and then returned to the engine control room. The oiler also made an inspection round of the machinery spaces and returned to the engine control room. The third engineer then began his inspection tour of the machinery spaces. While the third assistant engineer was outside the control room making his round of the machinery spaces, the unlicensed junior engineer and the oiler remained in the control room talking with each other. They were located at the port side of the control room, near the log desk. A fire and boat drill was scheduled to occur at 1230 and they were standing-by for the start of the drill. All watch personnel stated that they did not observe any abnormal conditions in the engine room before the start of the fire during their inspection rounds. The engine room alarm log printout indicates that there were no abnormal alarms active before the start of the fire. The last alarm to activate (ACT) before the start of the fire was "#1 Compressor Running" at 11:46, and that alarm was cleared (CLR) at 11:57. The next alarm to activated (ACT) was "PME [Port Main Engine] overspeed tripped" at 12:07:48, which signaled the start of the fire event and represented a loss of voltage to that safety device. According to the alarm log printout, a large number of other alarms followed in rapid succession, about 20 alarms activated within about 1 minute after the first alarm that occurred at 11:07:48.

1.2. Activities of other key off-watch engineering crew before the fire. According to statements made by other engine room personnel during interviews conducted by investigators on scene after the accident, all off-watch licensed engineers were in the mess hall having their lunch shortly before noon.

1.3. Activities of the engineering crew after the fire started. During interviews by investigators, both the unlicensed junior engineer and the oiler described the start of the fire event in similar terms. They reported that they saw a bright arc and sparks emerge from the upper portion of the switchboard section at its starboard end (unit 12). During the interview, the on-watch unlicensed junior engineer stated:

> And we were talking and pretty quickly -- it was kind of weird sound -- it wasn't that loud, but it was a disruptive sound, kind of a "poof" and then it just ..., and it's like somebody's running an arc welder, a big arc welder. And the number one panel lit up, sparks come out the top of the panel, across the roof, bouncing off of the forward bulkhead and then they start coming out the bottom of the panel and out the holes around the breakers, and it wasn't probably a split second, it moved down to the second panel. By this time, the first panel was started to smoke and there was fire coming out of it. The second panel lit up and the noise got louder. By that time, I grabbed Lee by the collar and said, "Let's get the hell out of here."

The oiler on watch stated in a separate interview:

> I don't really know how to explain it because the panel, the electrical panel, nearest to the entrance door into the control room, just, basically, just exploded out of the top of it. Fire and smoke and just a pretty loud roar. I turned and looked over my left shoulder at it and it wasn't but just a second at the very most when the second panel toward us did the same thing before I could even get out of the chair. It looked like it was coming right down the panel towards us and we left the control room, out the door on the other end of it ...

After the unlicensed junior engineer and oiler exited the engine control room through the port side fire screen door, the unlicensed junior engineer told the oiler to call the bridge and report the fire. The unlicensed junior engineer then began to look for the third assistant engineer to inform him of the problem.

Meanwhile, the third assistant engineer on watch was in the machinery spaces making an inspection round, when he noticed the number 2 generator surging and moving erratically on its foundation. (See figure 1.) There were three identical auxiliary diesel generators installed side by side in the auxiliary machinery room, which was adjacent to the main engine room. In the interview he stated:

> I was checking out the main generators and I noticed number two generator started acting erratic. It was shaking erratically, it was shaking erratically and it was having intermittent speed. It would go from a slower speed to a higher speed and it was shaking and rattling ...

After he saw the generator operating erratically, the third assistant engineer went to the engine control room to see if he could determine the cause of the erratic operation. He described his observations and actions as follows:

> ... so I ran up to go and see what the problem was and then, when I got up to the -- I also noticed the lights dimming, brightening up, dimming, changing the tone -- I ran up to the control booth, that's when I opened the door and I saw fire coming out of the first panel closest to the starboard door, as you're goin' in. I also had seen, heard a large popping sound and seen the panels coming, sort of coming off the side of the breaker board ...

The unlicensed junior engineer found the third assistant engineer near the starboard door to the engine control room and saw that he was carrying a CO_2 fire extinguisher. The unlicensed junior engineer told the third assistant engineer not to renter the space to attack the fire, that it was contained and was not going anywhere. In the interview the unlicensed junior engineer stated:

> [the third assistant engineer] was just coming up the stairs, I grabbed him, he had a Co2 bottle. I told Dan, I said, "Don't open the door." I said, "Man, it's hot." I said, "Just leave

> the door closed." I said, "It's in the room, just leave it closed, don't give it any air." I said, "Let's get it shut down and get all the power shut off."

The third engineer then returned to the lower level of the auxiliary machinery room and shut down the number 2 auxiliary generator. He then began to stage fire fighting equipment at the starboard fire screen door of the engine control room. He allowed the number 1 auxiliary generator to continue to run.

According to statements made by the off-watch and day working engineers (chief engineer, first assistant engineer, day third assistant engineer, and second assistant engineer), they were having lunch in the mess hall at the time of the fire when the lights begin to flicker shortly after 12:00 noon. They believed that there was a problem with the electrical generators in the engine room, and they dropped their forks and headed for the engine room to investigate. The chief engineer stated that he heard the ventilation fan motors slowing down and the emergency diesel generator start. The first assistant engineer stated that he noticed that the lights flickered for a longer period if time than would have been expected in a situation where there had been a loss of normal power to the main switchboard. In his interview he stated:

> The emergency generator is on the mess deck, just around the corner, and we could hear that come on. And I noticed that the lights were still flickering. And normally when that generator takes over, then the lights will steady out and that generator takes over the load. But, I noticed that they just kept dimming and coming back on and dimming and coming back on. So, I made a beeline over to the emergency generator room, to make sure it was working okay. And so, I just looked inside, everything was running, and I looked at the gauges and then I went right down to the engine room.

The day third assistant engineer stated that he when he arrived in the engine room he encountered the on-watch oiler and the oiler told of a fire in the engine control room. The day third assistant engineer then went to the nearest phone to notify the bridge of the fire in the engine room. However, the day third assistant engineer had to leave the engine room to raise the alarm because there was not a phone or a fire alarm in the engine room. In his interview he stated:

> And the thought in my mind was I need to initiate a fire alarm, I need to initiate some communications to the bridge. And I kind of did a little spin and then I, as I was leaving the engine room, I realized, number one, we don't have a fire pull, we don't have access to a general alarm, and we don't have access to a fire alarm. We have access to no phone outside of that booth. So, my world was crashing around me at that point, ...

When the chief engineer arrived in the engine room he met the third assistant engineer on watch. The third assistant engineer was stretching out fire hoses from the auxiliary machinery room, and he had already staged several CO_2 fire extinguishers near the starboard door to the engine control room. The chief engineer assessed the situation in the engine room and noticed that the number 1 generator was operating erratically. In the interview he stated:

> And immediately, while I went in there to check to the scene, checked around the area to see that everything – what the generators are doing, what the casualty looked like in there, number one I saw was still on-line and it looked like it was starting to shake a little bit too. I wanted to hear it to see if it sounded like it was overloading. It did sound like it was overloading.

After feeling the fire screen door on the starboard side of the engine control room for heat build-up, the chief engineer then opened the door and saw heavy black smoke, but no fire. He immediately closed the door and began directing his and his crew's attention to checking the engine room, securing the main engines, securing the fuel oil and lube oil centrifuges, securing the fuel oil isolation valves, and starting a fire pump.

The fire team began to assemble fire fighting gear at the scene and the ships fire team suited out. The one of the fire team members reported to the control room and the engineers decided to attack the fire rather than letting the ships fire team enter the engine control room. The first engineer stated in his interview:

> And then one of the deck crew was all suited up too, and that was, he was all suited up, but we didn't want to send him into the control room, because he wasn't familiar with the location of the breakers and all of that. So, we decided that we should go in ourselves.

The chief engineer became concerned that the emergency diesel generator was continuing to feed electrical power to the main switchboard, so he decided to send the day third assistant engineer into the engine control room to open the bus tie breaker between the main switchboard and the emergency switchboard. The day third assistant engineer, under the direction of the chief engineer attempted to make entry into the engine control room, but after entering the space became concerned about his own safety and felt the need to have a lifeline attached to him. Therefore, he withdrew from the space and requested that he be given a lifeline. In his interview the day third assistant engineer stated:

> ... The Chief opened the door, and it was real dark in there. So, I dropped down as close as I could get to the deck, and I knew exactly where the bus tie was, I wasn't, I didn't feel any danger or any problems with for myself, I was just worried about getting the ship in a safe and secure mode. So, I crawled 15 feet into the booth and I am running into the chair and I know pretty much I am close to where the engineer sits, I am kind of judging where my bus tie is. And I turn the flashlight to my face mask and I couldn't see the light, so I said, oh, boy, you are in deep trouble. So, I said, let's get out of here, to myself, backed out, and I told the Chief, I said, I need a life line so I can get my butt out.

Around this time, the first assistant engineer joined the efforts of the third assistant engineer to enter the space. The chief engineer had noticed the number 1 auxiliary diesel generator was operating erratically. In addition, he was concerned that one of the diesel generators may have been supplying electrical power to the main switchboard, and he directed the first assistant engineer and day third assistant engineer to enter the engine control room and make sure that the bus tie from the emergency diesel generator was open and that the auxiliary diesel generator breakers were open. In his interview, the chief engineer stated:

> I told them, I says, "Look, everything looks pretty good. The generator's still running, but it's starting to act funny. I need to get that generator off the line. I think it's still supplying the bus." And I said, "there's, if we can get in there," since they were suited up, I said, "go on in there and see if you can see the auto transfer switch. If it's still closed, open it, that will kill the board and if you can check the generators and if it's not off the line, try to trip them off the line."

Suited out with a SCBA (self-contained breathing apparatus), the first assistant engineer and the day third assistant engineer made entry into the space through the starboard side fire screen door on their hands and knees. The day third assistant engineer reached out to open the bus tie breaker and stated that he hand was knocked back by a blue arc. In the interview he described his actions in the control room as follows:

> I had the lead on the life line, so I went first, and Glen was behind me, the Chief held the door open, I dropped down on my hands and knees and my elbows, and crawled head long straight into the booth. At that point I am just nervous because this could get away from us. And I said, we are in deep [trouble]. And as I was passing the breaker panels, I could hear them crackling and popping and I am not sure if it was arcing, I can't put a finger on that. I can't put a finger on any flash of electrical light. And I am close to the, I know I am close to the breaker panel and I am just moving forward and I have got the chair on my left and I know where I am at, and I am dropped down as far as I can get and I am

> trying to shine the light on the panel, so I can get this particular switch that I am trying to get to, is encased or in, outlined in yellow and black tape ... And I find it, so, I move forward and I reach to touch it and I got about maybe three, four inches away from the panel, and I got a blue arc to my hand, and I knocked my hand back. And I turned to Glen and I yelled, I said, panel is hot, don't touch it, the panel is hot. He crawled over the top of me, and hit the breaker with the flashlight, thus opening the breaker. And I yelled to him, I said, let's go, and he turned to go and he reached up and hit two more breakers. We moved further towards the door, we know where we are at, he hit another breaker and it exploded.

The first assistant engineer described his entry into the engine control room with the day third assistant engineer as follows

> And we got to the approximate location and started shining the light and it is marked with the yellow strips. So, I knew that was the one. And I think Stan reached for it first, but he has told me that he saw some blue spark that made him pull away from it, with his hand. So, I reached over with the butt of the flashlight, and hit the breaker with that. And then we started to back out and there was still breakers that were close, so I just kept hitting those with the butt of the flashlight, and probably broke the bulb because the light went out. But, the third breaker that I hit sparked, it was a pretty big spark. So, we decided that that we should back out, and not attempt to open any more breakers. And when we got out, I had a discussion with the Chief about just killing the generator, turning the, hitting the stop switch on that generator so we don't have that power secure for that bus and to that board. And that is when we turned that generator off.

The chief engineer then decided that to shut down the number 1 auxiliary diesel generator. In his interview he stated:

> I made the decision and went on down there to kill the number one generator to make sure it was off the line. I knew if was off the line. And the auxiliary generator, and the uh, emergency generator was just supplying the emergency bus. At that time, I went down there, shut off the generator, came back up again and then we were just fighting fire from there on.

The first assistant engineer stated that he then returned his attention back to the engine room machinery. The day third assistant engineer assisted him. They began to arrange the starboard main engine for starting in case the vessel needed propulsion to avoid grounding. The first assistant engineer stated that the starboard main engine auxiliary equipment motors are supplied from the emergency switchboard and could be started without power from the main auxiliary diesel generators. When he attempted to start a fire pump to supply cooling water to the main engine he was unable to immediately do so. He instructed one of his subordinates to find the motor control cabinet for the fire pump, and then told the chief mate that he was not able to supply fire main pressure. The first assistant engineer then began assisting once again with the fire fighting efforts.

The first engineer stated that the lights continued to go from bright to dim repeatedly for an extended period of time, perhaps until the number 1 auxiliary diesel generator was shut down by the chief engineer. In his interview he said:

> They flickered a few times when we were down there. And I couldn't say exactly when they did settle out. Because there are lights down there that will, aren't on the E circuit, they are just on the main generator. And I couldn't say whether they were all out at that time and it was just on the emergency lights. I know after, you know, we secured the ship service generator, that the lights weren't flickering anymore.

When asked how long the lights continued to fluctuate in brightness, the on-watch third engineer stated that the condition persisted until the number 1 generator was shut down by the chief engineer. In his interview he said:

> ... when I took off the number two generator, it had stopped temporarily. I'd say for maybe another minute and-a-half. And then number one generator was acting erratic, the same behavior; speeding up and slowing down and the lights continued dimming. And then changing from dim to bright, dim to bright. And that continued on – throughout the time we were observing the fire and it just kept going on and on. And that's finally when the chief said, "Well, there's no use for a number one generator. You might as well take that off the line because it's just feeding the power to the fire. So I'm going to take that off." So he went down and took off the emergency generator. I mean, the number one generator, excuse me. But they were doing the same behavior, the lights dimming and that was well into, as the fire was raging on. As the fire was raging on, we still had the one generator going and maybe five or ten minutes later that's when the chief decided he wanted to take it off the line.

Around this time the USCG fire fighting team arrived on board and began assisting the ships crew with extinguishing the fire in the engine control room.

2. Damage Description

2.1. Electrical system

2.1.1. Main switchboard. The main switchboard consisted of 12 units (modules). (See figure 2.). The starboard-most unit was identified as unit 12 and consisted of three rows of circuit breakers. Each row had four circuit breaker locations. Only ten of the twelve locations had circuit breakers installed. Units 8 and 10 each had two rows of circuit breaker locations. Unit 8 and unit 10 had 8 circuit breakers installed. Units 9 and 11 were ventilation spaces and had no circuit breakers installed. The three main generator circuit breakers were located in units 2, 3 and 4. The major portion of the damage to the switchboard occurred at the breakers and stab type connections at the line side of the breakers in units 10 and 12 (starboard end of the switchboard). (See figure 3.) Numerous breakers and the associated stab connections in these two sections had experienced damage from high temperature.

The main switchboard horizontal and vertical riser bus bars located electrically upstream of the breakers were largely undamaged. No arcing was noted on any load side conductors (cables). In addition, heat and flame impingement damaged the insulation on all load side cables. Units 1 through 9 did not exhibit any evidence of electrical arcing.

The damage to the FPE circuit breakers that were installed in unit 10 and unit 12 was consistent with damage that would be caused by an arcing fault that occurred on the exterior side of the breakers. No evidence of arcing was found inside the breakers. The damage to the molded case of the breakers indicted that the heat damage was from the outside to the inside of the breaker. The line side cable lugs of the new 400 amp breaker that had been installed in circuit P412 during the recent shipyard period showed no evidence of arcing faults. The new T-200 cable connected between Load Center P2 and the new 400 amp breaker (P412) installed in the main switchboard did not exhibit evidenced of overload heating.

There was no apparent damage to the auxiliary diesel generator circuit breakers. None of the main contacts on each of the breakers indicated any abnormal conditions. The circuit breakers were manufactured by the Federal Pacific Electric Company, and had the following specifications: type FPS-50, frame 1600, rated max voltage 600 AC, rated frequency 60 cycles, rated continuous current 1600, rated interrup current 50,000, close voltage 125 DC, trip voltage 125 DC, charge motor 125 DC, series trip device SSD-6, time current curve no 12006B0750, instr manual no C3-217-5.

The reverse power relays on the main switchboard were the reverse power relays for the diesel generators were found to be in the "not tripped" position (red flag was not visible) after the emergency situation ended, according to witness statements (chief engineer). The reverse power relay time dial settings for all three generators were set at "3" on the dial. According to the instruction sheet in the switchboard technical manual, this time dial setting dial setting will result in a minimum time of 3 seconds. The nameplate data for the reverse power relays was: Westinghouse, Style: 289B988A17A, 20-120 watts, 5 amps, 120 volts, 60 hertz, instruction leaflet 41-241.3, type CW power relay.

A 3/8 inch diameter by 1-1/4 inch long steel bolt with an oversized flat washer and a lock washer (the washers appeared to be attached to the bolt by melting) was found to the left and behind and just below the line side connections of breaker P442 on an angle support bracket. Arcing, melting, or spatter marks were present on the bolt and washer. The bolt found near breaker P442 was of the same size and had the same washer arrangement as those bolts used to connect the tulip clip post to the angle bracket.

NTSB and Alaska state fire marshal fire investigators collected and carefully examined the debris that they found on the deck below the bus bars. The debris collected consisted of metallic and non-metallic items, and is documented in the fire group's factual report. Investigators did not find any discernable foreign objects, such as hand tools, in the debris they removed from the switchboard.

2.1.2. Generators. No damage to the windings or cabling of any of the three diesel generators was found during post accident testing by the vessel's crew.

2.1.3. Motors. Post accident testing of electrical motors and their associated controllers did not reveal any damaged components.

2.2. Control room. The control room was largely undamaged, except for a film of settled smoke covering nearly all surfaces within the space. A new video monitor that was installed during the most recent shipyard period as part of the door surveillance system, was damaged by heat. The plastic case was melted by exposure to high temperature. A plastic light diffuser from one of the fluorescent light fixtures in the overhead near unit 10 of the main switchboard was distorted (melted) by high temperature.

2.3. Engine room in general. No other significant damage was found in any other part of the machinery spaces.

3. Work done in main switchboard and auxiliary diesel generators before fire

3.1. Work done by ship's crew. According to statements made by the vessel's chief engineer during his interview with investigators, the crew of the vessel had not done any maintenance or repair work within the main switchboard or the auxiliary diesel generators before the fire accident. AMHS management had reduced the size of the vessel crew during the lay-up period, and chief engineer had limited crew resources. Chief engineer stated that immediately before the accident they had not experience any operational difficulties nor had they been doing any maintenance or repair work in the main switchboard.

3.2. Work done by shipyard. According to statements made by the crew of the vessel and shipyard personnel, electrical workers from the Alaska Shipyard & Drydock performed work in the main switchboard during the winter lay-up period before the accident, under the specifications of a work item in the federal project.[1] (See figure 5.) The so-called *federal projects* were funded by the federal government for items of a capital improvement nature. State funded projects were routine repair items, and the vessel was having work done about the same time as the federal project.[2] The federal project was supervised by a project engineer from the Juneau headquarters

[1] The work item for the modifications was contained in Section 3 of the contract specifications for Federal Project No. 7532. The contract extended from January to May 2000.
[2] The state contract was MT-1281 (COL), and the availability extended from the fall of 1999 until May 2000.

office of Alaska Marine Highway System, and a dedicated inspector. The dedicated inspector was one of the two chief engineer's assigned to the vessel, and was acting in the capacity of an inspector on a temporary assignment. The State funded project was supervised by a local Ketchikan port engineer and the ship engineering crew.

The work item that required entry into the main switchboard was the installation of rescue boat on the boat deck. The davits for the rescue boats required an electric source of power – they had electric motors and related controls. The source of this power was power panelboard P2, located outside the near the emergency diesel generator room. (See figure 6). The pre-existing P2 panelboard was inadequate in size to handle the additional loads, so the panelboard was upgraded (changed-out) to allow the addition of more breakers (to support additional new circuits to be supplied to the rescue boats). The Coast Guard approved changes to electrical system drawing.[3] Since the original panelboard P2 was only a 200-amp panel, there was a need to run an additional source of power in parallel with the existing power cable to supply the additional 200 amps. Upgrade of power service to P2 panelboard required the connection of the new cable to a breaker mounted on unit 12 of main switchboard. The new 200A cable entered the main switchboard at the unit 10, on forward side (rear) of the switchboard. The new cable was connected to the existing breaker base (circuit P412). Since the shipyard electricians did not have the cable connector lugs to connect the cable to the base stabs, they removed the connector lugs from the spare breaker base located at the upper right corner of unit 12. The cable that they removed the connectors from was secured to the rear of the main switchboard with nylon cable ties.

Inspections of shipyard work done in main switchboard. Shipyard workers performed work in the main switchboard on three separate occasions in conjunction with the work item to install the new rescue boats. According to statements by the shipyard electrical foreman that supervised the work in the switchboard, upon completion of each of the three periods of work in the main switchboard, no one from the crew, port engineering staff or USCG inspected their work before the covers were bolted back on to the switchboard frame. According to statements by the ABS surveyor who did inspections onboard in conjunction with renewal of the vessel class certificates, ABS did not inspect the interior of the switchboard upon completion of the work inside the switchboard.

4. Engineering Systems Descriptions

4.1. Electrical system

4.1.1. Generators. The three auxiliary diesel generators supply all electrical power needs for the vessel. The following data applies to each of the three auxiliary diesel generators:

Manufacturer: Caterpillar, Model: D3512D, Cylinders: 12, Generator: 1056 KVA, 845 KW, Connection: Series, 440 volts, 1386 amps, 1200 RPM, Exciter: 34 volts, 8.6 amps

The following data applies to the emergency diesel generator:

Manufacturer: Deutz, Model: BF12L413F, Cylinders: 12, Rating: 250 KW, Speed: 1200 RPM

4.1.2. Switchboards. The electrical system was of the ungrounded type. The vessel had two 450 VAC dead front type switchboards: a main switchboard and an emergency switchboard. The main switchboard was located in the engine control room, and the emergency switchboard was located in the emergency diesel generator room on the cabin deck. A switchboard is the structure used to support and house meters, circuit breakers, switches, indicator lights, rheostats, resistors, and fuseholders. The location of the equipment is such that all components requiring monitoring, adjusting, or manual setting can be operated from the front of the switchboard without opening the hinged panels. All other components are mounted within the switchboard. The main switchboard contains the necessary devices for the control and protection of the three auxiliary diesel generators, which operate at 450VAC,

[3] USCG letter dated March 13, 2000, Serial: E2-0000682. See list of digital attachments.

3 phase, 3 wire, 60 HZ, and 0.8 lagging power factor. The main switchboard and the emergency switchboard were interconnected with an automatic bus tie breaker. During normal operation the emergency switchboard was supplied electrical power from the main switchboard through the automatic bus tie circuit breaker, and the emergency diesel generator is in a standby condition. Upon loss of voltage at the main switchboard, the automatic bus tie circuit breaker would open, the emergency diesel generator would start, and the emergency diesel generator circuit breaker would close, thus supplying electrical power to the emergency switchboard. According to the manufacturer, all bus work in the switchboards was installed in accordance with IEEE #45.[4] The main and emergency switchboard, including the breakers installed on the switchboards, were manufactured by the Federal Pacific Electric Company of New Jersey. The company is no longer in business.

4.1.3. Switchboard protective devices. The electrical switchboard was fitted with design features and devices that were intended to protect it from damage. All three of the auxiliary diesel generator circuit breakers were fitted with undervoltage trips that would mechanically open the breaker if the voltage fell to between 30% and 60% of normal. The breakers were also fitted with overcurrent trip devices that would trip the breaker in an adjustable time setting (long time and short time delay settings). In general, the higher the overcurrent the shorter the delay before the breaker is tripped by the overcurrent device. And finally, the electrical system has a selective coordination tripping arrangement. Selective coordination is a system whose overcurrent protection devices are carefully chosen and their time-current characteristics are coordinated. Only the device immediately on the line side of an overcurrent will open for any overload or short circuit condition.

4.2. Fire protection and detection systems[5]

4.2.1. Fire main and sprinkler system. There were four pumps that supplied the sprinkler system and the fire main system. Three of the pumps are 50 HP, 400 GPM, and one is a 50 HP, 460 GPM pump.

The automatic sprinkler system was a dry sprinkler system that serves the upper vehicle stowage with 72 heads and car deck area with 304 heads. The system was divided into eight zones by manifolds. A supervisory panel in the wheelhouse would alarm and provide indication of flow in both the wheelhouse and the engine control room. An 800-gallon pressure tank was automatically maintained at pressure and available to supply sprinkler water upon activation of the system.

The fire main supplied fire fighting water throughout the vessel at 75 fire stations. Three connections were provided for connection to a supply of shore fire main water.

4.2.2. Fire alarm system. The alarm system consisted of 20 manual pull stations and one smoke detector in the paint locker that activate an alarm in the wheelhouse and lights the fire or trouble light on the supervisory panel in the wheelhouse. The manufacturer of the fire detection system (heat and/or smoke) is Henschel Corporation.

4.2.3. Heat detectors. There were heat detectors throughout the ship covering lockers and stores. The fire detection panel on the after bulkhead was divided into 21 areas.

4.2.4. CO_2 systems. The vessel was protected by four independent systems.

4.2.4.1. One main CO_2 system of 35 bottles was located in the CO_2 room and consists of two subsystems.

4.2.4.1.1. Engine room system. The main engine room was the largest and its use requires the discharge of all 35 cylinders. Controls for activation of the system were located on the car deck, frame #112, inside the passageway leading to the engine room, and in the CO_2 room.

[4] Main and Emergency Switchboard Technical Manual, book number M-1622, Federal Pacific Electric Company, 150 Avenue "L", Newark, New Jersey 07101.
[5] The information in this section was taken from the pre-fire plan booklet of the vessel.

4.2.4.1.2. Auxiliary machinery room system. Activation of the auxiliary machinery room system required the discharge of 20 cylinders. Controls for activation of this system were located between the CO_2 room and the auxiliary machinery room at frame #73, and in the CO_2 room.

4.2.4.2. Paint locker system. The paint locker on the car deck, starboard side, frame #10 was protected by an independent CO_2 system. The controls for the system were located outside the space.

4.2.4.3. Emergency diesel generator room system. The emergency diesel generator room on the cabin deck, amidship, frame #95, was protected by and independent CO_2 system that was heat activated or manually activated by controls outside the space.

4.2.4.4. Hose reel system. A hose reel system was located amidships in the lower level of the auxiliary machinery room, frame #86.

4.3. Communications systems

4.3.1. Sound powered phones

4.3.1.1. The phone system consisted of four independent sound-powered systems, with phone stations installed in the various crew and operating spaces. The four systems were designated as 1-JV (six stations for vessel maneuvering), 2-JV (six stations for senior engineering officers quarters and engineering spaces), 3-JV (15 stations for senior officers quarters and other spaces), and 4-JV (nine stations for chief steward quarters and public spaces), for a total of 36 stations.

4.3.2 Public address systems.

4.3.2.1. Power sources

4.3.2.2. Areas of coverage

4.3.2.3. Problems with system operation experienced during fire emergency

4.3.3. General alarm

4.3.3.1. Location of contact makers

4.4. Propulsion system

4.4.1. Main Engines. The vessel had two main diesel engines driving twin propellers through reduction gears. The propellers were of the variable pitch type. The following data applies to the main engines and reduction gears:

Engine Manufacturer: Delaval Enterprise, Model: DMVR-16-4, Cylinders: 16, Stroke: 4, Rated speed: 403 RPM, HP: 6164 x 2

Reduction gear manufacturer: Luffkin, Model: RHS H4830, Gear ratio: 1.797:1

5. AMHS maintenance policy

5.1. *Columbia* switchboard maintenance. When the chief engineer was asked when the last time the main switchboard had been inspected or cleaned, he responded that he believed the last time was in 1995, but was not certain. In his interview when asked about the last time the switchboard had been inspected for loose connections he stated:

> I really couldn't say. I don't know when the last time something like was, the only time that it might have done is when we took out number one AC plant. It might have been done then. It might have been checked then. Well, it is, it is basically, I mean, I have it as something that I would like to do, if time permits. If I can, you know, have the people in a time and the effort to do it. It is on my basic, overall list to do, but it never hap-- and the best time to do it, of course, is when go into lay up, but when we go into lay up, we're down to either one person or no people.

According to the chief engineer, the vessel had a thermographic survey program. According to the chief engineer, once per year a contractor boards the vessel and performs a survey of distribution panels and motor controllers. The last survey was done in October of 1999.[6] During the survey the bus bars of the main switchboard are not checked with the thermal imaging camera. The chief engineer stated that all of the discrepancies noted during the last thermographic survey had been corrected before the fire accident. When asked if the main switchboard was checked during the thermographic survey, the chief engineer stated:

> 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 to try to do any -- 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, we have not, because, the first thing you would have to do, in order to be able to get to those panels, on the breakers, there's a fuse panel. There's a cover. You have to unscrew, take that cover off, in order to be able to unscrew and take off the metal plate, get behind it and actually get to what he needs to is the lugs and the leads coming in to take a picture of.

In addition, the main switchboard was mounted against the forward bulkhead of the engine control room and did not have access covers on its rear (forward) side. Therefore, thermal imaging of the rear side of the bus bars was not possible.

In the main switchboard technical manual, the manufacturer of the main switchboard made a recommendation to "physically check the tightness of all electrical connections and parts" and to "ascertain that no tools or extraneous materials are adrift" annually or during shipyard overhaul.

5.2. In correspondence, AMHS was asked about its preventive maintenance program:

> At the time of the accident, did AMHS have a preventive maintenance program for all vessels in the fleet? Did the preventive maintenance program address maintenance of electrical equipment, including switchboards? Did shoreside engineering personnel centrally manage the preventive maintenance program, or was the program developed and managed by the each ship's engineering department? Please provide copies of guidance or policy documents covering the AMHS shipboard preventive maintenance program.

In reply, AMHS stated:

> In regards to AMHS preventive maintenance program for all AMHS vessels the following documents are provided as attachment (8): Engineering Policy 001 (Reporting and Engineering Activities), SMS Manual Chapter 2.0 (Maintenance), M/V Columbia Maintenance Manual and the Columbia's work list for FYOO overhaul. AMHS does have a maintenance program for all vessels in the fleet. Each vessel developed their own maintenance program specific to all the equipment onboard the vessel. The maintenance tasks are also coordinated with ABS and U.S. Coast Guard periodic equipment and system inspection and testing requirements. The maintenance records are planned, recorded, and retained onboard each vessel according to AMHS policy defined in the ISM manual. The maintenance manual for the Columbia was developed by Bill Dunn the Chief Engineer, who has recently retired. The manual does address switchboard maintenance. The emergency switchboard maintenance was scheduled to be accomplished during the FYOO overhaul period according to the planning documents dated September 5, 1999.
>
> Shoreside management does not centrally manage the maintenance program. The maintenance planning developed by the ships engineering department is oftentimes discussed with the port engineer and recommended changes are made. On the enclosed

[6] The October 1999 survey was performed by Heat Loss Analysis, Inc., of Anchorage, Alaska. The stated purpose of the survey is to identify existing or potential problems in the electrical circuitry, such as poor physical contact, overload, or load imbalances.

maintenance planning sheet for the main engines, you will notice notes where the port engineer cancelled maintenance item 16 and put a "maybe" beside maintenance item 17.

We are currently installing a computer maintenance planning system "Spectec-AMOS for windows" which will present the maintenance planning tasks in a uniform method throughout the fleet. With this future program, the central office will have the ability to monitor the maintenance efforts of the engineering department onboard all ships with the AMOS system installed. This system is due to be implemented on the first six ships in August of 2001 following over two years of vessel crew, shore maintenance, and contractor effort and over 500k of fleetwide investment.[7]

The Ships Operations Manual, Chapter 2.0 – Maintenance, states the following:

Each vessel lead chief engineer will maintain a maintenace manual which will include a maintenance schedule of upcoming major scheduled maintenance items.

Maintenance/Inspection work is recorded in a machinery history log specific to each vessel. A work log is also kept of day-to-day labor in progress to more easily pass information to the next watch or crew. Applicable information from the work logs is transferred to the maintenance schedule for the official up-to-date maintenance/inspection record.

Items of ship upkeep, modifications and main requiring shoreside support are determined by the port engineer's and port captain's offices in consultation with the master and chief engineer. These maintenance items are requested by the master and shipboard department heads via the AMHS Ship Maintenance Request form. Quarterly inspection generate items for further attention as well as an overview of the effectiveness of present procedures.

The chief engineer shall maintain and update the class survey items as appropriate in the maintenance manual's maintenance schedule. The machinery manufacturer's maintenance recommendations will be utilized as a guide for scheduled maintenance planning unless otherwise directed by the port engineer's office. The chief engineer must record the machinery hours, and in conjunction with the machinery survey items, ensure that the established maintenance schedule is being followed. Any deviation from the maintenance schedule must have prior authorization from the port engineer's office.

5.3. According to statements by an AMHS port engineer in Ketchikan, AK, AMHS did not provide guidance to its vessels in the area of switchboard maintenance, but instead left the vessel crew to determine what maintenance should be done. This maintenance policy did not only apply to the main switchboard, but extended to the maintenance of all vessel equipment in general. AMHS did not have a centrally implemented maintenance policy that specified maintenance actions to be done by the vessel crews. However, after the accident the AMHS senior port engineer issued a memorandum to all vessels in the fleet to inspect the main and emergency switchboards every two years.

6. ABS inspections and certifications

6.1.1. ABS certificates. According to an ABS class survey status report on the vessel, the main switchboard is a continuous survey item and was scheduled for survey in Jan 2001. The status report does not indicate when the last time the ABS surveyed the switchboard, but it should have been inspected in 1996 (5 year cycle).

[7] AMHS Letter dated April 5, 2001, page 4.

6.1.2. Preventive maintenance. AMHS did not have the Preventative Maintenance Condition Monitoring (PMCM) certification, and therefore all equipment was on a continuous survey cycle in which 20 percent of the vessel's equipment is inspected each year.

6.1.3. According to an ABS surveyor in the Seattle office of ABS Americas, the main switchboard survey normally involves a visual inspection of the interior for cleanliness and the presence of unauthorized modifications to the arrangement. A check of the tightness of electrical circuit fasteners is not normally part of the survey.

7. Alaska Shipyard & Drydock (ASD) Quality Assurance Program

7.1. According to statements by ASD management, the shipyard did not have a formal Quality Assurance (QA) department, and quality inspections for work items were the responsibility of individual trade foremen. In addition, quality assurance "checkpoints" or "sign-offs" were contained in the test memos developed as part of the work package. Four test memos were developed as part of Columbia package and these memos were as specified and approved by the owner of the vessel (AMHS). None of these test memos contained a QA "checkpoint" or "sign-of" for the owner, USCG, or ABS to inspect the work in the main switchboard upon completion. The shipyard did not have a formal process to track the completion of test memos.

8. USCG and ABS requirements for switchboards, accessibility

8.1. Design requirements.

8.1.1. USCG regulations. The 1987 Coast Guard electrical regulations do not require a working space behind the switchboard, but requires that bus bars be within 20 inches of the front of the switchboard.[8] Similarly, the current regulations require that each component and bus bar connection on the switchboard that is not accessible from the rear, except a bus bar connection for a draw-out type circuit breaker, must be within 0.5 m (20 in.) of the front of the switchboard. Both the 1987 and 2000 versions of USCG electrical regulations incorporate by reference IEEE Std 45 – 1983 (IEEE Recommend Practice for Electric Installations on Shipboard). IEEE Std 45 – 1983 recommends that the switchboard be accessible from the front and the rear.[9] The 1998 version of IEEE Std 45 states that switchboards should accessible from the front and the rear, except for switchboards that are enclosed at the rear and can be fully serviced from the front. The vessel was delivered to its owners in 1974.

8.1.2. ABS rules. ABS rules do not require switchboards have access from the rear if they are fully serviceable from the front.[10]

9. Tests and Research

9.1. JHU-APL report.

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[8] 46 CFR 111.30-1(3) states that switchboards must "Have a working space behind the switchboard that is at leat 0.6 m (24 in.) from the nearest bulkhead and at least 0.5 m (18 in.) from the nearest stiffener or frame, or have no rear access." 46 CFR 111.30-3 states "Each component and bus bar connection that is not accessible from the rear, except a bus bar connection for a draw-out type circuit breaker, must be within 0.5 m (20 in.) of the front of the switchboard."

[9] Section 17.1 of IEEE Std 45 – 1983 states "The switchboards should be installed in a dry place, away from the vicinity of steam, water, and oil pipes and should be so located as to be accessible from the front and the rear. The space in the rear of the switchboard should be ample to permit maintenance, in general, not less thatn 24 inches in the clear, except that this may be reduced to 18 inches in wasy of stiffeners and frames. Where practicable, access should be from both ends should be provided."

[10] ABS Rules for Building and Classing of Steel Vessel, 1991: Switchboards are to be located in a dry place so as to provide a clear working space of at least 914 mm (36 in) at the front of the switchboard and a clearance of alt least 610 mm (24 in) at the rear which may be reduced to 457 mm (18 in.) in way of stiffeners or frames except that, for switchboards which are enclosed at the rear and are fully serviceable from the front, clearance at the rear will not be required unless necessary for cooling.

9.1.1. Background of Investigation. An expert in the area of arcing faults in marine switchboards was contracted by the Office of Marine Safety to assist in the investigation of the accident. The contractor was an employee of the Johns Hopkins University – Applied Physics Lab, and had investigated a number of U.S. Navy switchboard fires while under contract to the U.S. Navy. In this investigation, the contractor was tasked with investigating the cause and origin of the switchboard fire.

9.1.2. The investigation. The contractor, with the assistance of party representatives, thoroughly examined the switchboard and all of its components. During the on scene portion of his investigation, the contractor found a steel bolt and two washers perched on a ledge at the lower side of the supporting framework of the switchboard. The bolt found was of the type used within the switchboard.

9.1.3. Findings of report. In his report, dated 27 July 2000, the contractor concluded that the most likely origin of the fire was in the vicinity of the port steering gear breaker, P456, located in switchboard unit 12. The report also concluded that the two most likely causes of the fire were a faulty connection of the switchboard bus bars or the loose bolt found during the examination of the switchboard. Because of the location at which the bolt was found, its appearance and other factors, the contractor concluded that it was very likely that the bolt was the initiator of the arcing fault that spread through the two sections of the switchboard.

9.1.4. Other topics discussed in report

9.1.4.1. Arc fault detection systems. These protection systems are designed to interrupt the circuit in which an arc fault has developed before significant damage can occur. Two systems are available, one designed by JHU-APL, and a second by ABB Marine Group. See JHU-APL report for additional details.

9.1.4.2. Commercial and U.S. Navy switchboard design initiatives. See JHU-APL report for details.

9.2. NSTB materials laboratory testing

9.2.1. Background of testing. The Office of Research and Engineering Materials laboratory tested the bolt found within the switchboard by the contracted expert to determine the nature of the deposits on the bolt and the manner by which the two washers were bonded to the bolt. In addition, two other bolts were tested for comparison purposes.

Description of testing. The metallurgical tests were done on the bolt in accordance with a test plan agreed to by parties to the investigation. The bolts and washers were examined visually and by optical microscopy. The subject bolt was ultrasonically cleaned in soapy water and then reexamined. The bolts and washers were then sectioned longitudinally, polished, and etched with 2 percent nital. The cross-sections were then examined using optical microscopy and scanning electron microscopy (SEM). The cross-section of the subject bolt and washers were also examined using energy dispersive x-ray spectroscopy.. The bolt testing was done on September 19 and 20, 2000, and was attended by representatives from Alaska Marine Highway System and Alaska Shipyard and Drydock (ASD).

9.2.2. Significant findings. The material between the bolt and the washer of the subject bolt was determined to be copper. The report makes no conclusions regarding the metallurgical conditions found, and any conclusions made will be discussed in the engineering analytical report.

9.3. IR Thermography. Infrared thermal imaging (thermographic survey) 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 used by a number of vessel owners as part of the condition based preventive maintenance program.

9.3.1. The USCG has used IR Thermography as part of its Reliability Centered Maintenance (RCM) program aboard its newest ice-breaking cutter, the USCGC Healy. The use of IR

Thermograpy was discussed in a paper published in the SNAME journal Marine Technology11

9.3.2. UK Coast Guard Agency Guidance Note on Electrical Equipment and Thermal Imaging. In a 1999 Merchant Note Guidance, the UK Coast Guard Agency advised shipowners, 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 pin point problem areas at an early stage."12

9.4. USCG accident database. The USCG provided information from their accident database on the number of electrical fires on vessels between 1992 and 2000.

9.4.1. Number of electrical fires during reported period. A total of 334 accidents involving electrical fires were reported on all types of vessels. Of the 334 accidents, 4 listed the switchboard as the ignition source of the fire. During the same period, 69 electrical fires aboard all classes of passenger vessels were reported. Of the 69 accidents, 2 listed the switchboard as the ignition source of the fire.

10. AMHS Postaccident Actions

10.1. The damage to the main switchboard was of such a nature that the vessel could not be operated without extensive and lengthy repairs. The owner removed the vessel from active service following the accident, and it was placed in a lay-up status awaiting repairs. During the lay-up period, repairs to the switchboard and modifications to other systems were completed by a shipyard facility in Ketchikan, AK. The vessel was scheduled to return to active service for the 2001 summer schedule. Among the work performed during the shipyard repair period were:

10.1.1. Switchboard renewal. Included repairs or renewal of load cables within the switchboard.

10.1.2. Phone system renewal. A new SOLAS approved dial phone system, including a 48-station PBX (private branch extension) was to be installed. The existing sound-powered system was to remain on board.

10.1.3. Public address system renewal. A new SOLAS approved system was to be installed.

10.1.4. Electrical system inspection. Inspection of all electrical system transformers and motor controllers was done by the ships crew after the accident.

10.1.5. Testing of old switchboard components. According to a memo received from the owner dated 31 January 2001, no testing of electrical equipment was completed or scheduled during the removal of the old switchboard.

10.2. On 7/24/00, issued Engineering Policy 034 titled "Switchboard Maintenance" that directed all ships in the fleet to perform "cleaning and tightening of fastenings of the main and emergency switchboard during overhauled period at least every other year. On alternate years, all the electrical distribution boards should be maintained by cleaning and tightening fastenings. Maintenance work will normally be done by the crew."

11. Definitions[13]

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[11] USCGC *Healy* (WAGB 20) -- A Case Study for Implementing Reliability-Centered Maintenance. Marine Technology, Vol. 37, No. 1, January 2000, pp. 50—56. Document is available on the web at http://www.jima.com/Documents/Features/rcm.pdf.

[12] Maritime and Coast Guard Agency Merchant Guidance Note MGN 132 (M+F), December 1999, available at: http://www.mcga.gov.uk/mgn/MGN132.pdf

[13] Terminology from General Electric publication GET-8032A – Spectra Series Switchboards http://www.geindustrial.com/industrialsystems/switchgear/notes/GET-8032A.pdf, and Cutler-Hammer training website glossary: http://www.ch.cutler-hammer.com/training/slfstudy/glossary.htm

11.1. Arc fault – a high impedance connection, such as an arc through air or across insulation, between two conductors

11.2. Bus bar – a solid aluminum or copper alloy bar that carries current to the branch or feeder devices in a power panelboard or switchboard. There is at least one bus bar for each phase of the incoming electrical service

11.3. Dead front – a type of electrical construction, usually a switchboard or panelboard, where energized parts are not exposed to a person on the operating side of the equipment. back

11.4. Enclosure – a constructed case to protect personnel against contact with the enclosed equipment and to protect the enclosed equipment against environmental conditions

11.5. Line – refers to the incoming (live) side of the equipment or device

11.6. Load – is the outgoing (switched) side of the equipment or device

11.7. Lug – a device used to terminate cables back

11.8. Overcurrent – any current rated in excess of the rated current of equipment or the ampacity of a conductor that can result from an overload, a short circuit or a ground fault

11.9. Panelboard A wall-mounted electrical power distribution device for use in commercial and industrial applications. It provides circuit control and overcurrent protection for light, heat or power circuits.

11.10. Switchboard - a large single panel, frame, or assembly of panels having switches, overcurrent, and other protective devices, buses, and usually instruments mounted on the face or back or both. Switchboards are generally accessible from the rear and from the front and are not intended to be installed in cabinets

Figures

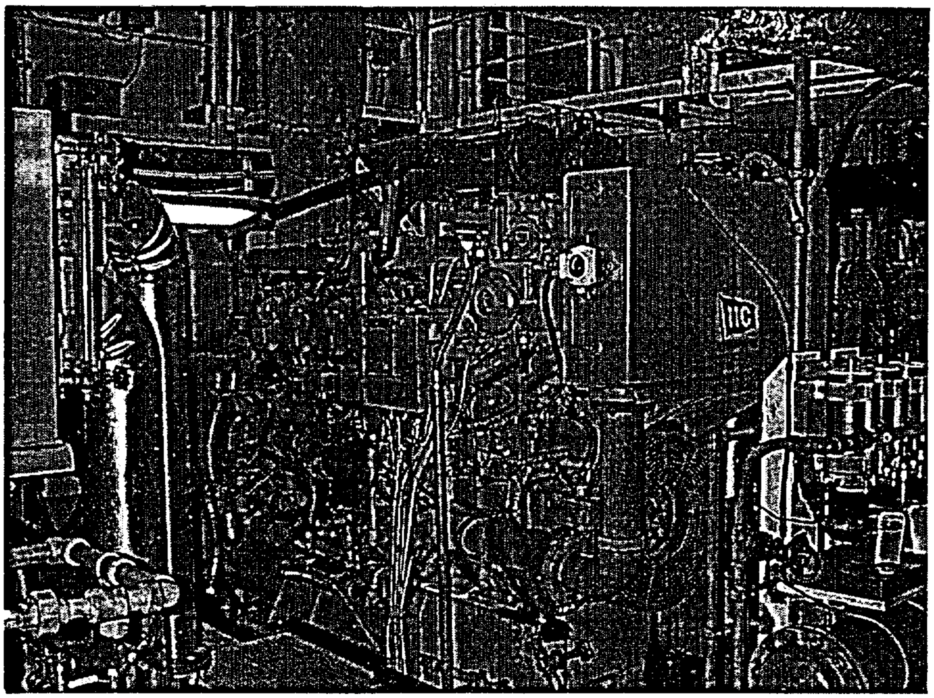

Figure 1. One of three auxiliary diesel generators

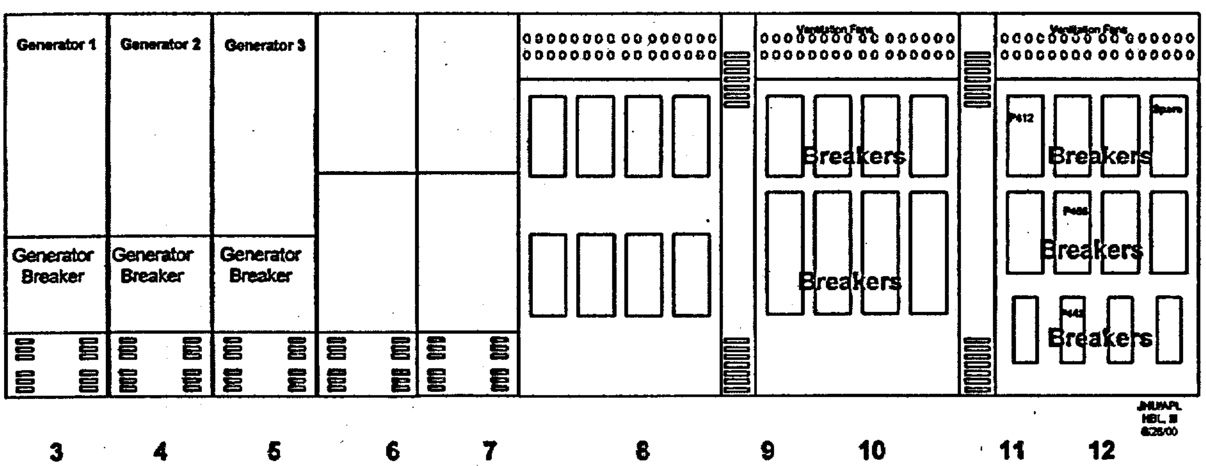

Figure 2 Outline view of main switchboard, showing arrangement of units 3 through 12

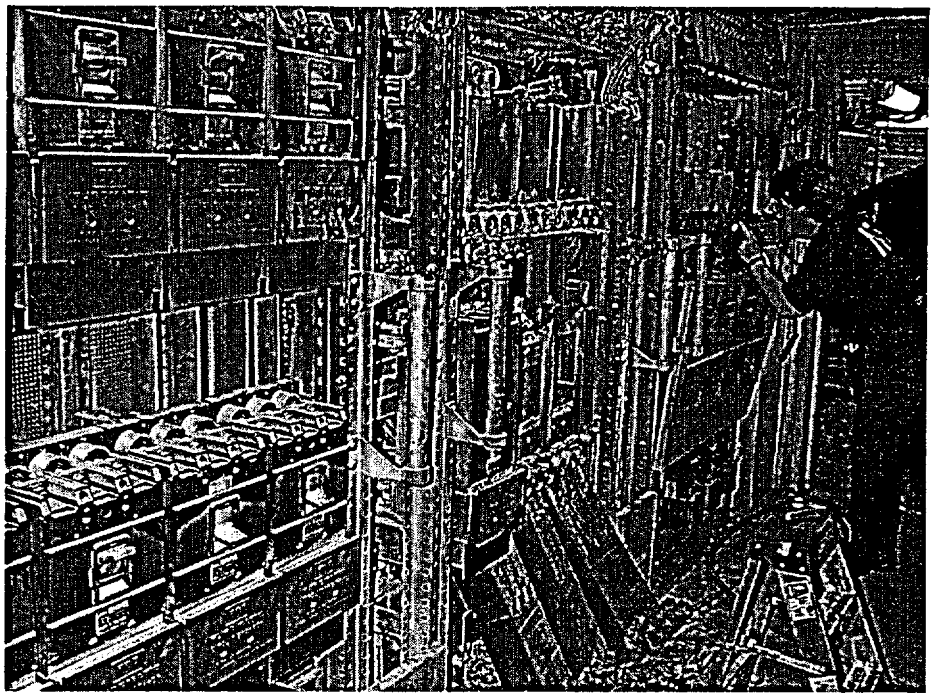

Figure 3 Main Switchboard – units 8, 9, 10, 11, and 12. NTSB investigator at right side of photo is looking into switchboard unit 12.

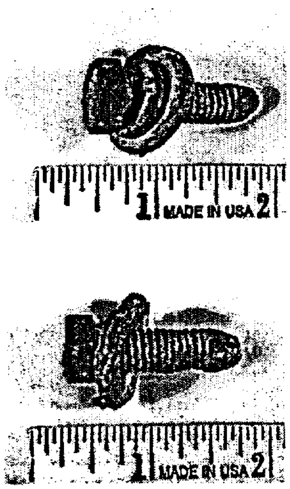

Figure 4 Bolt found on front (aft side) framework of switchboard

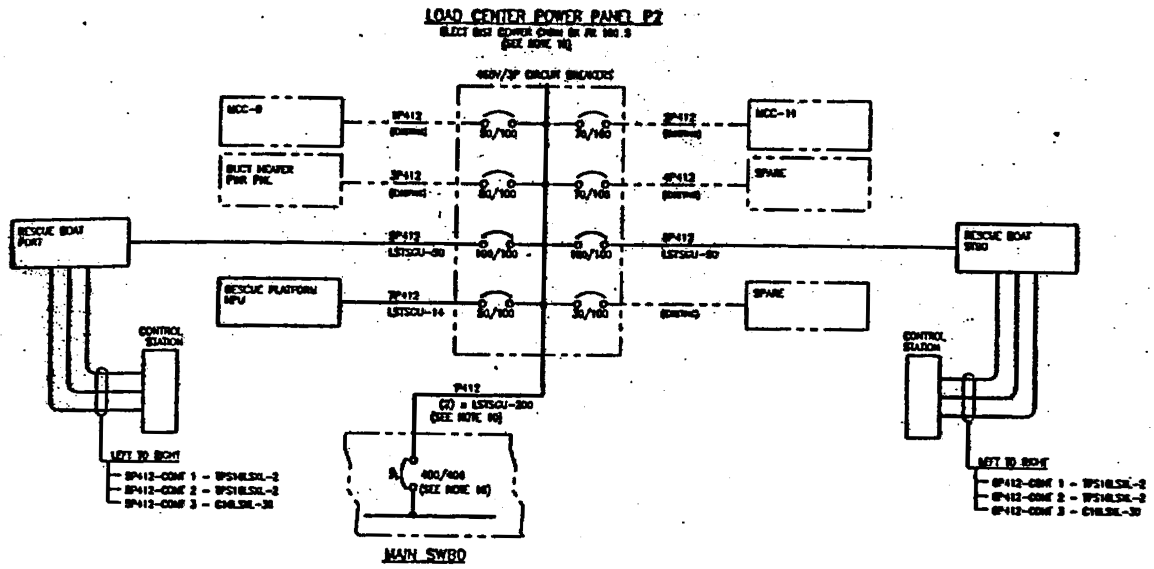

Figure 5. Modifications to main switchboard and electrical system done by shipyard during federal project. Electrical One Line Drawing Modifications, Dwg. No. 00008-6-8050 Rev.-, page 2.

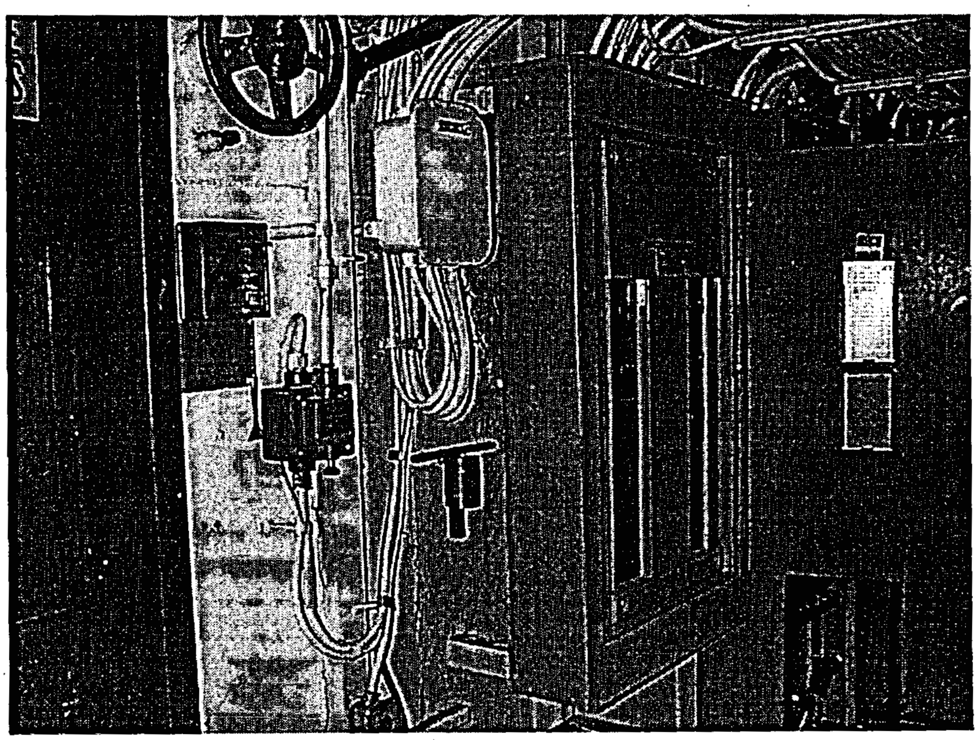

Figure 6 Power panelboard P2 installed during shipyard period