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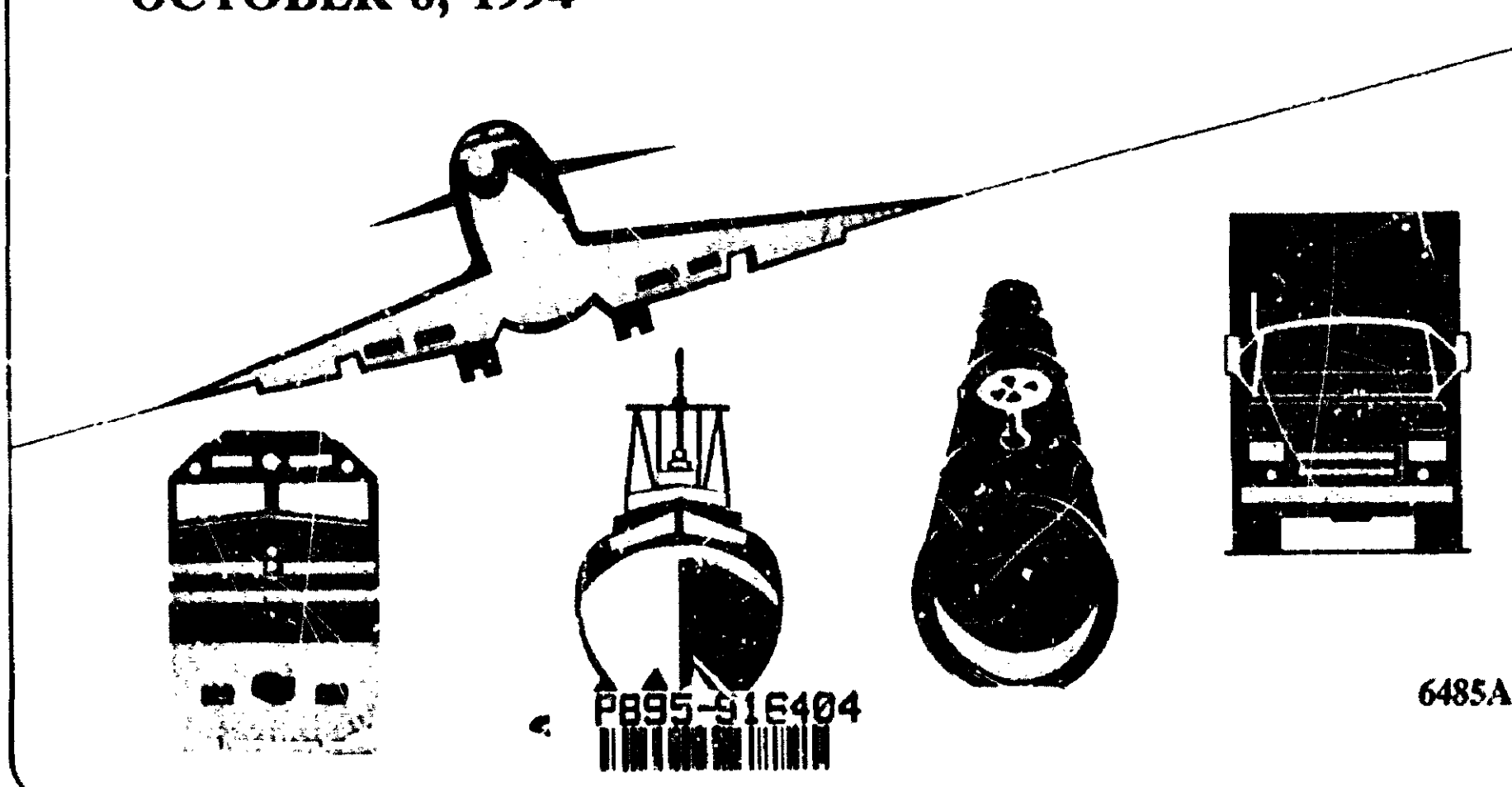
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NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C. 20594

MARINE ACCIDENT REPORT

ENGINEROOM FIRE ON BOARD THE LIBERIAN TANKSHIP SEAL ISLAND WHILE MOORED AT THE AMERADA HESS OIL TERMINAL IN ST. CROIX, U. S. VIRGIN ISLANDS OCTOBER 8, 1994



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Adopted: December 12, 1995

Notation 6485A

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EXECUTIVE SUMMARY

On October 8, 1994, the Liberian tankship SEAL ISLAND was moored at the Hess Oil Refinery in St. Croix, U. S. Virgin Islands. About 0845, while engineering personnel were changing the lubricating oil strainer on the ship's service turbo generator, lubricating oil sprayed onto the hot turbine casing and a fire erupted. The fire burned about 6 hours before it was extinguished.

The fire resulted in the death of three crewmembers and serious injury of six other crewmembers. The fire seriously damaged the tankship's engineroom; heat, smoke, water, and soot badly damaged the accommodations and pilothouse. The tankship was declared "no longer a useful carrier" and its owner, the Seal Island Shipping Corporation, had it towed to Spain where it was sold as scrap for $12 million.

The National Transportation Safety Board determines that the probable cause of the fire on board the SEAL ISLAND was the chief engineer's failure to recognize the risks introduced by the temporary repair to the engineroom oil strainer. Contributing to the loss of life were the suddenness and severity of the fire, the inability of the crew to use the control room emergency escape hatch, and the lack of fire and escape drills in the vessel engineroom.

This report discusses the following safety issues:

- The adequacy of management oversight of maintenance and repair practices on board the SEAL ISLAND.
- The decision to make and the risk introduced by the temporary repair modification to the lubricating oil duplex strainer.
- The adequacy of emergency equipment and drills on board ocean-going ships.
- The adequacy of the emergency response by refinery personnel.
- The adequacy of the U. S. Coast Guard's fire contingency planning for St. Croix.

As a result of its investigation of this accident, the Safety Board made recommendations to the U. S. Coast Guard, the Governor of the U. S. Virgin Islands, Hess Oil Virgin Islands Corporation, and the National Petroleum Refineries Association.

INVESTIGATION

Events Preceding the Accident

About 4 months before the accident, the Liberian-registered tankship, SEAL ISLAND (see figure 1), was fully loaded with crude oil, and en route from Lagos, Nigeria, to St. Croix, U.S. Virgin Islands. In response to a medical emergency, Atlantis Agency, Inc. (Atlantis), the management company for the vessel, recalled a chief engineer from vacation. On June 10, he boarded the SEAL ISLAND with a replacement chief engineer,[1] who was scheduled for an 80-day tour on the tankship. Upon arriving aboard the SEAL ISLAND, the chief engineer took over the management of the SEAL ISLAND engineering department. During the voyage to St. Croix, he helped the replacement chief engineer become familiar with the routine operation of the tankship's engineering systems and machinery.

After boarding, the two chief engineers went to the engineroom. The first engineer said that he informed the chief engineer that the lubricating oil duplex strainer (see figure 2) for the ship's service turbine generator (turbogenerator) was leaking about a quart an hour or 6 gallons per day past the lower O-ring on the directional flow valve. The chief engineer examined the leak at this time, and said he would repair it first thing in the morning.

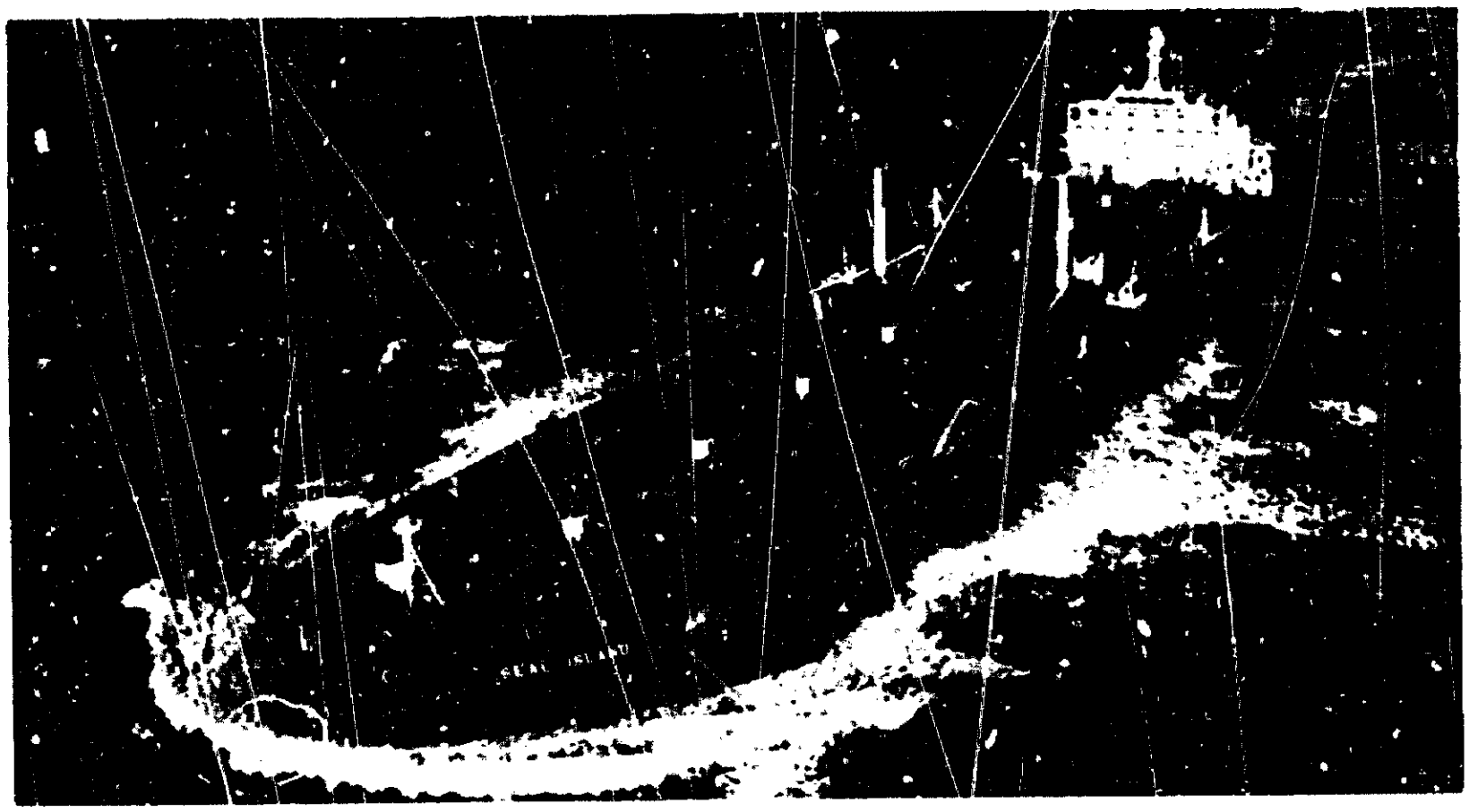
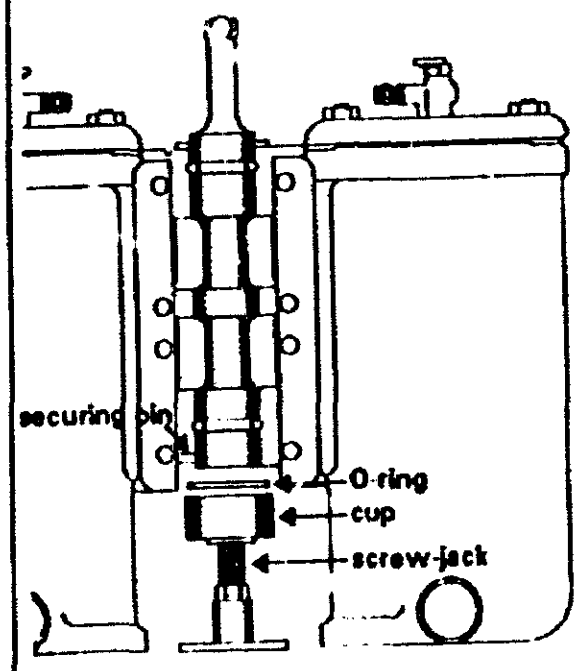


Figure 1 — The SEAL ISLAND

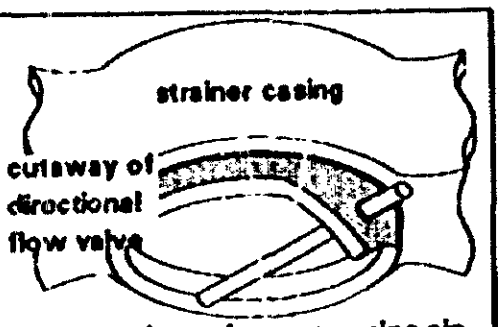
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[1] For ease of reference in this report, the chief engineer who was a 10-year company veteran and who had been regularly assigned to the SEAL ISLAND is referred to as the *chief engineer*. The chief engineer who was a 2-year company veteran and who had primarily served as a relief chief on Atlantis' other tankships is referred to as the *replacement chief engineer*. The replacement chief engineer's tour from June 26 to August 28, 1994, was his first assignment on board the SEAL ISLAND.



To avoid shutting down the ship's service turbogenerator for 2 hours to make a permanent repair to the duplex strainer, the chief engineer devised an assembly comprising an O-ring, a metal cup, and a screw-jack. The cup was to fit around the bottom of the flow valve casing. The screw-jack was to hold the cup in place to achieve and maintain a tight fit.

When the first engineer tried to attach the O-ring and cup, the valve's lower securing pin prevented his getting a tight seal. The chief engineer directed him to retract the lower securing pin.



Above shows lower securing pin in its designed extended position. Below shows pin pushed in to allow a uniform surface.

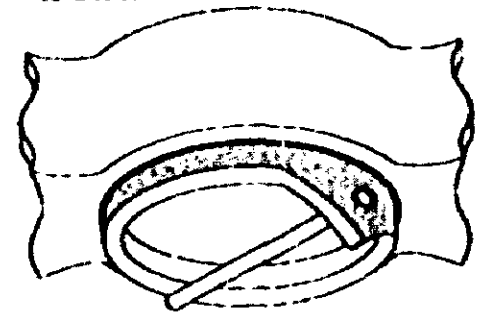
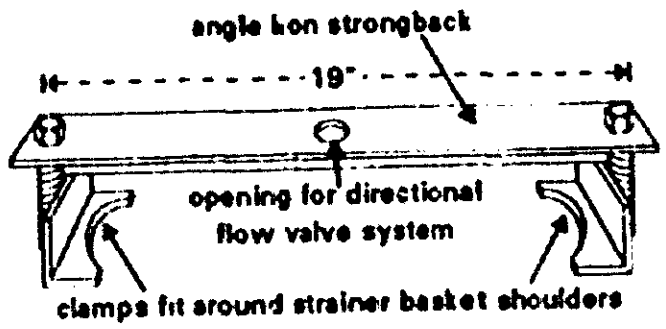


Figure 3 — (Left) A cutaway of the strainer casing area containing the directional flow valve with the screw-jack assembly below it. (Right) The lower area of the casing enlarged.

Later in the day, the first engineer tried to fit the cup and O-ring assembly against the strainer casing. The first engineer stated that during this attempt he noted and told the chief engineer that the lower securing pin in the bottom of the directional flow control valve interfered with the cup installation. The chief engineer told the first engineer to push the pin in and out of the way. The replacement chief engineer stated that he told them that it was dangerous to move the lower pin without providing a restraint to hold the valve in place. The chief engineer then ordered that a strongback clamp be constructed to install across the top of the strainer to keep the valve from rising. (See figure 4.)



When the chief engineer told the first engineer to retract the lower securing pin of the flow valve to make way for the cup, the replacement chief engineer cautioned that it was dangerous to remove the pin without having a device to hold the flow valve in place. The chief engineer designed a strongback, which was fabricated by a machinist in about 10 hours. On June 12, all four components of the temporary assembly were fitted on the oil strainer and the oil leak stopped.

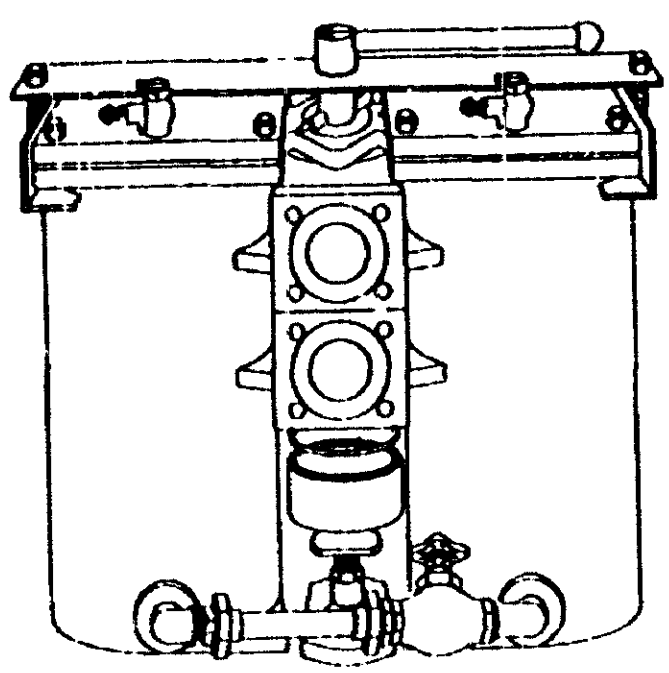


Figure 4 — (Left) The strongback. (Right) The strainer with the repair assembly components.

By June 12, the first engineer and a machinist had fabricated and installed all the temporary repair parts designed by the chief engineer for the duplex strainer. With the strongback clamp in place across the top of the strainer casing, the lower securing pin was pushed in so that the cup could be jacked up tightly against the casing bottom, allowing the O-ring gasket to form an oil-tight seal. The leak stopped. Now, however, the strongback had to be removed to clean or replace the strainer element.

When the tankship arrived at St. Croix on June 26, an Atlantis management representative came aboard for a routine meeting with the ship's officers to discuss operating conditions, maintenance, and other concerns. The chief engineer later testified that he did not tell the company official about the temporary repair to the lube oil strainer because he considered the fix "a small repair" that was "not serious," and not worth mentioning. He also didn't tell officials about his unsuccessful attempt to transfer the electrical load to the diesel generator, or about his concern that the diesel generator might experience an overheating problem carrying a load above 600 kw. After the meeting, the chief engineer departed the SEAL ISLAND to resume his vacation without having provided Atlantis shoreside management with a verbal or written report about the strainer repair.

The replacement chief engineer was also at the June 26 on-board management meeting. He stated that he didn't mention the temporary strainer repair because he thought the chief engineer had reported the strainer condition to the company and had made plans for the permanent repair.

During the 80 days that the replacement chief engineer was in command of the SEAL ISLAND engineering department, he did not advise Atlantis management about the temporary repair to the lubricating oil strainer, either in a written report or verbally during regularly scheduled management vessel visits. He stated that while he was on board the SEAL ISLAND, the differential pressure reading at the lubricating oil strainer never reached the range established by the chief engineer for maintenance,[5] therefore he did not order the strainer cleaned or changed between June 26 and August 28. Following a routine on-board management meeting at St. Croix on August 28, 1994, the replacement chief engineer departed the SEAL ISLAND, and the chief engineer returned to duty aboard the tankship. Two days later the SEAL ISLAND departed St. Croix for Hounds Point, Scotland, to pick up a load of crude oil.

The Accident

On October 5, 1994, the SEAL ISLAND arrived at the Hess Oil Refinery, St. Croix, (see figure 5.) and began offloading its cargo alongside dock No. 3. Cargo transfer operations continued without incident until they were completed at 2200 on October 7, 1994.

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[5] The turbine operating manual states that strainers should be switched when the differential pressure is 11 to 17 psi. The larger the pressure differential between the lubricating oil inlet pressure and the outlet pressure, the dirtier the strainer. The chief engineer had established an on-board maintenance standard requiring that the strainer be changed when the differential was about 6 to 7 psi. He stated that changing-over to a clean lubricating oil strainer on the turbogenerator usually occurred about once every 30 to 40 days.

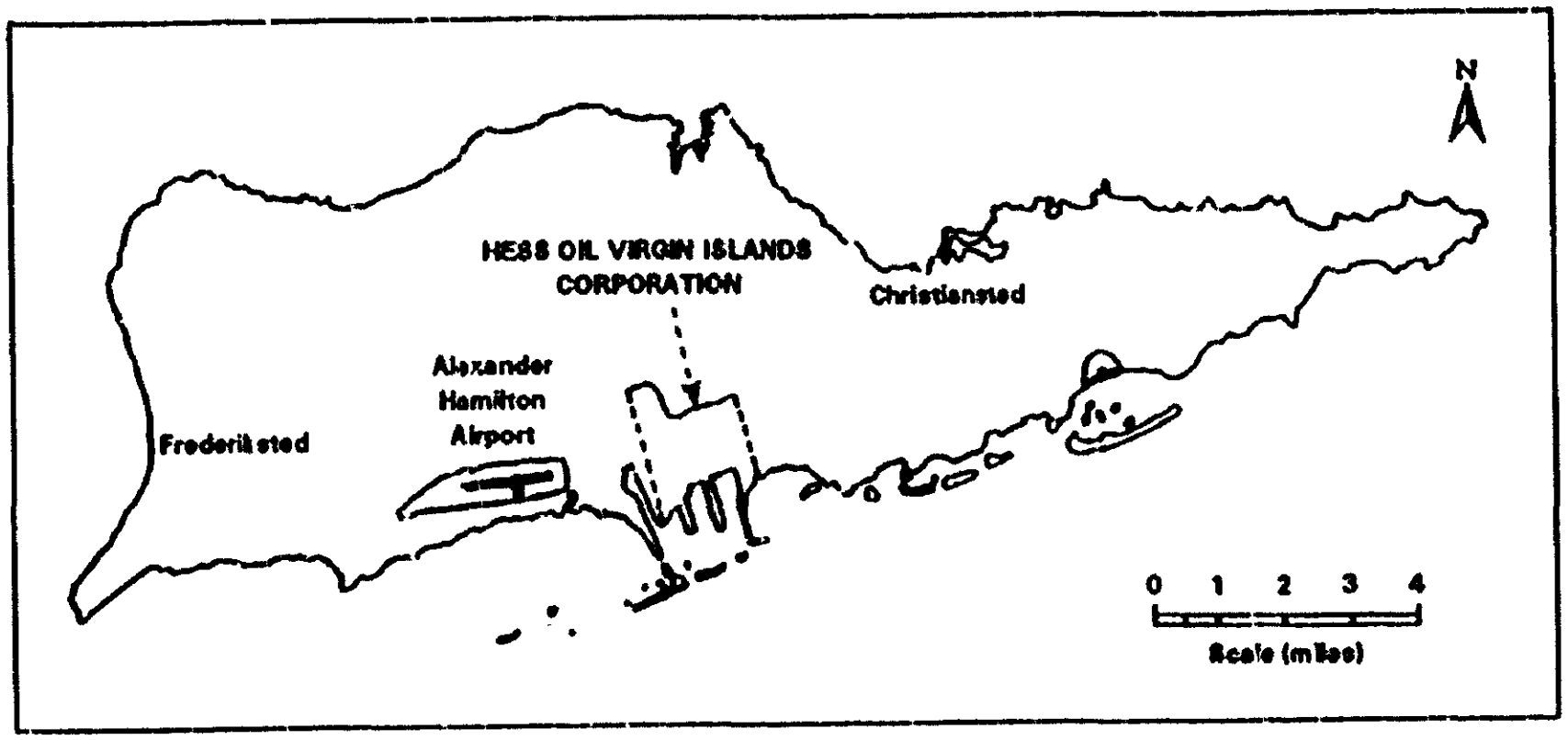


Figure 5 — The Hess Oil Refinery on St. Croix.

At 0800 on October 8, the first engineer[6] was conducting a routine daily work assignment meeting in the engine control room, which was attended by the chief fireman, two machinists, and a wiper.[7] The chief engineer and the on-watch third engineer were also in the control room.

The first engineer assigned the chief fireman and a wiper to construct a wooden storage box outside of the machine shop, and the two machinists to work on a metal sign for the boiler. During the meeting, no one mentioned working on the turbogenerator, or changing its lubricating oil strainer. The meeting ended about 0815, and the engineering crewmen went to their work assignments.

While the work assignment meeting was in progress in the control room, the on-watch fireman was making a routine round in the engineroom. He later testified that he checked the lubricating oil in the turbogenerator and observed that the lubricating oil temperature was 116°F and the outlet pressure was 129 psi, both of which were within the manufacturer's operating specifications for the unit.

The third engineer testified that the chief engineer and he were chatting in the control room and the chief indicated that he intended to have the first engineer change the lubricating

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[6] Atlantis deck and engineering officers operate on an approximate 90-day rotation cycle. While one officer is on board, his alternate is on vacation. The first engineer on board the SEAL ISLAND on October 8, 1994, was not the first engineer who assisted in fabricating and installing the temporary repair assembly.

[7] Firemen, machinists, and wipers are unlicensed crew who assist the engineering officers as directed. An engine department fireman is responsible for monitoring the boiler water levels and the fuel oil firing the boilers, and recording various equipment temperatures and pressures. A machinist's tasks include pipe fitting, lathe work, and so forth. A wiper is a day laborer whose duties involve general cleaning.

oil strainer on the turbogenerator. The chief engineer later testified that he knew the strainer had not been changed since he had returned on board the tankship (August 28) and that it was obvious to him from the 7 psi pressure differential that the strainer element was dirty and in need of changing.

The two machinists were working on the boiler sign in the machine shop when the fireman directed one of them to come with him to the turbogenerator area, where they joined the chief engineer, and the first engineer. As the chief engineer and the crewmembers observed, the first engineer rotated the change-over handle to switch the strainer operation from the forward basket to the aft basket. The oil pressure differential increased, meaning the aft basket was not only dirty, but more clogged than the forward basket. The first engineer therefore turned the handle back to forward basket operation.

About that time, the on-watch third engineer walked near the turbogenerator to observe the operations. The chief engineer, realizing that both strainers were dirty, told the third engineer to go to the upper control room level and get a clean spare strainer element. When the third engineer found the spare strainer element, he saw that it was dusty, so he took it to the machine shop to blow it out with compressed air. He was gone about 6-8 minutes.

Meanwhile, the first engineer loosened the clamps holding the strongback on the strainer, and removed the strongback. He handed it to the machinist, who placed the strongback on the deck. The first engineer then unscrewed the four nuts on the aft strainer basket cover, and removed the basket cover. He took out the dirty strainer element and examined it.

The chief engineer went to see what was delaying the third engineer with the spare strainer element. After a minute or so, the chief engineer returned with the clean strainer element, and gave it to the first engineer, who inserted it in place. The machinist then gave the basket cover and four nuts to the first engineer, who reinstalled them. The machinist and the fireman both testified that the first engineer tightened all four nuts.

The fireman testified that the first engineer opened the valve in the connecting pipe line between the two baskets and opened the vent cock until lube oil squirted out.[8] The first engineer then closed the vent and the connecting valve and moved the directional flow control valve handle to the aft basket's clean strainer element.

The machinist had picked up the strongback from the deck and was waiting to hand it to the first engineer when lubricating oil suddenly sprayed upward from the duplex strainer. The first engineer and the chief engineer tried to stem the oil flow with their hands, but the temperature of the oil was too hot. The two men pulled their hands away from the oil stream, and flammable lubricating oil sprayed upward, splashing against the overhead steel plating, which was the deck/underside of the paint locker, machine shop, and welding shop on the level above. Oil that had sprayed or fell onto the hot (900°F) surface of the turbogenerator auto-

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[8] This allows the air from the basket to vent through the basket cover while the oil fills the off-line basket.

ignited. These flames ignited oil that had atomized and oil that had splashed on nearby electrical power cables, machinery, bulkheads and the deck.

The chief engineer tried to activate the turbine steam supply emergency trip to shut down the turbogenerator, but found that the automatic low lubricating oil pressure trip had already activated. When the turbine started to slow down, the entire electrical load shifted to the diesel generator.

The chief engineer's clothing was coated with lubricating oil and caught fire. He said that he threw himself onto the deck and rolled around to extinguish the fire on his clothes. He ran into the engine control room and activated the fire alarm and the engineers' emergency call. He said that he had to reduce the electrical load on the diesel generator so that he would have enough power to start the engineroom fire pump. He disconnected all the "preferential switches"[9] on the control console, which shut down the power to the air conditioning, the engineroom ventilation, and other equipment.

The chief engineer stated that about the same moment the third engineer attempted to start the fire pump, the engineroom went black. The diesel generator had shut down, causing the loss of all main electrical power. Within seconds, the emergency generator started automatically, supplying electrical power to the emergency lights and vital ship equipment.

Survivors stated that the lubricating oil fire produced intense heat and large volumes of dense black smoke that almost immediately filled the engineroom, obscuring the emergency lights and reducing visibility to near zero. The smoke rapidly spread to the control room.

When the fire started, nine people were in the SEAL ISLAND engineroom. Three crewmembers — the first engineer, an electrician, and a machinist — failed to escape and died. All six survivors suffered burn and inhalation injuries during their escape. A description of their escape efforts and routes appears in the "Survival Factors" section of this report.

Postaccident Response

About 0845, the SEAL ISLAND master was working in his office one deck below the pilothouse when he heard the ship's fire alarm sound. He immediately ran to the pilothouse, looked at the fire detection panel, and noted that it indicated a fire in the engineroom. The master then received a radio transmission over VHF-FM channel 11 from the terminal port captain asking if there was a problem on the SEAL ISLAND, because "a lot of black smoke" was coming from around the ship's stack.

The master went to the starboard bridge wing, looked aft, and realizing that the fire was "something big," immediately radioed the terminal port captain for assistance. A total of

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[9] A separate panel section on the control console contained the "preferential switches" for all nonessential machinery that could be shut down to reduce the electrical load without affecting navigating the vessel.

about 140 Hess Oil Virgin Islands Corporation (HOVIC) refinery personnel[10] responded to the fire. The refinery dispatched five fire trucks to the scene. Three refinery fire trucks pumped water from the shoreside fire hydrant to fire hoses on the SEAL ISLAND's main deck. Two more trucks were on stand-by.

In addition, two HOVIC foam tank trucks and two HOVIC tugs responded. The two tugs sprayed water on the hot hull and superstructure to cool the vessel. Two refinery ambulances provided life support capability; one rescue vehicle contained various rescue equipment.

HOVIC responders transported the six injured crewmembers to St. Croix Hospital. Because of the fire and smoke, responders could not remove the bodies of the dead crewmembers from the SEAL ISLAND until October 10, 1994.

A description of the postaccident actions by the crew and the emergency responders appears in the "Survival Factors" section of this report.

Injury Table

Table 1 is based on the injury criteria set forth in Title 49 Code of Federal Regulations (CFR) 830.2.[11] A description of the injuries sustained in this accident appears in the "Medical and Pathological Information" section of this report.

Table 1 — Injuries in the SEAL ISLAND accident.

Injury Type	Crew*	Total
Fatal	3	3
Serious	6	6
Minor	0	0
None	24	24
Total	33	33

*The tankship normally had a 32-member crew. On the day of the accident, the vessel happened to have two masters on board, one of whom was beginning his duty rotation and one of whom was preparing to go on vacation.

[10] To handle emergencies such as fires and oil spills that may occur at the refinery, the HOVIC has its own fire brigade of about 200 members representing every department in the refinery.

[11] 49 CFR 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 received; (2) Results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second or third-degree burns, or any burn affecting more than 5 per cent of the body surface."

Vessel Damage

Fire damage extended outward and upward from the engineroom boiler platform level on which the turbogenerator was located.[12] Heat and fire severely damaged engineroom machinery and electrical power cables. Heat, smoke, and soot from the engineroom fire entered the accommodations house and caused extensive damage up to the pilot house on the bridge level. Water and foam used during the firefighting effort caused further damage to furnishings and equipment. After the fire was extinguished, officials from a London-based salvage company and industry insurance adjusters declared the SEAL ISLAND "no longer a useful carrier." The owners of the tankship, the Seal Island Shipping Corporation, had the vessel towed to Spain, where it was sold as scrap for $12 million.

Crew Information

The SEAL ISLAND had a 32-man crew; the 8 licensed officers were Italian nationals and the 24 unlicensed crewmembers were Philippine nationals. All were properly licensed or certificated under Liberian law. The common language by which they communicated with each other was English.

The Safety Board examined several human performance factors, including medical background, certification, and work experience for the licensed officers who were principals in this accident (see appendix B). Because the chief engineer managed the engineroom operations and was directing the strainer change when the accident occurred, the Safety Board also looked at his work/rest cycle and his activities preceding the accident.

The chief engineer testified that he was in good general health at the time of the accident and was not suffering from any apparent chronic or acute illnesses. He stated that he was not using any type of medications or other drugs, including alcohol.

During the 3 days before the accident, the SEAL ISLAND was in port at St. Croix and engaged in discharging cargo and taking on provisions; the officers and crew were engaged in meetings with shoreside management. This was typically a high workload period for the chief engineer. The chief engineer maintained a day-night/wake-sleep cycle during the period, although he received about 4 hours of rest during each of the first 2 nights in port. The chief engineer slept at night and worked during the day, as was his regular schedule in port or at sea as the senior engineering officer. He normally took an afternoon nap and he said that he did so during the days before the accident. On the night before the accident, the chief engineer reportedly received about 7 hours of uninterrupted rest. He reported for duty in the engineroom about 0700 on October 8.

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[12] A drawing of the SEAL ISLAND aft area containing the engineroom appears in the "Vessel Information" section of this report.

Vessel Information

General Description — The SEAL ISLAND was a single hull VLCC (Very Large Crude Carrier) tankship, measuring 1,117 feet long, 170 feet wide, and 84 feet deep, with a deadweight tonnage[13] of 259,042 tons. The vessel was built in 1973 by Kokums Mekaniska Verkstads AB at Malmo, Sweden, and originally named the ESSO DALRIADA.

The tankship met the requirements of the International Convention for the Safety Of Life At Sea, 1974 (SOLAS '74), and the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL '73/'78). The vessel was built in accordance with Lloyd's Rules and Regulations for the Construction and Classification of Steel Ships. In 1984, the Seal Island Shipping Corporation, a subsidiary of Amerada Hess Corporation, purchased the vessel and renamed it the SEAL ISLAND. At this time, the owners transferred the tankship to the American Bureau of Shipping (ABS) Classification Society and the SEAL ISLAND became subject to ABS requirements.

The SEAL ISLAND was all welded-steel construction with a continuous main deck, raised foc'sle, straight raked stem, and a bulbous bow. Two deckhouses were on the main deck aft of the 17 cargo tanks, over the engineroom. The forward deckhouse, the "accommodations house," contained the navigation bridge, radio room, crew accommodations, dining facilities, recreation rooms, steward's dry stores, hospital, cargo control room and the emergency equipment locker and storeroom.

The aft deckhouse contained the emergency diesel generator room, the inert gas system machinery, and the CO_2 firefighting system storage tank and operating controls. The diesel-driven emergency generator and switchboard were located one level above the CO_2 room. The emergency diesel electrical system provided power to selected vital ship systems, such as steering, communications, emergency lighting, fire pumps, and bilge pumps.

The Engineroom — The engineroom was below the main deck, and the forward and after deckhouses. (See figures 6a and 6b.) It extended from the tank top to the main deck, a height of about 80 feet. The engineroom contained the propulsion boilers, steam turbine main engines, and other machinery, such as the ship's service diesel-driven generator and the ship's service steam turbine-driven generator. The main machinery control console on the first level of the two-level engine control room contained the on/off switches and gauges for the ship's electrical equipment. A separate panel section on the console contained the "preferential switches" for all nonessential machinery that could be shut down to reduce the electrical load without affecting navigating the vessel.

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[13] The cargo weight that a vessel can carry. Deadweight tonnage is measured in long tons of 2,240 pounds.

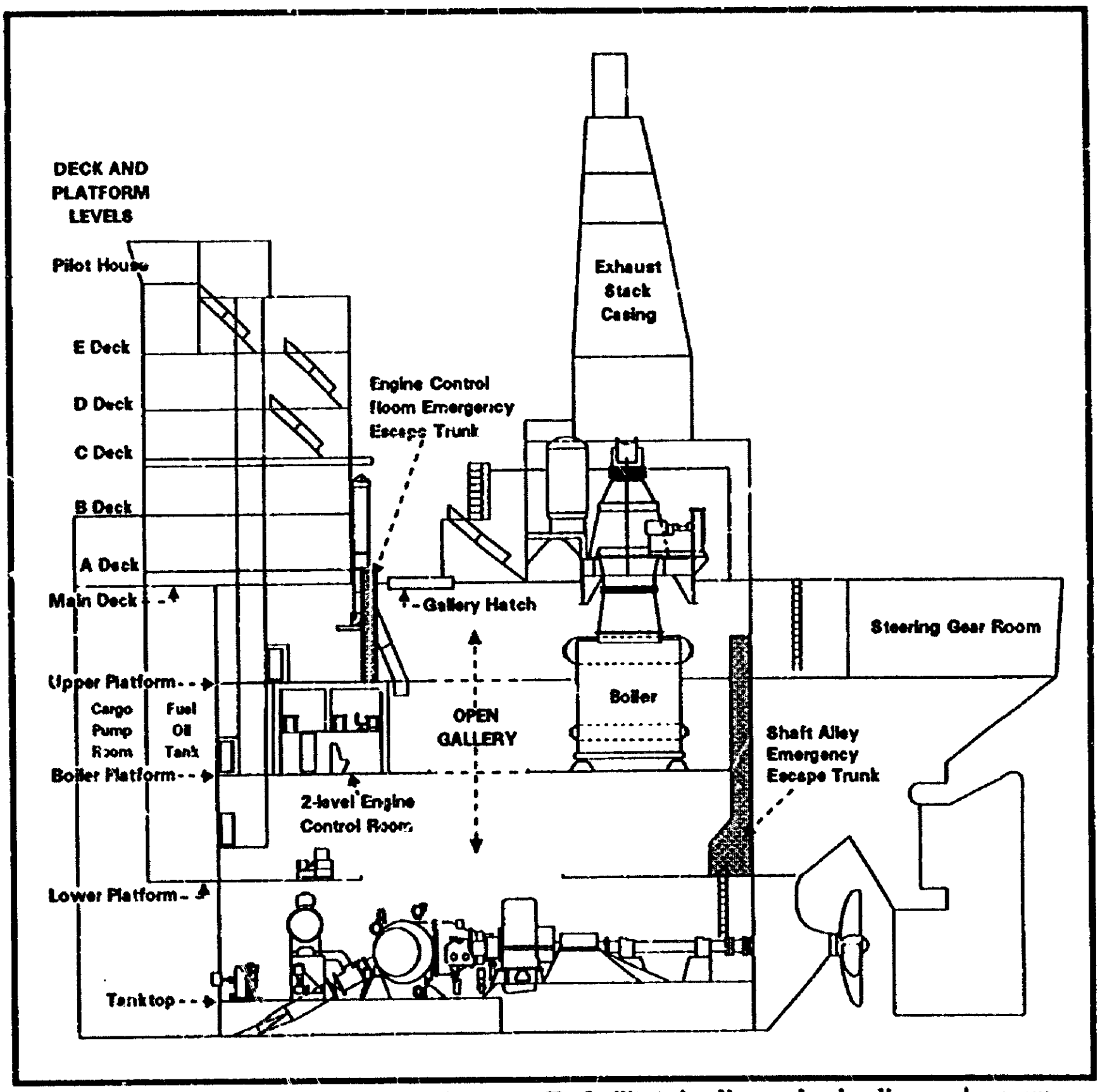


Figure 6a — Inboard profile of engineroom. To facilitate loading and unloading engineroom equipment, an open gallery extended 80 feet from the tanktop level to the main deck.

Means of Escape — The SEAL ISLAND's engineroom emergency exit layout met the requirements of the SOLAS 1974. Two separate open steel stairways led up to exits on the main deck. The engineroom also had two emergency escape trunks. The shaft alley escape trunk extended from the tank top level at the aft end of the engineroom, upward to the steering gear room and from there via a ladder to the main deck. A second emergency escape trunk in

the upper level of the engine control room led up to the main deck. Routes were marked with exit signs and arrows.

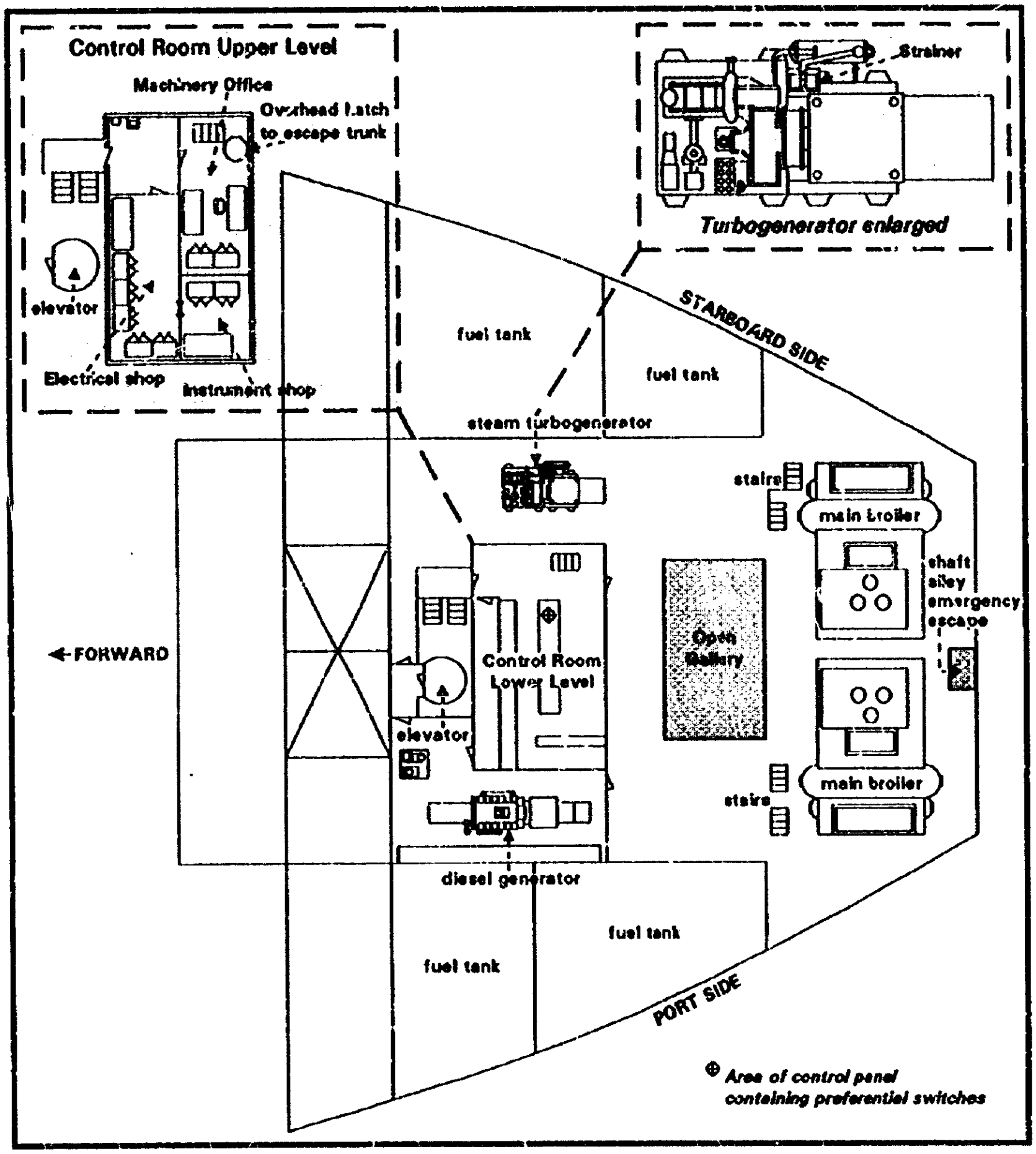


Figure 6b — Plan view of boiler platform level in engineroom.

Engineroom Ventilation — Supply and exhaust ventilation fans driven by the main electrical power system provided forced-air through ducts to the engineroom. Outside ambient air was drawn through manually controlled vent dampers (louvers) on the vessel's exterior and circulated to all levels in the engineroom with the exception of the control room. Air for the two-level engine control room air was drawn from the engineroom interior.

Main (Ship Service) Electrical Power

Generator capacity — Main ship service electrical power was generated primarily by the turbogenerator, which had a rated capacity of 1350 kw at 440 volts and 60 cycles per second (cps), and was augmented occasionally by the ship service diesel generator, which had a rated capacity of 940 kw at 440 volts and 60 cps. Each generator could be operated alone or in parallel for added electrical capacity. Safety Board investigators examined engineroom log books and determined that the SEAL ISLAND's average at-sea electrical load was about 750 kw and that its average electrical load when maneuvering or conducting cargo (loading/discharge) operations was about 1100 kw. Further, the Safety Board reviewed ABS classification surveys and tests dating from 1992 for the ship service generators and their prime movers. During ABS examinations and operational tests, the generators and prime movers of the ship service generators were disassembled, examined, reassembled, and test-operated to 80 percent of rated capacity. The SEAL ISLAND's last ABS test in February 1994, showed the generators operated satisfactorily. (See appendix C.)

Operating conditions established by chief engineer -- The chief engineer had sailed on the SEAL ISLAND for 10 years. He repeatedly testified that neither the turbogenerator nor the diesel generator alone could provide the tankship with adequate electrical power. He said that the turbogenerator and the diesel generator could carry maximum electrical loads of only 950 kw and 550 kw respectively.

The chief engineer stated that electrical loads over 550 kw would cause the diesel generator's prime mover to overheat and shut down. He said that the Caribbean and the South Atlantic seawater temperatures were too high (about 86°F) to provide sufficient diesel engine cooling. He directed that the routine at-sea electrical load be carried by the turbogenerator alone. He did not operate the diesel generator unless he needed additional electrical capacity. Engine logs indicate that the diesel generator's electrical load rarely exceeded 300 kw. The chief engineer expressed his opinion about the diesel generator's load capacity to the other engineers, but never advised Atlantis management either during meetings or in written reports.

Ship Service Generators — Because of the chief engineer's testimony and the nature of the accident, Safety Board investigators focused particular attention on features that were designed to keep the ship service generators from overheating and/or operating.

Ship service diesel (driven) generator -- The generator's diesel drive engine had two means of reducing heat caused during normal operation. An engine-mounted lubricating oil pump supplied cooled lubricating oil to the diesel engine bearings and treated fresh water

cooled the jacket surrounding the cylinder liners. The fresh water itself was cooled by seawater in a heat exchanger outside the engine. The diesel high temperature jacket cooling water trip was set to alarm at 185°F, and shut down the diesel engine at 194°F.

Ship service turbogenerator — The oil lubricating pump system of the turbogenerator had several redundant features and safeguards designed to maintain the pressure and flow of cooled lubricating oil to the turbine bearings and to the governor speed control as long as main or emergency electrical power was available and oil remained in the 210-gallon sump.

The primary pump of the oil lubricating system was gear-connected to and powered by the turbine drive. An electric motor-driven lubricating oil pump discharged oil to the bearings during normal operating conditions when oil pressure dropped below a given set-point. Should the SEAL ISLAND lose main electrical power, the emergency diesel generator would power the electric lubricating oil pump. During the Safety Board's postaccident on-scene examination of the turbogenerator, investigators found the oil sump empty.

Lubricating Oil Strainer — The oil being pumped flowed through the system strainer and lube oil coolers to the turbine bearings and to the speed control governor. The turbine manufacturer's operational manual states that the strainer has a maximum differential pressure rating of between 11.6 and 17.4 psi, meaning if the operating differential pressure is in this range, the strainer can no longer function as designed and must be cleaned.

Lubricating Oil — The manufacturer's product data sheet for the TRO-MAR T lubricating oil used in the steam turbogenerator lists its flash point as greater than 460° F and its auto-ignition point as 500°F. The temperature of the steam in the turbine was about 950° F.

Firefighting Systems and Gear

Ship's firefighting systems — The SEAL ISLAND had a variety of firefighting systems and equipment. Two electrically driven main fire pumps, which supplied pressurized seawater to the fixed firemain system, were located port and starboard on the engineroom tank top level. Hydrants were located throughout the vessel, and water/foam monitors (cannons) were mounted on the main deck centerline above the cargo tanks. Two international fire hose connection hydrants were on the main deck aft of the cargo tank valve manifolds. Remote controls for starting/stopping the starboard fire pump were in the engine control room, the navigation bridge, the foam room, the cargo control room, and on the emergency generator switchboard. The port fire pump could be started at the pump itself, or from the engine control room.

An emergency diesel-driven fire pump in the main deck foc'sle compartment provided pressurized seawater to the firemain system and deck monitors in the event the main fire pump became inoperable. The emergency diesel fire pump could be started from the navigation bridge, the engine control room, and at the fire pump diesel engine. On March 15, 1994, the

U.S. Coast Guard tested the emergency fire pump during a routine Port State boarding inspection in St. Croix, and determined that the diesel and the pump operated satisfactorily.

The firefighting foam system provided additional fire extinguishing capability from the foam room on A deck in the forward part of the accommodations house to the pump room, and the cargo deck area's nine foam monitors (canons). Firefighting foam could be pumped to the engineroom from the foam pump room on the main deck. Seven foam monitors were on raised platforms along the centerline, and two were on the port and starboard of the main deck, aft of the cargo block. The foam proportioner pumps and all the valves to direct foam to the deck monitors were located in the foam room. The foam system was inoperable without the pressurized fire main.

The engineroom had a dedicated fixed 11.3-ton bulk CO_2 fixed system. Portable and semi-portable CO_2 fire extinguishers were located throughout the engineroom. The SEAL ISLAND's CO_2 firefighting system had last been surveyed on November 30, 1993, and recertified until November 30, 1994.

Individual safety gear — The SEAL ISLAND had a number of individual safety gear items, most of which were stowed within or near the engineroom. The vessel had 9 self-contained breathing apparatus (SCBA) with 13 spare air cylinders. Of these, 2 SCBA's and 3 air cylinders were stowed in the engineroom, and 7 SCBA's and 10 spare air cylinders were stowed in the emergency gear lockers, the accommodation house, and near the cargo control room and the pump room. The SEAL ISLAND had 11 10-minute EEBA's (Emergency Escape Breathing Apparatus), of which 4 were in the engine control room, 1 was in each of the three emergency gear lockers, 3 were in the pump room, and 1 was in the cargo control room. Other safety gear included 8 fireman outfits,[14] a fire blanket in the machine shop, and a fire suit in the control room.

During postaccident examination of the vessel, Safety Board investigators found one empty SCBA about 8 feet from the body of the electrician. Investigators found two unopened EEBAs, one on a shelf in the engine control room and the other on a stairway leading to the second level of the control room.

Emergency Equipment — The ABS issued a 2-year Cargo Ship Safety Equipment Certificate for the SEAL ISLAND on June 8, 1993, in St. Croix, U. S. Virgin Islands. The certificate states that the SEAL ISLAND was outfitted with two lifeboats to accommodate 50 persons each; 97 personal flotation devices (PFD's); 3 liferafts; 8 lifebuoys; 35 immersion suits; 2 emergency positioning indicating radio beacon's (EPIRB) for survival craft; 10 two-way radiotelephone apparatus and one portable radiotelegraph apparatus for survival craft.

U.S. Coast Guard Vessel Boarding Examinations — On March 15, 1994, Coast Guard inspectors conducted an annual tank vessel examination of the SEAL ISLAND,

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[14] According to the Safety of Life At Sea Convention of 1974, Regulation II-2A-17, as amended, a fireman's outfit consists of protective clothing, boots, helmet, flashlight, axe, and an approved breathing apparatus.

following which the Coast Guard issued an examination letter that was valid for 1 year. The examination letter states that the safety examination was completed as required by 46 U.S.C. 3714, and that the vessel was considered safe for the carriage of crude oil and lower cargoes. Two days before the accident, a U.S. Coast Guard marine inspector had performed a routine examination of the SEAL ISLAND while it was moored at the Hess Oil Terminal in St. Croix and noted no deficiencies.

Waterway Information

General — The Island of St. Croix in the Lesser Antilles island chain is one of the constituent islands of the U.S. Virgin Islands and is about 80 square miles. The main cities on the island are Christiansted and Frederiksted.

Hess Oil Terminal — The Hess Oil Refinery, located at Limetree Bay on the south shore of St. Croix, is the largest refinery in the Western Hemisphere. It operates a marine oil transportation facility with 10 berths for ships up to 300,000 deadweight tons. VLCCs exceeding a 55-foot draft limitation must be lightered before entering the harbor. The refinery operates 24 hours a day, 365 days per year.

Operations

Management Structure and Policy — The SEAL ISLAND was owned by the Seal Island Shipping Corporation and managed by Atlantis Agency, Inc., both of which are subsidiaries of Amerada Hess Corporation. According to Atlantis officials, company management is organized in accordance with the International Standards Organization's 9000 series management system (ISO-9000).[15] At the time of the accident, Atlantis shoreside management had completed 16 months of the 18-month ISO-9000 certification process. However, the ISO-9000 had not been fully implemented on the ships managed by Atlantis. In the Atlantis management hierarchy, every shipboard senior officer, including the master, chief engineer, and chief steward, is an Atlantis manager or department head. Written company policies and procedures outline each officer's responsibilities.

As a link between shoreside executive management and on-board management of vessels, Atlantis has shoreside representatives who visit an Atlantis-managed ship whenever it is in port. Atlantis officials stated that the shoreside representatives include company port captains, port engineers, and ship superintendents. The ship superintendents are the primary liaisons between the ship and the company for maintenance, supplies, and repairs. Atlantis officials stated that all shoreside are individuals who "generally have extensive sea-going experience and possess advanced merchant marine licenses." Officials explained that the

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[15] The ISO-9000 standards, which are generic in nature and applicable to all industries, contain quality assurance requirements and quality management guidance. The ISO organization is made up of 91 member nations and is based in Geneva, Switzerland. The United States representative to the ISO, the American National Standards Institute (ANSI), issues the ISO 9000 series as the ANSI /ASQCQ90 Series. Atlantis Agency received its ISO 9000 certification from Lloyd's Register Quality Assurance in December 1994.

purpose of the visits is for shoreside representatives to meet with the vessel's master and chief engineer and to tour the vessel to get a general idea of its condition. Areas covered in the routine walking tours typically include the accommodations house, engineroom, machinery spaces, cargo control room, main deck, and pumproom. On these tours, a senior officer of the ship is to accompany the shoreside representative(s) to point out areas where maintenance is needed, planned/requested, in progress, or has been completed. Atlantis officials stated that the meetings and tours allow on-board managers to speak face to face with company representatives, and to identify items for shipyard maintenance during annual vessel examinations. The shoreside representatives must develop a report during each vessel visit, and submit it to senior management for review and discussion.

Between ports, the on-board managers (master/chief engineer) are required to complete monthly requisition and maintenance reports, which can be filed electronically by means of shipboard computers. Atlantis-managed vessels have a variety of equipment to facilitate ship-to-shore communication. The SEAL ISLAND had a telex, a facsimile machine, several international maritime satellite telephones, and a standard marine radio.

In addition to the vessel visits by ship superintendents and the required monthly maintenance reports from on-board officers, Atlantis contracts independent safety consultants to perform inspections of company-managed vessels.

SEAL ISLAND Visits and Reports — The Safety Board reviewed all company visit reports and associated records, such as requests for repairs and spare parts, and maintenance records for the 2 years before the accident. Records show that Atlantis officials, usually ship superintendents, made vessel visits to the SEAL ISLAND about monthly. Safety Board investigators determined that the SEAL ISLAND's chief engineer had filed maintenance reports and forms in accordance with Atlantis requirements.

The Board found that no report from any on-board or shoreside employee addresses an over-heating problem in the diesel generator's diesel engine. Further, no record shows that the turbogenerator or the diesel generator had a capacity problem. No report filed by the chief engineer mentions the strainer leak or the temporary repair.

Atlantis shoreside officials visited the SEAL ISLAND several times after the temporary assembly was placed on the oil strainer. On June 26 and 27, 1994, shoreside representatives made a routine visit to the tankship. Both the chief engineer and the replacement chief engineer attended the meetings, but neither mentioned the repair of the lubricating oil strainer.

On August 29-31, 1994, the Atlantis president, a marine manager, and a ship superintendent visited the tankship as part of an ISO 9000 certification audit. During this visit, the Atlantis engineering manager and a contracted ISO consultant participated in meetings held on August 29-30. During their 3 days on board the SEAL ISLAND, shoreside management representatives explained policies relating to corporate quality, safety, and environmental protection to the SEAL ISLAND master, the chief engineer, and the replacement chief engineer. Atlantis officials stated that they emphasized the importance of feedback from on-

board personnel. The visit report indicates that the master and chief engineers made "constructive suggestions to improve the system and its procedures" throughout the discussions, which resulted in actions being taken immediately on their suggestions and procedure changes being made. Neither the chief engineer nor the replacement chief engineer mentioned the repair to the lubricating oil strainer during the visit.

On October 7, the day before the accident, an Atlantis marine manager, an ISO consultart, and an Atlantis senior ship superintendent conducted a scheduled internal safety audit. The chief engineer attended the meetings, but made no mention of the strainer repair or problems with the diesel generator.

The replacement chief engineer later testified that he thought the chief engineer, as the regular head of the ship's engineering department, would report the strainer repair, rather than he, who "was just a temporary replacement." The chief engineer testified that he did not consider the temporary strainer repair "serious enough" to warrant mentioning during a meeting. The report for the June 1994 visit shows that the maintenance discussions included such items as maintenance of tank cleaning gear and the IGS air intake, replacing broken tiles in the crew shower, and replacing lighting fixtures and bulbs.

The chief engineer testified that he spoke to three people about the repair to the turbogenerator lubricating oil strainer. He said that shortly after completing the strainer repair, during a meal he told the master that there had been a small oil leak, but that it has been fixed. The chief engineer testified that he told a safety consultant about the strainer repair during the consultant's visit on June 23-26, 1994. He said that during the June 26 Atlantis management ship visit, the Atlantis senior ship superintendent had asked him when he was going to fix (make permanent repairs) the turbogenerator strainer. These three individuals testified that they did not remember the chief engineer talking about the strainer or its repair.

The independent safety consultant was on board primarily to observe cargo operations. His rough notes of his examination contain a cryptic note referring to the turbogenerator lubricating oil strainer caps (covers). However, no information about the strainer appears in his final report to Atlantis. He later testified that he did not remember seeing the temporary assembly and made no mention of it to anyone at Atlantis.

Repair Opportunities — The chief engineer repeatedly testified that he did not have an opportunity to make a permanent repair to the turbogenerator's lubricating oil strainer between the time that he had the temporary assembly put on the strainer and the accident. He said that he could not make the repair while at sea because he could not slow the vessel. Other SEAL ISLAND engineers and Atlantis shoreside engineers stated that one forced-draft fan could be shut down with minimal or no reduction in the firing rate of the boiler to reduce the at-sea electrical load. The chief engineer stated that on the runs between Lagos and St. Croix, the (86^0) seawater was too hot to transfer the electrical load to the diesel generator. He said that he could not make the repair while in port because both generators were always in use during car-

go operations. The Safety Board reviewed the ship logs to determine whether engineering personnel may have had the 2 hours necessary to change the O-ring in the directional flow valve.

About 0930, September 14, 1994, the SEAL ISLAND arrived at the Hounds Point, Scotland, anchorage at which Atlantis had scheduled inspection and maintenance for the starboard boiler. As part of this inspection, engineering personnel were to identify maintenance that needed to be performed at the SEAL ISLAND's next shipyard period in December 1994, during which the tankship was scheduled for its annual ABS inspection.

The chief engineer stated that during their 4 days at Hounds Point, he and the rest of the engineering staff were too busy with the boiler inspection and maintenance to complete the 2-hour permanent turbogenerator strainer repair. He said that in order for the SEAL ISLAND engineers to disassemble the starboard boiler casing for inspection, they had to put out the fires in the boiler and allow it to cool before they could proceed. In this case, the boiler work did not start until the next day, September 15.

While the SEAL ISLAND was anchored at Hound's Point, the temperature of the seawater was cool, 52°F. The chief engineer did not attempt to repair the strainer.

The boiler inspection and maintenance was completed and the boiler fires were re-lit at 1620 on September 17. After lighting the boiler, the period of warmup was about 8 hours. No attempt was made to shut down the turbogenerator so that permanent repairs could be made to the turbogenerator strainer. On September 18, the SEAL ISLAND sailed for St. Croix.

When asked when he intended to repair the turbogenerator lube oil strainer after departing Hounds Point for St. Croix, the chief engineer said, "It was always my intention to fix it at the first opportunity. But, other repairs came up of a more important nature, and it just didn't get done."

Medical and Pathological

Medical Findings — On the day of the accident, all six engineroom survivors were taken to St. Croix Hospital where they were stabilized. The chief engineer and the machinist were then flown to Pavia Hospital in San Juan, Puerto Rico. The six survivors were subsequently transported to St. Barnabas Hospital Burn Center in New Jersey. The chief fireman, fireman, wiper, and third engineer were admitted at St. Barnabas on October 9 and the chief engineer and machinist were admitted on October 12. The chief engineer, who suffered the most severe burn injuries, was transferred on January 23, 1995, to the hospital's burn service clinic where he remained until March 14, 1995. Table 2 summarizes the medical findings.

The bodies of the three crewmembers who died in the fire were transported to the Medical Examiners Office in the U. S. Virgin Islands for autopsy. The electrician, the first engineer, and the machinist all died from smoke inhalation, asphyxia, and heat exposure with first and second degree burns.

Table 2 -- Medical Findings

Injured Crewman	Dates Admitted to/ Released from St. Barnabas	Nature of Injury
Third Engineer	October 9/ October 11	Mild smoke inhalation
Wiper	October 9/ October 19	Smoke inhalation; second degree burns on face, ears, right forearm from fire and hot oil
Fireman	October 9/ October 19	Smoke inhalation; second and third degree burns from fire and hot oil
Chief Fireman	October 9/ October 19	Smoke inhalation; second degree burns on face, ears, hands, fingers and left forearm from fire and hot oil.
Machinist	October 12/ October 22	Smoke inhalation; second degree burns on left hand from fire and hot oil
Chief Engineer	October 12, 1994/ January 23, 1995*	Severe smoke inhalation, including burns to lungs; burns on face, hands, torso and lower extremities from fire and hot oil

* On January 23, 1995, the chief engineer was transferred to the St. Barnabas Burn Service Clinic where he remained until March 14, 1995.

Toxicological Testing — The marine employer and the U.S. Coast Guard did not collect toxicological specimens from the crewmembers involved in the accident because they had been injured during the fire and transported away from the scene. Specimens taken from the injured crewmen for purposes of medical treatment by the hospitals were destroyed within 24 to 30 hours after they were collected and were therefore not available to the Safety Board for postaccident toxicological examination.

Toxicological specimens taken from the deceased crewmembers by the St. Croix Medical Examiner were forwarded for examination to the Center For Human Toxicology (CHT), Salt Lake City, Utah. Examination of the specimens did not detect the presence any illicit drugs or alcohol. Specimens taken from the electrician contained two substances typically found in over-the-counter cold medications: Acetaminophen, an analgesic; and Dextromethorphan, a cough suppressant.

Wreckage

Fire and heat damage extended from the boiler platform upward throughout the upper engineroom. Interior and exterior steel decks and bulkheads had warped from the heat, piping had fractured, electrical power cables had been incinerated, and machinery and electrical controls been burned.The boiler also had sustained heat damage.

The open central stairwell from the boiler platform to the accommodations deckhouse sustained severe heat damage. On the A deck above the engineroom, the dry stores compartments had completely burned, and a deck cabin with a door ajar had suffered heavy heat and smoke damage to its interior. The door from the central stairwell into C deck was open, and

the passageway was heavily damaged from smoke and heat. All levels in the accommodations house were flooded with water. Heat had destroyed the electrical cable trays next to the central stairwell in the A deck storerooms and in the overhead above the passageways. The welds at the base of the accommodations house exterior (main deck) bulkheads were fractured.

Areas below the boiler platform sustained little heat damage. However, the lower engineroom was flooded with about 5 feet of water from the firefighting efforts.

Survival Factors

This section of the factual is divided into two main parts. The first part provides the regulatory basis for shipboard drills and reconstructs the escape and response events on the day of the accident based on testimony. The second part provides information related to general incident command systems, the Hess Oil Virgin Islands Corporation (HOVIC) incident command system, and the response actions and events on the day of the accident.

Emergency Training and Drills — According to SOLAS 74:

> Each member of the crew shall participate in at least one abandon ship drill and one fire drill every month. The drills of the crew shall take place within 24 hours of the ship leaving a port if more than 25 percent of the crew have not participated in abandon ship and fire drills on board that particular ship in the previous month. The Administration may accept other arrangements that are at least equivalent for those classes of ship for which this is impractical .... Fire drills should be planned in such a way that due consideration is given to regular practice in the various emergencies that may occur depending on the type of ship and its cargo. [16]

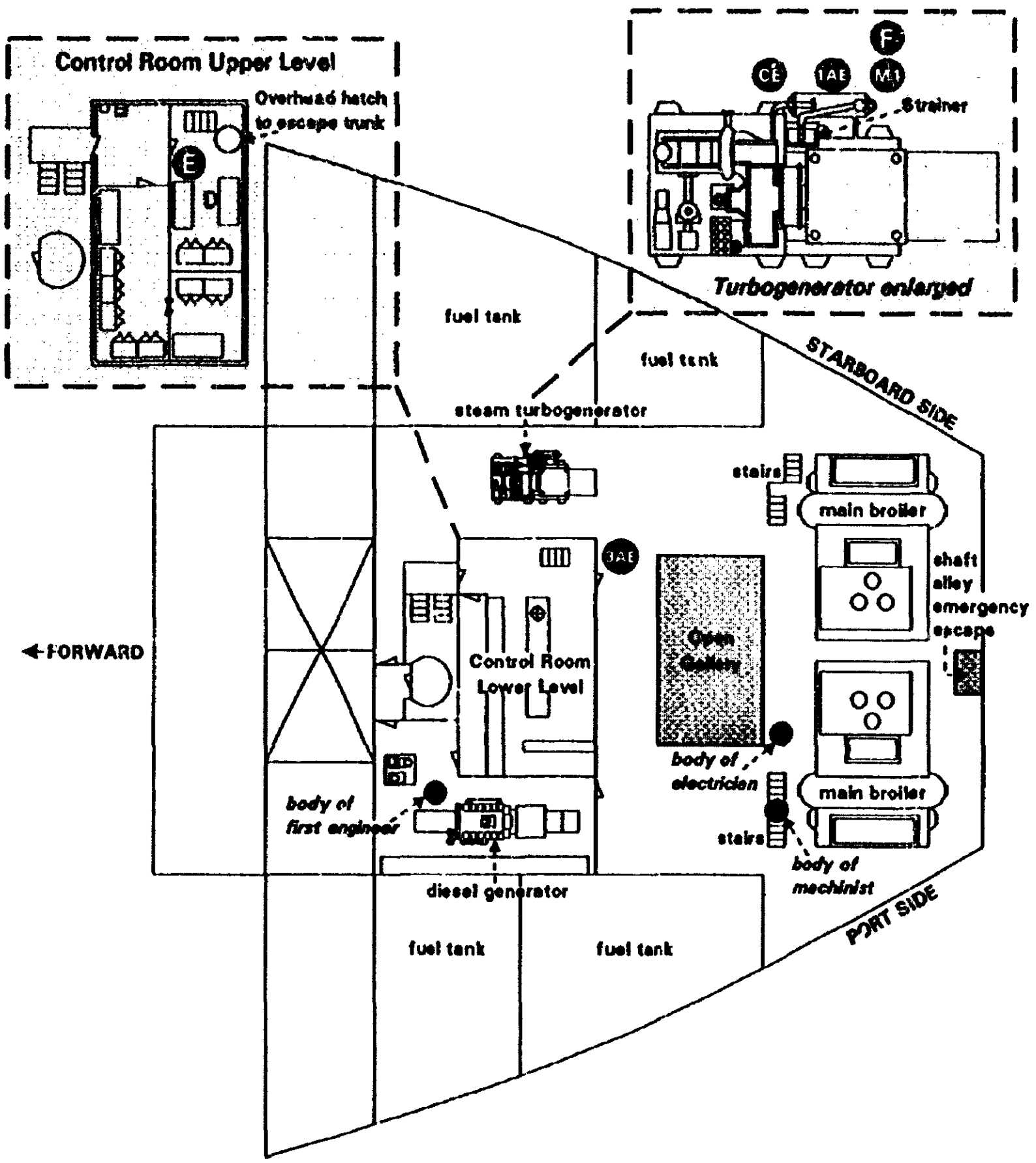
The SEAL ISLAND crew testified that every Sunday they participated in fire drills, which involved reporting to their fire stations and performing their Station Bill emergency duties. No crewmember could recall a fire drill simulating an escape from the engineroom. The machinist could recall one occasion during which the crew had to respond to a simulated fire in the SEAL ISLAND engineroom. The chief engineer testified that fire drills on board the SEAL ISLAND were usually conducted on the main deck.

Escape From the Engineroom — When the lubricating oil ignited, five crewmembers were standing near the turbogenerator. (See figures 7a and 7b.) The chief fireman and a wiper were on the upper platform level, the electrician was in the electric shop on the control room upper level, and a machinist was in the machine shop. Survivors testified that the fire spread within seconds from the turbogenerator outward and upward along the starboard

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[16] 1991 Amendments, Chapter III, Part B Ship Requirements, Section I-Passenger Ships and Cargo Ships, Regulation 18, "Emergency training and drills."

When the fire erupted, six employees were on the boiler platform level. The first engineer (1AE) was next to the lubricating oil strainer. The chief engineer (CE), a machinist (M1), and the fireman (F) were standing nearby. The third engineer (3AE) was near the door to the lower level of the control room. The electrician (E) was on the upper level of the control room. This figure does not show the locations of the chief fireman, a wiper, and another machinist because they were on higher engineroom levels.



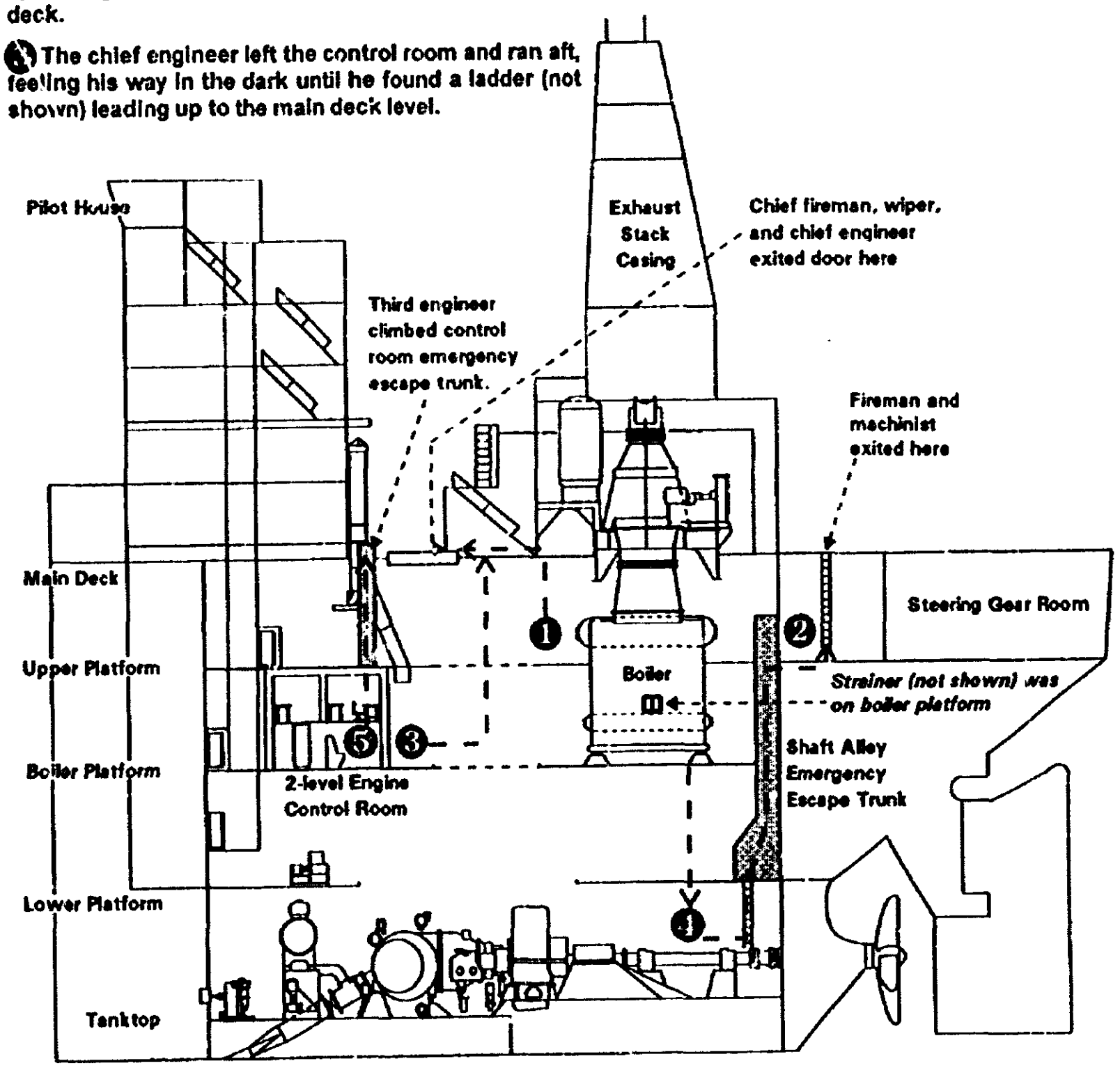
When emergency responders were able to enter the engineroom after the fire was extinguished, they found the bodies of the first engineer and the electrician on the boiler platform level, near the diesel generator and aft of the open gallery, respectively. The machinist's body was on a stairwell leading up to the next platform.

Figure 7a — Above shows the locations of the crewmembers who were on the boiler platform level when the fire erupted. Black dots show where responders found the bodies of the deceased.

❶ The chief fireman and the wiper happened to be on the upper platform. They quickly ran up the nearest stairs (not shown) to a door the main deck.

❷ The fireman tried to use the stairs that the chief fireman and wiper had used, only to find that the fast-spreading fire blocked his exit. He ran aft to the steering gear room and climbed up a ladder to the main deck.

❸ The chief engineer left the control room and ran aft, feeling his way in the dark until he found a ladder (not shown) leading up to the main deck level.



❹ The surviving machinist ran aft and felt his way down ladders (not shown) to the tanktop level. He felt his way aft to a ladder that led back up to the lower platform level. From there, he used the shaft alley escape trunk to climb to the upper platform level from which he climbed the steering gear room escape ladder to the main deck.

❺ The third engineer was stranded in the lower level of the control room. He found a portable VHF radio and called for help. On the main deck, the third mate heard his radio call and opened the hatch cover to the engine control room emergency escape trunk. Opening the hatch allowed the accumulated smoke to escape, which, in turn, enabled the third engineer to climb the escape trunk to the main deck.

Figure 7b — Exits taken by surviving crewmembers. In this profile of the engineroom, the stairs, several ladders, and the turbogenerator's oil strainer either are not represented or are "blocked" by pictured equipment, such as the boiler.

bulkheads, and across the overhead plating (underside of upper platform deck) and upward into the engineroom gallery.[17] They described the visibility in the engineroom as "near zero" because of the thick, black smoke generated by the oil fire. Six of the nine men immediately ran for various exits, leaving the chief engineer, the third engineer, and the electrician in the engineroom.

Crewmembers killed in the accident — The escape routes attempted by the first engineer, one machinist, and the electrician are unknown because they did not survive the accident. No survivor could provide information about the escape attempts of the first engineer and the deceased machinist. The electrician was in the control room and was sharing a SCBA with the third engineer when he (the electrician) reportedly panicked, grabbed the SCBA from the third engineer, and ran from the control room. Emergency responders found the electrician's body lying on the deck aft of the gallery on the boiler platform. An empty SCBA was found lying on the deck nearby. Responders found the body of the first engineer in the diesel generator room and the body of the machinist on a stairwell one level above the boiler platform. The deceased machinist had a fire blanket wrapped around his head.

Survivors' routes — The chief fireman and the wiper were on the upper platform when the fire broke out. They quickly ran up the nearest stairs to the main deck. Even though they reached the main deck within seconds of the fire igniting, both received severe burn injures.

The fireman and the surviving machinist used preplanned avenues of exit to escape to the main deck. Both had worked on the SEAL ISLAND before and were familiar with the vessel layout. The fireman had participated in shoreside firefighting training that included engineroom escape. The fireman tried to escape to the main deck using the same stairs that the chief fireman and wiper had used, only to find that fire was blocking his exit. He then ran aft to the steering gear room and climbed up the emergency escape ladder to the main deck.

The surviving machinist had also participated in shoreside firefighting training. He later testified that he had determined beforehand that should an emergency occur on the SEAL ISLAND, he would use the shaft alley escape trunk. When fire broke out, he started to follow the chief engineer, but when the chief engineer went into the engine control room, the machinist ran aft and felt his way down ladders to the tanktop level. He felt his way aft to a ladder that led back up to the lower platform level. From there, he used the shaft alley escape trunk to climb to the upper platform level from which he climbed the steering gear room escape ladder to the main deck.

The third engineer was in the control room when the chief engineer came in and told him to start the fire pump. About the same time, however, the ship service diesel generator shut down, and everything went "black." Within seconds, the emergency lights came on. The chief engineer and the third engineer then went up the stairs to the upper control room, where

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[17] A 25-foot x 25-foot gallery opening, which was used to remove and install machinery, extended from the tanktop (bilge) through each engineroom deck to the main deck gallery hatch. The covered hatch was between the two deck houses, aft of the accommodations house.

they saw the electrician climbing back down out of the lower escape hatch. The Safety Board received conflicting accounts as to why the electrician was not able to exit to deck from the escape trunk. The chief engineer stated that the electrician was not able to move any of the "dogs," or latches, to the hatch cover when he reached the top of the escape trunk. The third engineer stated that the electrician had only climbed a couple of rungs and then had backed out of the escape trunk because accumulated smoke prevented his reaching the escape hatch.

The chief engineer stated that he briefly attempted to check the progress of the fire, but could see nothing in the dark, smoke-filled engineroom. He said that after telling the third engineer and the electrician to run, he left the control room and ran aft, feeling his way along his route because it was so dark. He said that he found a ladder leading up, but lost consciousness in the heavy smoke before he could ascend it. When he regained his senses, he climbed up the ladder to the main deck where he collapsed.

Meanwhile, the third engineer and the electrician were still in the control room, which obtained its air supply from the engineroom. Before the ship service power failed and shut down the ventilation system, the fans rapidly drew the thick, black smoke from the engineroom into the control room. The third engineer said that he could not keep his eyes open because of the smoke.

The third engineer and the electrician had attempted to locate emergency gear, and had found one SCBA stowed in the upper control room. The third engineer said that they were in the lower level of the control room, taking turns breathing from the apparatus, when the electrician panicked, grabbed the SCBA, and ran from the control room. The third engineer said that he knew another breathing mask was in the control room, but he could not get to it because the smoke forced him to lay prone on the deck in order to breathe. After a few minutes, he realized that he was lying next to a small refrigerator. He opened the refrigerator door and stuck his head inside to get a few breaths of clean air. He found a portable VHF radio and called for help. On the main deck, the third mate heard his radio call and opened the main deck escape hatch cover, which enabled the third engineer to climb the emergency escape trunk ladder to the main deck.

Emergency Response Plan

Marine firefighting guidance — The National Fire Protection Association (NFPA) publication 1405,[18] which provides guidance for responses to shipboard fires, states:

> The incident command system (ICS) provides a method for different agencies, organization, and individuals to work together toward a common goal in an organized, productive, efficient, and effective manner....The ICS is adaptable to any type of vessel incident whether fire, explosion, hazardous material, etc. It can be utilized for a small fire aboard a vessel, involving a single agency such as

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[18] *Guide for Land-Based Fire Fighters Who Respond to Marine Vessel Fires*, 1990, the National Fire Protection Association

the local fire department. It can also be used on the large complex incident involving vessel(s) and/or a terminal.

The Incident Commander (IC) has the responsibility for overall management of the incident. This includes staff functions such as information, safety, and liaison to support the command function. The IC will prepare incident objectives that in turn will be the foundation of subsequent action planning. The IC will approve the final action plan and all requests for ending and releasing primary resources....The Incident Commander coordinates the use of all available resources to meet the emergency and consults with the fire chief to develop fire fighting strategies.

> It must be recognized that the local fire chief normally has more experience in the art of fire fighting. In addition, the fire chief has the responsibility for the safety of his men and equipment, and to the community, to contain and extinguish any fires. The success of the operation is contingent on one person being in overall charge of the fire fighting aspects. In the case of shipboard fires, the local fire chief will be the person in charge of the fire fighting operation. The master plays a very important role in lending his experience and assisting the fire chief, which will greatly enhance the successful operation. The presence of the fire chief in no way relieves the master of command of his vessel. However, the master shall not countermand any orders made by the fire chief in the performance of fire fighting duties.

The HOVIC plan — The Hess Oil Virgin Islands Corporation (HOVIC) employees provide emergency services, including fire and rescue response, for the refinery. To handle emergencies such as fires and oil spills that may occur at the refinery, the HOVIC has its own fire brigade of about 200 members representing every department in the refinery. The HOVIC maintains a regular fire department that is composed of one supervisor (the Fire Chief), and two professional firefighters per shift.

Sections of the HOVIC emergency response plan include organizational charts, identify personnel within the incident command organization, and specify guidelines for staging area, safety unit, operations, logistics, planning, and finance. The emergency plan identifies the fire chief as the IC and includes the duties and responsibilities of all members of the HOVIC emergency response team. It also provides an inventory of HOVIC emergency equipment and other resources.

The duties of the IC and the refinery manager as listed in the HOVIC emergency plan are paraphrased in Table 3.

The HOVIC emergency plan does not specifically address procedures for responding to a shipboard fire or provide for the availability of marine consultants that could be used during a shipboard fire at the terminal.

HOVIC firefighting training — The HOVIC fire chief is responsible for the staffing, training, and assignments of the HOVIC fire brigade, which operates a variety of equipment, including water and foam tank-trucks, vacuum trucks, front-end loaders, and emergency rescue vehicles. The HOVIC 1994 fire brigade training program featured classroom lectures and field exercises that included drills and simulations. The curriculum focused on proper and speedy handling of firefighting equipment, including pumps, hoses, and breathing apparatus, and the attributes and handling of the various refinery products, including liquified petroleum gas (LPG), pressurized flammable liquids, and hazardous materials. The training stressed combating fires that occurred at the refinery, including fires within interior building structures, fires from ground spills, fires in storage tanks, and fires that occur when loading or unloading gasoline tank trucks. Neither the HOVIC firefighting training program nor the firefighters' reference manual addressed fires on board vessels docked at the refinery.

Table 3 — HOVIC Emergency Plan Duties

Incident Commander's Duties
Activate necessary fire and evacuation alarms
Establish and announce command post location
Obtain a size-up from operations chief and assess the incident situation
-determine if there are injuries or if rescue is required
-identify facilities and materials involved
-isolate incident area and establish "hot zone" perimeters
Determine if call out required
Develop "Incident Action Plan"
Ensure agency call outs are initiated
Brief command staff and operations chief engineer
Coordinate staff activities
Manage incident operations
Announce incident termination
Ensure "Incident Report" is completed and forwarded to the refinery manager
Refinery Manager's Duties
Obtain incident briefing from IC
Approve and authorize implementation of the "Incident Action Plan";
Oversee overall operation of the refinery
Monitor incident command operations to identify potential inter-organizational problems
Establish and maintain liaison with corporate management
Authorize release of information to news media
Approve requests for additional resources, equipment and supplies
Conduct critique of the incident and approve final incident report

Postaccident Response — In this accident, firefighting and/or rescue efforts lasted from about 0855 on October 8 until about 1200 on October 10 (see chronology sidebar). Most actions and events occurred within 1 1/2 hours of the fire starting; many occurred almost concurrently. Four individuals — the master, the fire chief, the refinery manager (IC), and a ship superintendent — figured in the leadership of the overall response. This section describes the phases of the postaccident response with particular attention on their actions.

Response of key figures — About 0845, when he became aware of the fire, the master of the SEAL ISLAND radioed the terminal port captain for assistance and directed the on-duty third mate, who was in charge of the first aid team, to report to his emergency station. After activating the bridge-mounted remote control for the ship's emergency diesel-driven fire pump, the master left the bridge and climbed down an exterior ladder to the main deck to direct emergency operations.

The HOVIC fire chief was at home when he was notified of a fire on board the SEAL ISLAND. After instructing his on-duty personnel to sound the terminal fire alarm, he drove to Dock 3, arriving on scene shortly before 0900, and boarded the vessel.

Meanwhile, a senior ship superintendent of another Amerada Hess Corporation subsidiary was working on an integrated tug-barge unit at Dock 8 when he became aware of the fire on board the SEAL ISLAND. Although he was not a professional marine firefighter, he said that because he was familiar with the layout of the tankship from his past experiences, he drove to Dock 3 to see if he could assist. He boarded the tankship about the same time as the fire chief.

The HOVIC refinery manager was notified of the vessel fire about the same time as the fire chief. The two men later testified that because of the size of the fire, the HOVIC refinery manager assumed the role of IC. The HOVIC refinery manager then proceeded to Dock 3, where he established a command post about 0925. A refinery employee advised the IC that the superintendent had gone aboard the SEAL ISLAND to assist.

Early evacuations — The third mate met his first aid team in the ship's hospital. They picked up medical supplies, and proceeded to the aft muster station on the main deck, arriving about the same time that the injured chief engineer and wiper emerged from the engineroom. The third mate placed the chief engineer on a stretcher and gave him oxygen. He then had crewmembers carry the chief engineer ashore to a HOVIC ambulance that had just arrived.

CHRONOLOGY OF EVENTS

Time	Event
October 8, 1994	
0843	Lube oil fire ignites at turbogenerator
0845	Master hears fire alarm
0855-0857	HOVIC firefighters and rescue team arrive. Begin helping injured crewmembers ashore. HOVIC fire chief arrives, orders fire hoses laid out, and requests an additional ambulance from Christiansted. Atlantis ship superintendent arrives and boards SEAL ISLAND. Overhears Master talking with firefighters.
0905	Fire chief calls for standby pumper trucks and for additional breathing apparatus.
	Firefighters try to hook up hose to ship's fire main, but fail because connections are incompatible
0923	Fire chief sends two rescue team members down to control room.
0935	Firefighters obtain international shore connection from tankship.
0940	Door on aft deckhouse blows open. Eruptions occur below deck. Fire chief orders his men out of control room.
0948	Fire chief orders firemen ashore; after speaking with Master, he too goes ashore.
	Master and superintendent release CO_2.
1100-1130	Fire chief asks ship superintendent to come ashore for a meeting with the IC. Superintendent brings the ship's Fire Control Plan with him. After meeting with shoreside firefighters, the superintendent returns to the SEAL ISLAND.
1400	Fire chief has men stop pumping foam into engineroom.
1545	Superintendent notices temperature increase and orders HOVIC tugs to direct more water at port side aft hull. Enters engineroom by himself and without a breathing apparatus.
1700	Owner's representatives arrive and superintendent is called to dock for a meeting.
1800	Four 2-man hose teams enter engineroom, but find it too dark and smokey to see. Fire chief orders men back out.
2000-2030	Fire chief seals engineroom, establishes fire watch, and sends firemen home with instruction to return next day.
2200	Fire chief goes home.

continued on next page

The third mate then heard the third engineer's radio call for help, whereupon he opened the main deck control room escape hatch cover, allowing the third engineer to escape from the control room. Within 20 minutes of the fire igniting in the engineroom, the third mate and his team had evacuated six injured engineroom crewmembers from the tankship to waiting HOVIC ambulances on shore.

Initial response actions — When the fire chief observed the SEAL ISLAND crewmembers assisting the burn victims while they were still on the tankship, he radioed for an additional ambulance from Christiansted. As he proceeded aft of the deckhouse, he noted that the deck was hot. By 0900, an initial contingent of HOVIC firefighters had arrived on scene and a rescue team had boarded the vessel. About 0905, the fire chief called for two stand-by pumper trucks to respond to the fire and for breathing apparatus and spare air bottles to be brought aboard.

CHRONOLOGY OF EVENTS

Time	Event
October 9, 1994	
0100	Fire chief responds of report of increased smoke coming from ship.
0400	Fire chief goes home.
0800	Fire chief and firefighters return to ship. They fine no fires on D, C, and B decks.
1130	Firefighters extinguish small fires still burning in an A Deck storeroom.
1340	Fire is officially declared "out." Firefighters begin opening hatches.
1630	Two 5-person teams enter engineroom to search for missing crewmen and locate two bodies. Teams have to leave engineroom because of low air supplies. Because it is almost dark outside, fire chief orders search called off until the next morning.
October 10, 1994	
0930	Rescue teams enter engineroom and locate third body.
1100	Last body is removed and released to St. Croix coroner.
1200	Incident is officially closed.

When the fire alarm sounded, crew members reported to their muster station aft of the accommodations house. The crew ran the fire hoses out on deck, but could do little more because no water pressure was in the ship's fire main system. Responding HOVIC firefighters were attempting to hook up a hose to the ship's fire main, but were having problems because the hose threads did not match the pipe threads on the hydrant.

The master observed that the hoses were not charged. He instructed the second engineer to go forward to the emergency diesel-driven fire pump to check to see if it was running, and to start it manually, if necessary.

Meanwhile, the ship superintendent was checking the status of the inert gas system indicators, which he determined were satisfactory. He then walked aft to where the master was talking with HOVIC firefighters. He noticed that there was no pressure in the firemain system. When he overhead the firefighters saying that they were having problems connecting their fire hoses, he directed the second mate and the second engineer to go to the pumpman stores locker

and get the ship's spare international shore fire hose connection.[19] By 0935, firefighters had received and attached the international shore fire hose connection (see figure 8).

In later testimony, the fire chief stated that he had considered the master responsible for the firefighting operations on the SEAL ISLAND itself, and that his role on scene had been to assist the master. The superintendent testified that HOVIC personnel were not knowledgeable of the ship and that they (deferred to him because they) recognized that he was. He further stated that after an early telephone conversation with the ship owner's representative, he understood that he was to be in-charge of the on-scene as the owner's representative.[20]

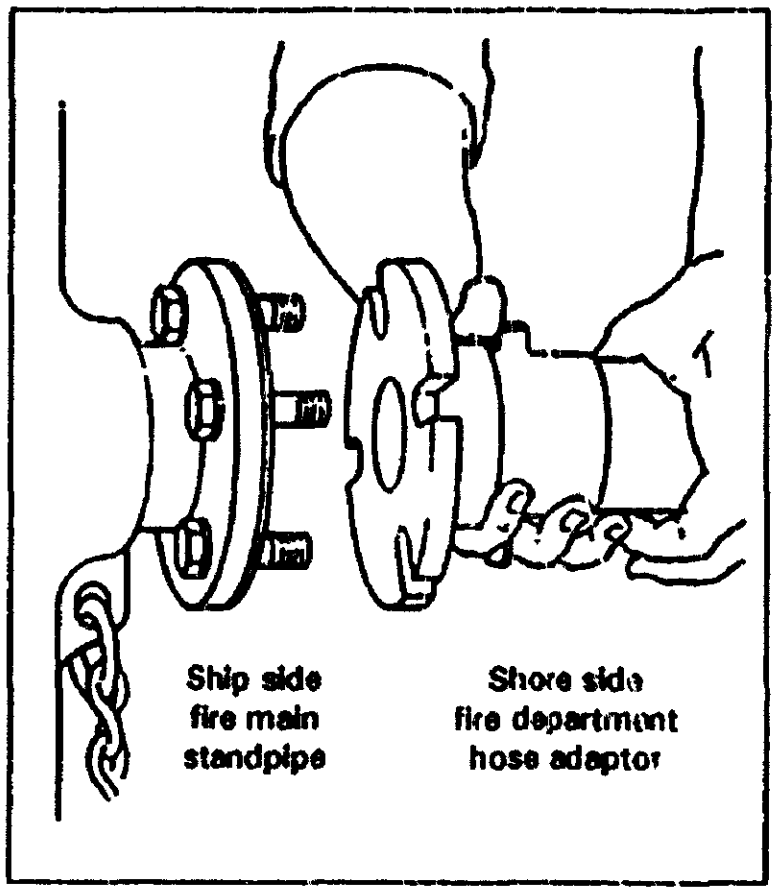


Figure 8 — International Shore Fire Hose Connection[21]

First attempts to enter the engineroom — Before the HOVIC rescue team arrived, the SEAL ISLAND chief mate and the second mate each donned a SCBA and made two attempts to enter the engineroom, one through the emergency escape trunk on the stern, and the other through the A deck access and down the central stairway. Because of the intense heat and dense smoke, they could not enter the engineroom to search for missing crewmembers.

About 0923, the fire chief sent a HOVIC rescue team and firefighters equipped with fire suits and SCBAs to the engineroom control room via the emergency escape trunk. At this time, the hoses were not charged.

About 0940, the port forward door on the aft deckhouse blew open and the fire chief felt several eruptions, or pressure waves, beneath his feet. The fire chief radioed the rescue team and the firefighters below to return to the main deck. When the fire brigade members had returned to the main deck, the fire chief ordered all shoreside firefighters off the vessel about 0950. He did not order the ship's crew to go ashore. A refinery employee listening to the radio traffic advised the IC that the firefighters were abandoning ship. Before leaving the tankship,

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[19] An International Shore Fire Hose Connection is a bolted flange plate specially designed so that it can accomodate any ship's firemain regardless of design, thus eliminating possible mismatches of various fire hose pipe threads. IMO regulations require at least one international shore connection on board ships of 500 gross tons and above.

[20] The representative later testified that he had not designated the superintendent as the person in charge.

[21] The above illustration is reprinted with permission from NFPA 1405, *Guide for Land-Based Fire Fighters Who Respond to Marine Vessel Fires*, Copyright © 1990, National Fire Protection Association, Quincy, MA 02269. This reprinted material is not the complete and official position of the National Fire Protection Association on the referenced subject, which is represented only by the standard in its entirety.

the HOVIC firefighters secured two 2.5-inch-diameter fire hoses in place in the engineroom skylight to the open gallery and the fire chief ordered shoreside firefighters to begin pumping foam from shore through these hoses into the engineroom.

CO_2 release — Before the fire chief left the ship, he informed the master that the HOVIC firefighters were leaving. The master inquired about activating the CO_2 system and the fire chief responded, "It's your ship, Captain, but I would."

Meanwhile, the ship superintendent felt the eruption below deck. He said that more smoke appeared to be coming from the open skylight in the gallery hatch. He then grabbed the ship's master and said, "We gotta close the hatch. We gotta pull the CO_2."[22]

At the CO_2 release station outside the CO_2 room, the master repeatedly expressed concern about releasing the CO_2 because it could kill anyone still alive in the engineroom. The superintendent told him, "The men are [already] dead." The master pulled the CO_2 lever; the superintendent noted no change in the gauge reading. The superintendent told the master to pull the lever again and this time they heard the flow of gas through the pipe. The superintendent walked aft and observed that the smoke issuing from the stack casing had changed from a "black" color to a brown haze. He yelled to the master to check whether all of the CO_2 had been released. The CO_2 gauge read zero.

According to testimony, no one had closed or directed crewmembers to close the open ventilation dampers (louvers) to the engineroom in the upper levels of the after deckhouse. At this time, only the superintendent, the master, chief mate, and second mate were on the tankship. After the release of the CO_2, they went around closing the hatches, vent dampers, and exterior doors of the engineroom and the superstructure, which the superintendent estimated took about 5 minutes.

Meanwhile, the IC heard radio traffic at 0950 indicating that someone was going to discharge the CO_2; about 0955, he heard more traffic indicating that the CO_2 had been discharged. Upon hearing that the CO_2 had reportedly been released, the fire chief observed that the color of the smoke coming from the stack changed from black to whitish grey.

Dockside meeting — Between 1100 and 1130, the fire chief radioed the ship superintendent to come down to the dock. When he left the ship, the ship superintendent took the fire control plan that was in an orange tube attached to the gangway. At the command post, the ship superintendent was introduced to the IC. The ship superintendent presented the fire control plan to the IC, reviewed it with him, and told him that the CO_2 had been released. The IC advised the superintendent that he (the IC) had been looking for the fire control plan and that he and the fire chief had needed it during earlier fire operations. The IC said that he asked

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[22] The SEAL ISLAND engineroom was protected by a CO_2 fire extinguishing system. Telling the master to "pull the CO_2," meant to pull the actuating release mechanism, which was outside of the CO_2 system room.

several of the firefighters if they had known where the fire control plan was stowed on the tankship and they said no.

Superintendent's actions — After the deckside meeting with the IC, the ship superintendent went back on board the SEAL ISLAND, walked around the deck to determine the status of conditions, and proceeded to direct several actions of the firefighting effort. He radioed the fire chief requesting that foam be injected in the fuel tank when he saw smoke coming from a starboard fuel oil vent. The superintendent himself placed a charged hose into the pumproom. He directed and redirected firefighters on shore and on the HOVIC tugs to aim the water sprays on areas of the tankship where he noted temperature increases. He directed the chief mate to monitor the oxygen levels in the cargo tanks.

The ship superintendent said that about 1545, he decided to go below deck to see if anyone was in the steering gear room. He did not discuss his intended action with anyone. He entered the area alone and without a breathing apparatus. When he did not find anyone in the steering gear room, he went into the engineroom, looked around briefly, and then returned to the main deck. About 1700, the superintendent was called to come ashore for another meeting because the representative of the SEAL ISLAND owner had arrived.

Second attempt to enter the engineroom — The fire chief continued measures to cool the ship. About 1800, he decided to try entering the engineroom to find the missing crewmembers. Before allowing entry, the fire chief had the engineroom air tested for explosive gases and for carbon monoxide. The engineroom atmosphere tested safe for entry. Four 2-man hose teams then entered the engineroom, but it was so dark and smokey, they could see nothing. The fire chief instructed the men to come out, and had the engineroom resealed. He then dismissed the fire brigade for the evening with instructions to return the next day.

At 0800 on October 9, HOVIC firefighters entered the superstructure, and extinguished the small fires still burning. The fire was officially declared out at 1340. During their search, firefighters found two bodies, but could not retrieve them, or continue their search for the third missing crewmember because their breathing apparatus were low on air. The fire chief decided to continue searching the next day because it was becoming dark.

On October 10, 1994, firefighters reentered the engineroom and located the third body. All three bodies were removed from the ship and released into the custody of the St. Croix coroner. The incident was officially closed at 1200.

Postaccident Critique and Actions — Following this accident, the HOVIC critiqued the response effort and identified several problem areas based on input from emergency responders and Safety Board investigators:

Incompatible hose fittings — With the loss of main power on the SEAL ISLAND, the tankship's fire pumps were inoperable. Responders were not readily able to use a shoreside fire pumper truck to charge the ship's fire water system because their fire hose fittings did not match the fittings on the tankship's fire main. Their firefighting equipment did not include an

international shore fire hose connection, which would have enabled them to attach their hoses to any hydrant regardless of design.

Communication problems — Only one radio frequency was available for use during the emergency response. The IC stated that the lack of a second frequency made it difficult for him to command and coordinate activities, such as obtaining additional resources, without interfering with firefighting operations. Further, because of the steel configuration of the SEAL ISLAND, the fire brigade's own radios did not work when they went below deck. They had to borrow the marine radios from the ship to use in this response. Responders attending the critique also observed that radios used during marine firefighting should be waterproof.

According to HOVIC officials, the company has initiated the following improvements to its emergency response program since the SEAL ISLAND accident:

- The company now equips all HOVIC fire trucks with international shore connections and maintains spare fittings at the fire station.

- The refinery now has an 18-channel radio system with a dedicated channel for rescue and fire operations. In the event of a large scale emergency, the IC can assign alternate channels for the various response activities. The HOVIC has ordered a deck scan unit for the fire station, a mobile scan unit for the command post, portable marine radios, and a separate radio system for confined rescue operations within steel structures.

- The HOVIC has scheduled marine firefighting training for the leaders of the fire brigade, and has established a field exercise area where other fire brigade members will participate in marine firefighting drills.

- The HOVIC refinery now maintains copies of fire plans for docking ships. To familiarize fire brigade personnel with HOVIC-affiliated vessels, the company maintains layout drawings of it ships and arranges for the responders to tour various vessels.

- The HOVIC asked a professional consultant to review its emergency plan for implementing the incident command system; the company incorporated the recommended changes, which included updating and alphabetizing the alert roster and updating the duties and assignments of listed responders.

Tests and Research

Bulk CO_2 Firefighting System — On September 12, 1994, a manufacturer-approved servicing facility performed an annual survey and recertified all safety equipment, including the bulk (11.3 ton) CO_2 fixed system, as being "in satisfactory operating condition." After the fire, a representative of the same servicing facility, under the supervision of Coast Guard

inspectors, examined the CO_2 system and found that the bulk CO_2 tank was empty, and that the actuating valves worked properly.

Emergency Diesel-Driven Fire Pump — The emergency diesel fire pump was designed so that it could be started either at the engine or by a remote control switch on the navigation bridge. If electrical power was not available, the pump had a hydraulic starting system as a backup.

On the day of the fire, the emergency diesel-driven fire pump failed to start despite repeated attempts, which eventually exhausted its battery power supply. In addition, the hydraulic starting system was unable to turn over the pump's diesel engine.

After the accident, a manufacturer's technician examined the electrical starting system and determined that the electric starting motor had shorted. The technician advised Safety Board investigators that it was not possible to determine whether the consecutive starting attempts damaged the starting motor, or if the starting motor was damaged before the fire. The SEAL ISLAND officers stated that less than a week before the fire, the ship had conducted a fire and lifeboat drill during which the fire pump operated satisfactorily. The hydraulic starting system was not used during drills, and was not required to be tested in addition to the electrical starting system according to U.S. and international regulations.

The technician also examined the hydraulic starting system and found the hydraulic starting motor misaligned. This condition resulted in insufficient starting torque to 'turn over' the diesel engine. After the examination, Atlantis repaired the electrical and hydraulic problems. The repaired diesel fire pump was tested and operated satisfactorily while U.S. Coast Guard investigators were present.

Turbogenerator Duplex Lubricating Oil Strainer — On October 10 and 11, 1994, Safety Board investigators examined the lubricating oil strainer and found the directional flow control valve extended upward more than 2 inches out of the strainer casing, exposing the empty upper O-ring groove. Investigators had the lubricating oil strainer removed and shipped to the Safety Board's laboratory in Washington, D.C., for examination. A description of the examination appears in appendix D.

Other Information

U.S. Coast Guard Fire Contingency Plan — At the time of the SEAL ISLAND fire, the Coast Guard had no firefighting contingency plan for Puerto Rico and the U.S. Virgin Islands. The Coast Guard's *Marine Safety Manual* requires that Captains of the Port (COTPs) develop firefighting plans for each port within their respective jurisdictions. The manual stresses cooperating with local communities in developing the plans, stating:

> Paramount in preparing for vessel or waterfront fires is the need to integrate Coast Guard planning and training efforts with those of other responsible

agencies, particularly local fire department and port authorities. COTPs shall work closely with the municipal fire department, vessel and facility owners and operators, mutual aid groups, and other interested organizations.[23]

As part of its investigation of an explosion and fire on board the U. S. Tankship OMI CHARGER on October 9, 1993, in Galveston, Texas, the Safety Board conducted a survey of 22 U. S. Coast Guard ports, and determined that 9 of those ports did not have firefighting contingency plans. The Safety Board therefore made the following Safety Recommendation to the U. S. Coast Guard:

M-94-47

Review existing fire contingency plans for all U. S. ports to ensure that these plans are complete and up-to-date by January 1996 and that they include, at a minimum, initial notification procedures, jurisdictional authorities, and identifications of resources to be provided and actions to be taken by the Coast Guard, vessel operators, and the community.

In a letter dated May 8, 1995, the Coast Guard concurred with the recommended action of M-94-47, and advised that it had participated in a joint working committee with NFPA to develop a firefighting manual for COTPs. The Coast Guard letter states that the manual identifies the COTP/Group Commander's role as the marine technical advisor to local fire-fighting units responding to vessel fires. The letter further states that the manual includes the requirements contained in Section 4202 of the Oil Pollution Act of 1990 (OPA 90), which indicates that the COTPs should adopt the following policy:

Plan for marine firefighting contingency plans for marine firefighting situations in the same manner as for oil spills. This includes developing response scenarios, identifying resources to meet response requirements, identifying any shortfalls in response capability and planning for any shortfalls.

The Coast Guard letter states that once the guidance is published in the third quarter of FY95, incorporation of the revisions to all area contingency plans (ACPs) will be completed during the annual review and update process of existing ACPs. The letter further states:

Additionally, in the aftermath of the M/V BALSA 37 incident in Tampa, Florida, the Marine Board of Investigation recommended that the Commandant initiate a study of the firefighting capabilities within the nations ports and harbors. Pending the availability of funding, this study will begin in the 1st quarter of FY96 and will include an assessment of the marine firefighting capability within each COTP's zone. If funded, the study is expected to be completed over an 18 month period.

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[23] Volume 6, Chapter 8, Section B.

In its response of June 20, 1995, the Safety Board stated that it was pleased that the guidance for COTPs was being developed and incorporated in ACPs, but stressed that because of the importance of the recommended action, the Coast Guard should implement M-94-47 by January 1996. The Safety Board advised the Coast Guard, "Pending notification by the USCG that the requested guidance has been provided to each COTP, Safety Recommendation M-97-47 has been classified Open—Acceptable Response."

Related Investigations

SS STONEWALL JACKSON -- On February 9, 1991, the U.S. LASH[24] ship STONEWALL JACKSON was underway in the Indian Ocean enroute from Singapore to the Suez Canal. At approximately 1423, an engineroom fire erupted when oil sprayed upward from the duplex lubricating oil stainer on the steam turbogenerator while the engineers were attempting to clean and change the strainer elements. In this accident, oil sprayed upward from the strainer and was ignited when it came into contact with the hot steam piping or surfaces of the turbine casing. All six of the on-duty engineering personnel lost their lives and about $2 million in damages resulted from this accident. In the report of this accident, the U. S. Coast Guard investigating officer made the following recommendations:

> Emergency escape breathing apparatus (EEBA) be provided in enginerooms or other vessel spaces where personnel normally would be working and could be trapped by smoke or noxious fumes;
>
> Owners of other ships equipped with the same duplex strainer as was in use on the STONEWALL JACKSON install spray shields around them to prevent oil from spraying on hot piping or turbine surfaces. (See figure 9.)

In his review of this report, the Coast Guard Commandant agreed that "availability of emergency escape breathing apparatus improves the likelihood of successful escape," and stated that the Coast Guard "will consider new regulations concerning the type, location, and quantity of EEBA's for use by engineroom personnel." Regarding the need for owners of other ships equipped with the same strainer as was in use on the STONEWALL JACKSON to install spray shields around them, the Commandant stated that he "concurred with the intent of this recommendation" and that "appropriate information will be disseminated."

T.S. BAY STATE — On December 22, 1981, the Massachusetts Maritime Academy training ship BAY STATE was moored at the academy at Buzzard's Bay, Massachusetts. Shortly after 1230, an on-watch engineering cadet and a second class cadet engineer were behind the ship's starboard boiler, attempting to shift strainers in the high pressure boiler fuel

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[24] An acronym for Lighter Aboard Ship, which refers to how cargo is carried on board a vessel. Cargo is loaded into barges, or lighters, which are floated into position where the entire barge is loaded into the cargo holds through a specially designed cargo handling system at the vessel stern. Discharging cargo is accomplished by returning the barges to the water using the same cargo handling system. This system allows the ship to trade at undeveloped or shallow water ports where other large, deep draft ships can not enter.

oil duplex strainer. Both cadets had difficulty moving the strainer's directional flow valve handle. Finally, the cadet engineer kicked at the lever with his foot. He stated that his foot slipped, then struck and broke off the brass vent cock valve from the cover of the forward strainer basket, which was in service. A pressurized (300 psi) spray of heated (150°F) fuel oil shot up over 12 feet, contacting a steam pipe line, and ignited. One fatality and 2 serious injuries resulted; the vessel's engineroom was destroyed and the vessel was scrapped.[25]

Following its investigation of this accident, the Safety Board recommended that the U. S. Maritime Administration, the vessel owner, install spray shields around flammable liquid strainers. The Board also recommended that the Massachusetts Maritime Academy regularly conduct training drills to acquaint all persons on board the training ship with the various routes available to exit the engineroom.

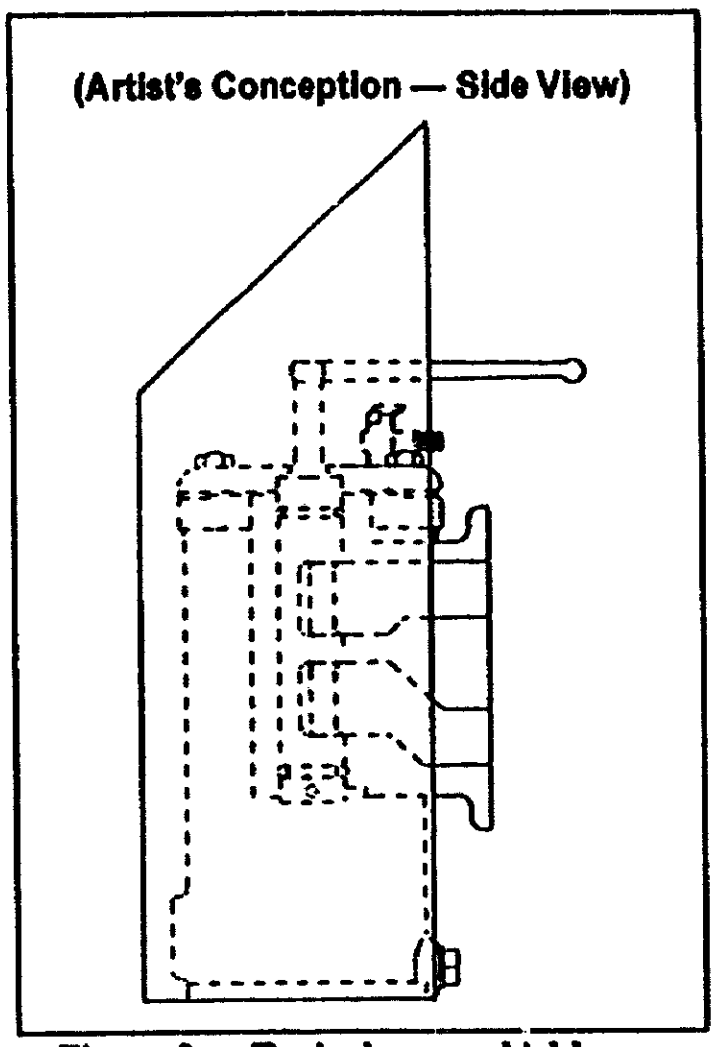


Figure 9 — Typical spray shield on a lubricating oil strainer.

[25] For additional information, read Marine Accident Report — *Fire On Board the Training Ship Bay State at the Massachusetts Maritime Academy, Buzzards Bay, Bourne, Massachusetts, December 22, 1981* (NTSB-MAR-82-7)

ANALYSIS

This analysis is divided into three main sections. In the first part, the Safety Board identifies the factors that it was able to exclude from being causal or contributory in the accident. The second section recounts the accident sequence, citing actions and events resulting in problem conditions. In the final section, the Board discusses the findings that support each safety issue identified in this investigation.

Exclusions

From documents and testimony, the Safety Board determined that the officers and crew of the SEAL ISLAND were properly licensed and certificated by the Liberian government, and were qualified to serve in their positions. Health was not a factor in this accident. The chief engineer's general health was good; he was not suffering from any apparent chronic or acute illnesses or using any medication at the time of the accident. Although his rest was somewhat reduced during the early part of the 72-hour period preceding the accident, he maintained his normal work/rest cycle. The Safety Board concludes that fatigue was not a factor in the chief engineer's performance on the day of the accident.

Surviving officers described the first engineer as alert and active when he went off his engineer watches. The first engineer who died in this accident was not the officer who had built and installed the temporary turbogenerator's lubricating oil strainer repair; therefore, the Board could not determine if and how much he had known about the turbogenerator's strainer repair.

The urgent need for medical treatment of the injured crewmembers prevented the timely collection of toxicological specimens for investigative purposes. Therefore, the Safety Board was not able to definitively eliminate drug and alcohol involvement from this accident. However, toxicological examination of specimens from the three deceased crewmembers did not reveal any use of illicit drugs or alcohol. Further, witnesses described the crewmembers as active, alert, and not exhibiting any indications of impairment. The Safety Board, therefore, concludes that drugs, including alcohol, were not a factor in this accident.

The Accident

About 8:10 a.m. on October 8, the recorded outlet pressure of the turbogenerator's lubricating oil strainer was 129 psi. Because this represented a 7 psi drop in pressure differential, the chief engineer directed that the oil strainer be changed.

To change the turbogenerator's lubricating oil strainer required that the strongback be removed from the casing. The strongback was part of a temporary assembly that the chief engineer had designed and had directed crewmembers to attach to the strainer 4 months earlier to stem an excessive oil loss caused by a defective O-ring. At that time, the chief engineer had believed erroneously that conditions prevented him from renewing the O-ring. (The chief

engineer's actions and decision-making are covered in a separate issue section in this analysis.) The temporary assembly had included a cup that was fitted beneath the cylindrically shaped directional flow valve to contain the oil. To get a tight seal, installers had to retract the pin holding the directional flow valve in place.

On the day of the accident, when the first engineer removed the strongback from the strainers, he removed the only device that kept a lube oil pressure buildup from forcing the directional flow control valve to rise. Turbine lubricating oil normally contained inside the strainer casing by the O-rings flowed under 136 psi pressure into the strainer. Because of the defective lower O-ring, lubricating oil leaked past the flow control valve into the cup. This caused turbine lube oil pressure to act against the interior of the cup and against the entire bottom area of the valve. Without the strongback retaining the directional flow valve, the lubricating oil pressure slowly moved the directional flow control valve up and out of the strainer casing.

When the directional flow valve reached the shoulder of the upper O-ring, it released lubricating oil at high velocity to the atmosphere. The crew could not reattach the strongback or take other measures to push the directional flow control valve back into the casing because of the high temperature of the oil. The lubricating oil, which had an auto-ignition point of 500°F, then contacted the hot (900°F) turbine casing and ignited almost immediately.

When the fire ignited, large volumes of dense black smoke blocked out lights and quickly filled the boiler platform area. Because internal combustion engines need air to operate, the diesel generator's drive engine quickly shut down when smoke replaced the engineroom supply of air. The Safety Board determines that dense smoke from the lubricating oil fire was drawn into the diesel generator's air intake, causing the engine to shut down.

The fire resulted in the death of three crewmembers and serious injuries to six other crewmembers. In its investigation of this accident, the Safety Board determined that the type of temporary repair made to the turbogenerator's lubricating oil strainer was not operationally safe and considered the chief engineer's decisions for making such a repair. The Board also found several safety problems in the general area of survival factors.

Decisions of the Chief Engineer

The Safety Board examined the chief engineer's decisions to make a temporary repair to the leaking turbogenerator's lube oil strainer assembly in June 1994, and to change the strainer on the morning of the accident. Analysis focused on why the chief engineer made these decisions, as well as on their adequacy.

As chief engineer, he had primary responsibility for ensuring all electrical, mechanical, and hydraulic systems and equipment on the vessel functioned properly. When faced with a situation that might adversely affect the performance of the vessel, he had to weigh options and determine which would produce the most positive, or least negative, outcome. Such decision-

making involves *risk assessment*, that is, subjectively evaluating the probability of different outcomes and assessing the benefits and costs of each.

Erroneous Assumptions — Effective risk assessment depends on accurate information to properly evaluate a given situation. The chief engineer's testimony indicates that he had several erroneous perceptions about the electrical operations, specifically the load capacity and output of the diesel generator. For example, he testified that he could not shut down the turbogenerator's turbine because the warm temperature of the seawater on the Nigeria/St.Croix run would not keep the water in the diesel generator's diesel engine jacket cool enough to prevent the engine's thermal trip from shutting down the diesel engine. However, other Atlantis Agency chief engineers testified that the electrical load from the turbogenerator could be shifted to the diesel generator in tropical water temperatures without difficulty. On June 11, the chief engineer made an attempt to transfer the ship's electrical load to the diesel generator. He had shifted 600 of the 750 kw load to the diesel generator without shutting down any non-vital equipment when he decided to abort the load transfer because he believed the jacket water would become overheated and the diesel generator would automatically shut down.

Safety Board investigators reviewed the ABS surveys and the service reports and invoices for the two generators and their prime movers and found no indication of an overheating problem in the diesel generator's prime mover. One ABS annual machinery survey showed that the diesel generator was test-operated under load for more than 2 hours in the warm (88^0 F) sea waters of the Persian Gulf (Dubai, U.A.E.) and functioned satisfactorily. Following annual surveys, inspections, and routine maintenance of the turbogenerator and diesel generator prime movers and their electrical components in January, 1993, and April, 1994, the two units were tested and functioned satisfactorily.

The chief engineer also stated repeatedly that he had to maintain full speed when the vessel was at sea and could not reduce at-sea electrical loads for a load transfer without reducing the ship's speed. Other SEAL ISLAND engineers and Atlantis shoreside engineers stated that one forced-draft fan could be shut down with minimal or no reduction in the firing rate of the boiler to reduce the electrical load.

The Safety Board determined that several non-vital electrical loads could have been shut down for 2 hours without adversely affecting the ship's speed. Such non-vital electric loads included the air-conditioning, part or all of the accommodations ventilation system, some or all of the engineroom ventilation fans, the potable and non-potable water pumping systems, and the IGS fans and scrubber pumps. Had the chief engineer shut down non-vital equipment having a total load of merely 150 kw, he probably could have transferred the load to the diesel generator and repaired the strainer with no danger of losing electrical power. He also could have scheduled the repair work when the vessel's electrical loads would typically be lowest, such as at night, when most crewmembers are asleep and the galley equipment is shut down. During a nighttime repair, any discomfort that the crew might suffer from a lack of air conditioning for 2 hours would be assuaged by the cooler outside temperature.

The chief engineer also testified that he could not complete permanent repairs to the turbogenerator's strainer while the vessel was in port because of the additional electrical loads required by cargo operations. However, with the master's concurrence, he could have had the 2-hour repair project performed before or after cargo operations with minimal delay to vessel operations. The SEAL ISLAND's masters and Atlantis management officials testified that they would not have objected to such a delay.

In the case at hand, a temporary repair avoided taking the turbogenerator off-line. Although a permanent repair would have been a preferable and safer alternative, the chief engineer was unwilling to stop the operation of the turbogenerator given his belief that the diesel generator could not carry the at-sea tankship electrical loads without overheating. The Safety Board concludes that the chief engineer's decision to make a temporary repair to the strainer was logical given his perception of the vessel's electrical capacity. However, the Board also concludes that the diesel generator probably would not have had problems with the engine jacket water overheating and that the electrical loads could have been transferred to the diesel generator without affecting the ship's operations or its speed. Further, both the regular and the replacement chief engineer had opportunities during the 4 months that the SEAL ISLAND was at sea and in port to shut down the generator's steam turbine so that a proper and permanent repair could be made to the turbogenerator's strainer.

The Temporary Repair — Because a clogged strainer can adversely affect a ship's operation, stopping the oil leak was the chief engineer's main focus in making the repair. His decision to undertake a temporary instead of a permanent repair to the lubricating oil strainer was made in consultation with other senior engineering officers. The cup and screw jack assembly that he devised could not achieve a leakproof seal because the lower securing pin retaining the directional flow valve interfered with positioning the cup. The chief engineer directed that the lower pin be moved out of the way. Another engineering officer advised him that if he took out the lower pin, he would have to provide something to hold the valve in place. The chief engineer then decided to add a strongback on top of the duplex strainer that would keep the flow valve in position. He oversaw the installation of all assembly components. The assembly achieved his goal of stopping the leak.

Once the leak was stopped, the chief engineer believed that the strainer required no further attention. In testimony he repeatedly answered that he did not perform a permanent repair because the strainer "was no longer leaking." It is evident that once he had solved the immediate problem of the leak with the temporary repair, he placed low priority on permanently repairing the strainer. He stated that other repairs of a "more important nature" kept developing, which prevented him from making a permanent strainer repair. In his assessment of the risks involved, the chief engineer failed to recognize the danger that the temporary repair posed to the crew and the vessel. Although the assembly did stop the leak and posed no threat to crewmembers while it was in place, the temporary repair was unsafe operationally because of the risk posed when the strongback was removed to clean or replace a strainer.

Other factors may have influenced the chief engineer's decision to perform a temporary versus a permanent repair. To perform a permanent strainer repair, he would have had to develop

a scheduling plan detailing which and when non-vital electrical equipment would be shut down. Such a plan required that he obtain the concurrence of the master and shoreside management, and that he notify the crew when air-conditioning and ventilation systems would be down.

The SEAL ISLAND's next annual shipyard period was scheduled for December 1994 through January 1995. During a shipyard period, all steam plant elements, including the boilers, turbines, and so forth, can be shut down and elements requiring maintenance can be dismantled to receive extensive attention. The chief engineer may have believed that because the strainer would be receiving shipyard maintenance, a temporary repair would suffice and a permanent repair was not worth the coordination and effort. He would also not be subject to potential criticism for delaying departure or arrivals in port if shipyard workers completed the permanent strainer repairs.

On the morning of the accident, the chief engineer decided to change a strainer element, which required removing the strongback so that the strainer basket cover could be opened. He did not direct a crewmember to obtain a replacement element before the strongback was removed or exhibit any urgency while overseeing the crewmembers performing the maintenance. Because the chief engineer proceeded without ensuring that a restraining device was in place to protect against the upward movement of the valve in the pressurized unit, he apparently failed to recognize that working on the strainer under these conditions was dangerous.

The Safety Board concludes that the chief engineer's decision to change a clogged element in the lubricating oil strainer was reasonable and logical. However, the Board further concludes that changing the strainer without a device in place to restrain the upward movement of the control valve created a hazard that ultimately led to the fire. Although the Safety Board cannot conclusively establish the chief engineer's rationale to proceed without first securing the directional flow control valve, the following circumstances may provide some insight.

Four months had passed since the chief engineer had devised the temporary assembly and overseen its installation. During that period, he was on vacation 8 weeks before returning to duty aboard the SEAL ISLAND. Moreover, he was not the person who had recognized the need for a substitute restraint to supplement the retracted lower securing pin. These circumstances suggest that the chief engineer may well have forgotten important details of the temporary strainer repair, including the repositioning of the lower securing pin for the directional flow control valve.

The Safety Board believes that on the day of the accident, the chief engineer proceeded with replacing the turbogenerator's aft lubricating oil strainer element without considering the consequences of the alteration made 4 months earlier. Thus, when the strongback was removed, the unsecured flow control valve gradually began to rise until it was partially out of the strainer casing, allowing pressurized oil to escape and ignite.

Atlantis Management Oversight — The chief engineer was a 10-year company veteran. Because of his misconception regarding the electrical capacity of the diesel generator and

the turbogenerator, the Safety Board examined the operational and maintenance history of the two generators, and the operating company's management responsibilities.

The Safety Board found the Atlantis Agency oversight program to be quite comprehensive. Written company policy and procedures require that the head of the vessel's engineering department include planned, in-progress, and completed maintenance work in monthly reports to the company shoreside management. In addition, all Atlantis ships have ship-to-shore communications links, which enable shipboard managers, including the head of engineering, to send interim reports and/or requests for goods and services to the company's headquarters while the ship is at sea. Further, management representatives visit the ships at every cargo loading and discharge port. According to Atlantis officials, these visits provide an opportunity for the shoreside management to maintain "a good general idea" of how a ship is being operated and maintained. They stated that the visits are not intended to be detailed, in-depth examinations of the vessel; however, the tours do afford vessel personnel opportunities to point out problems to management officials.

Company records show that the SEAL ISLAND's chief engineer had regularly filed the reports and forms required by the company. However, he never included any notes about his concerns about the electrical capacity of the diesel generator, the strainer leak, or the temporary repair in his reports to company management. Shoreside management received only one maintenance request, dated April 24, 1993, from the SEAL ISLAND's chief engineer concerning problems with the vessel's electrical generating capacity. Management promptly responded to that request, and had a service technician repair the problem. Company management representatives stated that other than this one occasion, none of the SEAL ISLAND's chief engineers, masters, or any other crewmember ever reported any electrical generating capacity problems, either in a report or during management's ship visits.

Between June 11 and October 7, 1994, Atlantis Agency representatives, including the company president, marine manager, port engineers, port captain, ship superintendents, an independent safety consultant, and a management consultant, visited the SEAL ISLAND on numerous occasions. However, the turbogenerator's lubricating oil strainer was not located in a high visibility or a well traveled area, and therefore could easily be missed unless pointed out to management by the engineering managers on board the vessel. During the tours by the shoreside officials, neither the chief engineer nor the chief who replaced him while he was on vacation showed the temporary repair to the management representatives. The replacement chief engineer testified that he thought that the other chief had reported the condition of the strainer to the company and had made plans to perform a permanent repair.

The chief engineer said that he never told anyone, either in writing or verbally, about the inadequate electrical capacity of the ship's generators because "the problem was well known in the company." In regard to the repair to the turbogenerator's lubricating oil strainer, he said that he did not consider it serious enough to warrant reporting to the company.

He stated that he had spoken to three people about the repair. He said that on June 12, while having lunch with the master, he told him that there was a "small oil leak, but that it had

been fixed." The chief engineer said he also had told a safety consultant about the strainer repair and had discussed the strainer with the Atlantis senior ship superintendent during their respective visits to the SEAL ISLAND in June.

The master testified that he had no recollection of the chief engineer informing him about the oil leak or its repair. The safety consultant testified that he did not recall seeing the strainer repair or speaking of it with the chief engineer. The senior ship superintendent stated the chief engineer never told him about any problems with the lubricating oil strainer or about any repairs to the strainer, and consequently, he knew nothing about the temporary repair.

Of all of the management representatives touring the engineroom, only the independent safety consultant took enough notice of the temporary assembly on the turbogenerator's duplex lubricating oil strainer to jot down a cryptic observation in his rough notes of his examination. In later testimony, he stated he did not remember the alteration to the oil strainer and made no verbal mention of it to anyone at Atlantis or in his final written report to management.

The Safety Board concludes that the maintenance policies, procedures, and practices of Atlantis Agency at the time of the accident were adequate. In the case of the SEAL ISLAND, the routine engineroom examination tours made by Atlantis management were adequate for the company's intended purpose. The Board found that the chief engineer did not fulfill his responsibility to keep Atlantis management informed of maintenance to the turbogenerator's lubricating oil system, namely the temporary strainer repairs, although he had ample opportunity to do so.

Survival Aspects

Given the rapid spread of the fire and the number and type of injuries, the Safety Board focused a major portion of its investigation on the survival factors in this accident. The Board determined that several actions by personnel were appropriate and effective; however, it identified a number of safety issues: the lack of flammable liquid strainer spray shields, the lack of engineroom fire and escape drills, a breakdown in the incident command system, an inadequate HOVIC emergency plan, and a partial lack of effectiveness in the HOVIC fire brigade's response. The Board also looked at efforts to develop a port fire contingency plan for the U.S. Virgin Islands.

Several actions by individuals either contributed to survivability or mitigated the severity of conditions. After the master heard the general alarm and observed smoke pouring from the stack enclosure, he realized that the fire was serious and immediately called for shoreside assistance. He properly assessed the fire to be beyond the capabilities of the ship's crew to extinguish without shoreside assistance and wasted no time in calling for outside help. This action by the master was appropriate for the conditions that confronted him.

When the crewmembers heard the alarm sound, they immediately mustered at a prearranged, central assembly location. The crew muster was carried out in good order, without confusion or panic. Certain individuals tasked with special responsibilities during a fire

emergency, such as the third mate who was in charge of the first aid team, executed them efficiently and expeditiously. The first aid team administered oxygen to injured crewmen, and carried or escorted them to ambulances on shore. Crewmembers also deployed fire hoses on deck and discharged fire extinguishers through the gallery hatch cover skylight into the engineroom. Crewmembers made two separate attempts to enter the engineroom to rescue missing crewmen, but were driven back each time by the fire's intense heat and dense smoke. Crewmembers located and installed the ship's spare international shore fire hose connection for the shoreside fire brigade's hoses to the ship's fire main. These actions by the ship's crew probably constituted all that they were reasonably capable of performing under the circumstances of this fire. The Safety Board concludes that the initial response by the ship's crew was timely and proper.

About 140 personnel responded to the fire from the terminal with five fire trucks, two ambulances and one rescue truck. The resources available were adequate and appropriate for the firefighting operations. Two tugs also responded with direct sprays to cool off the SEAL ISLAND. The HOVIC firefighters responded efficiently, probably as well as could be expected given that the focus of their training was on land-based fires. They arrived on scene in a timely manner, were well-organized, and expeditiously evacuated injured crew members to the local hospital. They followed proper firefighting procedures, such as donning emergency gear and testing for the presence of gases and carbon monoxide prior to entering the engineroom. They followed the orders given by the fire chief quickly and efficiently. However, the HOVIC fire brigade suffered a series of setbacks because they were not specifically trained and equipped for marine firefighting. (See "HOVIC Fire Brigade Response" later in this analysis.)

Safety Issues

Lack of Flammable Liquid Strainer Spray Shields — In this accident, the fire began when the directional flow valve of the strainer sprayed lubricating oil into the air, which ignited on the hot turbine. The first engineer and the chief engineer tried to stop the oil flow with their hands, but because the oil was too hot, they had to pull their hands away, which allowed the oil to spray upward.

U.S. Coast Guard accident statistics indicate that from 1991 to 1995, the number of engineroom fires occurring on board U.S. vessels and foreign-flag vessels in U.S. ports and waterways totaled 306. Of these, 124, or over 40 percent, were flammable liquid fires that occurred in enginerooms, an average of 25 per year.

Some steam ships, mainly naval vessels, now have a sheet metal spray shield installed around lube oil strainers for the express purpose of blocking an oil spray should a mishap occur. Had such a shield been installed between the duplex lubricating oil stainer and the turbine casing on the SEAL ISLAND, the oil would have been deflected from the hot turbine machinery and may not have ignited. The Safety Board therefore concludes that had the lubricating oil strainer been shielded from the turbine casing, the oil may not have struck the hot turbine casing and ignited, and the deaths, injuries, and property damage might have been avoided.

After this accident, Atlantis Agency installed spray shields at the turbogenerator's lubricating oil strainers on board their other company ships. However, no national or international standards require this type of protection for lubricating oil strainers. The Safety Board believes that not only this accident, but also those involving the STONEWALL JACKSON and the BAY STATE demonstrate that an installed spray deflector (blocking both sides, the top and bottom) at lubricating oil strainers would greatly improve engineroom fire safety.

The Engineroom Escape — Because atomized oil droplets filled the air around the turbogenerator, when ignition occurred, the fire immediately became very large, probably beyond the capability of the engineroom crew to extinguish. Their only option was to escape the engineroom, close it up after everyone was out, and extinguish the fire by discharging the CO_2 fire system. Three crewmembers -- the first engineer, the machinist, and the electrician -- died before they could escape. The Safety Board reviewed testimony and on-scene findings to determine what may have contributed to the loss of life or the survivability in this accident.

Survivors testified that they had a very short time to escape from the engineroom. Even the chief fireman and wiper, who had only to climb one flight of stairs to gain exit from the engineroom, did not escape without injury. Others described the engineroom as being filled with heavy, black smoke that stung their eyes and completely blocked out the light from the emergency lights. Visibility was so poor that they could not see the deck in front of them and actually had to feel their way to a ladder to climb to safety.

Under these conditions, it would have been an easy matter for a person to become disoriented and to wander away from an escape route. Such a person would probably have been overcome by the heavy smoke within a very few minutes.

The first engineer's body was found forward of the control room in the diesel generator room. He may have attempted to reach the control room where the breathing apparatus were stowed and an emergency escape trunk was located.

The machinist's body was found on a ladder one level above the boiler platform. He had wrapped a fire blanket around his head in an apparent attempt to use the blanket as a smoke filter before becoming overcome by the smoke.

The electrician's body was later found aft of the control room near a ladder leading up to the next level of the engineroom. When he had run from the engine control room, he was carrying a 30-minute breathing apparatus, which should have afforded him ample time to escape. The empty breathing apparatus was found on the deck about 8 feet from his body. The Board considered several factors that may have hindered the electrician's escape.

The electrician reportedly was in a state of panic when he ran from the control room. In such a state, he was probably breathing at an elevated rate, which would have depleted the air in the apparatus faster than if he were breathing at a normal rate. He also had been sharing the apparatus with the third engineer before leaving the control room. Thus, the apparatus was not full when he left the control room. His state of panic and the reduced visibility may have caused

him to become disoriented and wander until the air in the apparatus was depleted. Once the air in the breathing apparatus was gone, so were his chances of survival.

When the fire occurred, the fireman and the surviving machinist used preplanned avenues of exit to escape to the main deck. Both had worked on the SEAL ISLAND before and were familiar with the vessel layout. The fireman had participated in shoreside firefighting training that included engineroom escape. The machinist had also participated in shoreside firefighting training. He had determined beforehand that should an emergency occur on the SEAL ISLAND, he would use the shaft alley escape trunk. The training, preplanning, and familiarity with the escape routes from the SEAL ISLAND engineroom helped them to react quickly and escape correctly from the engineroom. The Safety Board concludes that the escape of the fireman and the machinist from the SEAL ISLAND engineroom was, in part, the result of their familiarity with the vessel and the training that they had received at shoreside firefighting schools.

The electrician and the third engineer remained in the relative, temporary safety of the engine control room. The electrician had attempted to use the control room escape hatch upper main deck cover, but was unsuccessful. The two men returned to the lower control room and shared a SCBA. The third engineer knew an EEBA was in the upper control room, but the dense smoke made it inaccessible; EEBA's were not located in the engineroom area along exit routes. The Safety Board concludes that the number of emergency escape breathing apparatus in the SEAL ISLAND engineroom were insufficient; their place of stowage was not readily accessible to facilitate escape from the engineroom.

Other survivors took avenues of opportunity to effect their escapes. Some, like the chief fireman and the wiper, just happened to be near an exit when the fire erupted. The chief engineer and the third engineer survived only because of fortuitous circumstances. The chief engineer was fortunate that he did not become disoriented and lost in the zero visibility and that he regained his consciousness before succumbing to smoke inhalation.

The third engineer, who was laying on the deck of the control room with his shirt wrapped around his head attempting to filter the smoke, heard the third mate on deck respond to his radio [walkie-talkie] call for help. The third mate opened the main deck escape hatch cover to the upper control room, and provided a safe escape route to the main deck. Had this hatch not been opened when it was, the third engineer might not have survived the accident. The Safety Board, therefore, concludes that escape from the SEAL ISLAND engineroom was largely a matter of luck for two crewmembers who were near exits when the fire started, and for the third engineer, who was nearly trapped in the lower engine control room.

After the SEAL ISLAND fire, Atlantis Agency reassessed the emergency equipment needs of its two remaining tankships, the ST. LUCIA and the MT. CABRITE, and added additional emergency equipment to each vessel. The company had an emergency gear locker installed on the boiler (engine control room) platform of the engineroom. Each vessel now has 14 SCBA's and 28 air cylinders. Two SCBA's and 4 air cylinders are in the engine control room; 3 SCBA's and 6 air cylinders are stowed in each of the four emergency gear lockers. Each tankship now carries 23 EEBA's, of which 8 are in the emergency gear lockers, 4 are in the engine

control room, 4 are around the boiler platform level, 2 are in the lower engineroom near the emergency escape trunk, 4 are in the pumproom, and 1 is in the cargo control room. Each of the tankships now carries 14 firefighting outfits. The Safety Board commends Atlantis Agency for its proactive efforts to improve fire safety on board its company vessels and views these efforts as a major safety accomplishment resulting from the Board's investigation of this accident.

Failure to Close Dampers — When the main electrical power failed, all electrical ventilation (supply and exhaust) fans stopped circulating fresh air throughout the engineroom. Although the forced ventilation stopped, manually operated dampers [louvers at each ventilation supply and exhaust deck vent] were left open because the master and ship superintendent failed to direct crewmembers to close them. The Safety Board found that the failure to close the engineroom ventilation supply and exhaust dampers before the bulk CO_2 was released into the engineroom diluted the CO_2 concentration and allowed outside air to continue to support the fire.

Emergency Training and Drills — Weekly emergency response drills were held on board the SEAL ISLAND during which the crew practiced lifeboat abandon ship and firefighting procedures and using lifesaving and firefighting equipment. The drills typically simulated a fire on deck. The fire alarm was sounded, the fire pumps were started, and the crew reported to their various assigned stations. It was not typical to hold a drill simulating a fire in the engineroom. In fact, only one crewman interviewed recalled a drill being held on the SEAL ISLAND in which an engineroom fire was simulated. No drills were held to practice escape from the engineroom.

During the fire, the electrician started to climb up the engine control room emergency escape trunk ladder. The Safety Board received conflicting accounts as to why the electrician was not able to exit to deck from the escape trunk. The chief engineer stated that the electrician was not able to move any of the "dogs," or latches, to the hatch cover when he reached the top of the escape trunk. The third engineer stated that the electrician had only climbed a couple of rungs and then had backed out of the escape trunk because accumulated smoke prevented his reaching the escape hatch. Because the electrician died, the Safety Board could not determine why he did not exit the escape hatch. Regardless, the escape trunk hatch dogs should have been easy to open to facilitate immediate escape from the control room. Escape trunks and their associated hatch covers should be used during fire drills to ensure that crewmembers become familiar with their locations and to ensure that the hatches open easily. Had the control room upper escape hatch cover been opened by the electrician, the chief engineer may have received less severe injuries, and the electrician would have survived the accident.

The Safety Board cannot conclude that escape drills would have reduced the loss of life in this fire. However, had such drills been conducted on the SEAL ISLAND, the engineroom personnel would have been better prepared when the fire erupted and they might have had increased chances of survival. The Safety Board concludes that fire drills held on the SEAL ISLAND were less than adequate to prepare personnel to escape from the engineroom.

As this accident shows, it is imperative that engineering crew members react quickly and correctly because of the rapid rate at which fire can spread within the confines of an engineroom and the large volume of smoke that can be generated. So that they will react properly during an

actual emergency, engineering crews should participate in practice drills that include how to find exits, check escape hatches, and locate and don breathing apparatus.

Current international requirements do not specifically mandate that fire and escape drills be held in enginerooms. SOLAS '74, as amended, states, "Fire drills should be planned in such a way that due consideration is given to regular practice in the various emergencies that may occur depending on the type of ship and its cargo." This could be interpreted as a requirement for engineroom drills, or, as in the case of the SEAL ISLAND, it may not. Given the fire risk of enginerooms and the limited protection afforded engineroom personnel, the conduct of engineroom drills is very important. The Safety Board believes that these requirements are vague and subject to interpretation. The Safety Board concludes that the safety of shipboard engineering personnel would be significantly improved if engineroom fire and escape drills were required. The Board, therefore, believes that the Coast Guard, as the official U.S. representative to the International Maritime Organization (IMO),[26] should propose that periodic engineroom fire and escape drills specifically be required on board all ships.

Before the accident, the emergency diesel fire pump on board the SEAL ISLAND was tested weekly using the electrical starting system during fire drills conducted by the master, and as required in the presence of Coast Guard inspectors during boarding examinations. However, the hydraulic starting system was not tested until after the accident and the hydraulic motor was found to be misaligned.

Had the emergency fire pump's diesel engine been periodically tested using the engine's hydraulic starting system during fire drills, the crew may have detected and corrected the problem, and been able to use the emergency diesel fire pump during firefighting operations. The emergency diesel fire pump had been recently tested during fire drills using the electrical starting system, which was in accordance with international regulations that do not require that the hydraulic starting system also be tested. The misalignment in the hydraulic starting motor was therefore not detected. The Safety Board believes that the current international regulations should be revised to require testing of all available modes of fire pump starting systems, including electric, hydraulic, and pneumatic, on board ships.

Incident Command System — In this accident, three individuals — the master, the fire chief, and the refinery manager — had unique responsibilties in the incident command structure. As commander of the ship, the master was ultimately responsible for the safety of the vessel and its crew. Had they followed NFPA standard 1405, the fire chief would have been in charge of firefighting operations for the dockside vessel fire, which included safeguarding the firefighters and the community, and containing and extinguishing the fire. Typically, the fire chief would also have served as Incident Commander (IC) for the total emergency response effort. Because of the magnitude of the fire, the HOVIC refinery manager assumed the role of IC so that the fire chief could concentrate on combating the fire.

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[26] The International Maritime Organization is a specialized agency of the United Nations that develops international maritime safety standards. Its regulations generally apply to ocean-going ships on international voyages.

When the accident occurred, a ship superintendent for another Hess subsidiary was working on a vessel nearby. Based on past work experience, he was familiar with the SEAL ISLAND's layout and emergency systems, and came on board the SEAL ISLAND to assist in the emergency response effort.

During the IC's initial planning discussion with the fire chief, he did not include the ship's master and the ship superintendent. Consequently, the roles and lines of authority were not clearly defined and coordination suffered. The fire chief did not consider himself to be in charge of the overall firefighting operations. Instead, he thought it was his role to assist the master. The ship superintendent was not aware of the IC's role on scene; he believed that the fire chief was in charge of the HOVIC personnel. The ship superintendent also erroneously believed from telephone conversations with Atlantis representatives that he was acting on their behalf until they arrived on scene.[27] He gave the HOVIC emergency responders information about the SEAL ISLAND's layout, emergency systems, and fire control plan, but did not provide the IC with a copy of the plan until about 2 1/2 hours after the IC's meeting with the fire chief. The fire control plan was a vital document that the fire chief should have had for planning firefighting strategies.

The superintendent continued operating independently, taking actions without conferring with the IC, the fire chief, and the ship's master. Although the ship superintendent had technical knowledge about the SEAL ISLAND, he was not a firefighting expert and should not have been allowed to act independently during the emergency. He essentially usurped the command prerogative of both the master and the IC in their respective areas of authority.

The master should not have relinquished his decision-making authority to the superintendent regarding actions taken on his vessel during the fire. He should have established and maintained continuous communications with the IC and the fire chief, and developed a decision-making arrangement with them. He should have taken a more active role in the response effort by providing and explaining the ship's fire control plan to the IC and by arranging to have the only engineer not injured in the accident available to answer the IC's questions about the engineroom.

Likewise, the IC should not have relinquished command of firefighting activities on the tankship to the Atlantis management representatives when they arrived on scene. While they may have had marine expertise and knowledge of the tankship, they were not firefighting experts.

No action should have been taken, especially actions with potentially dangerous results, such as entering a smoke-filled space, or pumping water or fire fighting foam into a compartment, without the master's expressed concurrence and the IC's knowledge. While on board the vessel, the fire chief took actions, such as ordering his men into the control room, without asking the master for his approval or concurrence. The master was not advised when the shore fire brigade entered the engineering control room and injected water and foam into the engineroom. The ship superintendent not only entered the engineroom, but also ordered foam pumped into the fuel tank without discussing these actions with the master beforehand.

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[27] The Atlantis president stated that the ship superintendent was not their designated man in charge, but he was responding to assist the master.

At the superintendent's urging, the master discharged the CO_2 system into the engineroom without first ensuring that the vents, doors and hatches to the engineroom were closed. As a result, the effectiveness of the fire extinguishing system may have been compromised.

Throughout the response effort, separate operations were occurring concurrently with very little communication, consultation, and coordination among the IC, the HOVIC firefighters, the ship superintendent and the SEAL ISLAND's master. No injuries or deaths can be attributed to this disjointed effort. The Safety Board concludes that the Incident Command System was not executed as designed. No one single person had overall charge of the incident. Both the master and the IC allowed individuals who were not in the incident command structure to usurp their authority and direct critical response operations. Further, by acting independently without the knowledge and expressed consent of the master and the IC, the ship superintendent initiated actions that could have jeopardized his safety.

Limited Communications — The HOVIC firefighters and the IC had only one radio frequency available for use during their response. The lack of a second frequency made it difficult for the IC to coordinate activities without interfering with firefighting operations. Although he had discussed firefighting strategies with the fire chief initially, the IC only learned after the fact what took place on the ship. The Safety Board concludes that the lack of a dedicated radio frequency compromised the effectiveness of the command exercised by the IC.

HOVIC Fire Brigade Response — Firefighting operations were delayed about 30 minutes because the fire brigade did not have an international shore fire hose connection with which to pressurize the fire hoses. They probably would not have been able to extinguish the fire because its size and intensity precluded entering the engineroom. To make matters worse, the firefighters were not familiar with the layout of the ship. Their ability to enter the engineroom to fight the fire effectively with fire hoses under these conditions was probably not good. Even so, the delay in pressurizing the fire hose was excessive and, under slightly different circumstances, could have had serious results.

Although firefighters participated in firefighting training and had developed their own training program, it did not include training or drills for shipboard firefighting. Because the fire brigade had not participated in shipboard firefighting training, they were not knowledgeable about the use of the international shore fire hose connection, the ship's layout, and shipboard systems. They lacked knowledge, experience, and specialized equipment that is necessary to effectively fight a shipboard fire. For example, the fire brigade did not know the location of the fire control plan on the ship. This plan was important in developing firefighting strategies; yet, it was not reviewed by the shoreside responders until 2 1/2 hours after they arrived on scene. Firefighters had to borrow the ship's marine radios because their own radios did not work below deck on the SEAL ISLAND. The vessel construction also presented other problems for which their shoreside training did not prepare them. Shipboard interior passageways were narrower and shorter than those in buildings ashore. Unlike shoreside buildings, which typically have many windows, the vessel offered very little natural lighting. Unlike typical stairways in buildings, the shipboard ladders were steep and narrow with multiple changes in direction. All such differences can present problems for firefighters entering a ship with firefighting equipment for the first time.

The Safety Board concludes that the HOVIC fire brigade personnel were inadequately trained in shipboard firefighting.

HOVIC Emergency Planning — The HOVIC emergency plan was less than adequate because it did not address the response to shipboard fires. The duties and responsibilities of the emergency response team, as well as the communication equipment and other available resources, should have been addressed in the emergency plan. It should also have included the role of other responding agencies and how to contact them.

The need for consultative marine expertise was obvious in this type of accident; yet, the HOVIC emergency plan did not address this need. The ship superintendent who provided marine expertise in this instance just happened to be working on another vessel at the terminal when the fire erupted. When the IC was asked what he would have done if the ship superintendent had not been in the area, he said that he did not know. Although the vessel master and the second engineer were available for consultation, the IC did not fully avail himself of their expertise.

Planning for consultative marine expertise should have been accomplished before an actual emergency so that the emergency responders and the person(s) providing the expertise know their responsibilities and their role as it relates to the IC and other emergency responders. But more than just the need to identify consultive marine expertise, the emergency plan did not address the HOVIC's response to a fire on board a ship moored at a terminal dock. There were no provisions for an international shore fire hose connection, no knowledge of fire control plans, no procedures set forth for towing a burning vessel from the terminal, no procedures set forth for maintaining inert gas levels in cargo tanks containing flammable products. These items and more should be addressed in a comprehensive emergency response plan. The Safety Board concludes that the HOVIC emergency plan was not adequate because it did not address responses to shipboard fires.

The Safety Board believes that HOVIC should conduct a risk assessment to identify the resources necessary to develop a comprehensive shipboard firefighting plan and revise the HOVIC emergency response plan accordingly. Assessment should identify, at a minimum, (1) the need for marine technical expertise; (2) the duties and responsibilities of the emergency response team and other agencies; and (3) the names, addresses and telephone numbers of other agencies that can provide necessary resources.

The Safety Board is concerned that the safety problems identified in this accident relative to the HOVIC response to a ship fire may be present in other refineries that operate marine oil transfer facilities. The Board, therefore, believes that the lessons learned from this accident should be disseminated as widely as possible. The Board further believes that the National Petroleum Refineries Association (NPRA) is the appropriate organization to take this action. The NPRA membership includes 464 petrochemical manufacturers and petroleum refinery operators. The stated mission of the association is, in part, to promote the general welfare of its members. It publishes an association newsletter that informs its members about matters related to the refining and petrochemical industry.

U.S. Coast Guard Fire Contingency Plan

There was no need for outside resources to respond to this accident; however, the need still exists for a port fire fighting contingency plan to address the lines of authority, resources and responsibility for vessel fires. Numerous vessels carrying passengers and cargo routinely enter the U. S. Virgin Islands, and one of the world's largest oil refineries with berths for as many as ten ships is located in St. Croix. This highlights the importance of a comprehensive fire contingency plan that involves the U. S. Virgin Islands to respond to vessel fires that are beyond the capabilities of local firefighters.

According to the May 8, 1995, letter from the Commandant of the Coast Guard, guidance for developing firefighting contingency plans will be provided to the COTPs, and a study will be conducted to assess the firefighting capabilities within the nation's ports and harbors. These actions show that the Coast Guard is attempting to provide contingency plans at each port and harbor to protect against the dangers of marine fires. However, the Government of the Virgin Islands has not indicated to the Safety Board that it is working in cooperation with the Coast Guard and other agencies to help complete a firefighting plan for the Virgin Islands.

On November 18, 1980, following its investigation of a March 30, 1979, fire on board the passenger ship ANGELINA LAURO at the Charlotte Amalie Harbor in St. Thomas, U. S. Virgin Islands, the Safety Board recommended that the Governor of the U. S. Virgin Islands:

> M-80-115
>
> Revise its contingency plan to include more comprehensive provisions for rendering fire fighting services to vessels calling at Virgin Island ports, including vessels at anchor in the harbor of Charlotte Amalie.
>
> M-80-116
>
> Provide training in marine fire fighting at an approved practical fire fighting school for its supervisory firefighters.

On March 13, 1983, the Governor of the U. S. Virgin Islands responded:

> Enclosed for your information are photocopies of the contingency plan which has been adopted by the Virgin Islands Fire Service. As you will notice, the plan addresses all types of emergency operations, including ship fires. On ship fires, however, the plan concentrates on ships that are docked. Hopefully, this will be expanded, in the near future, to include vessels at anchor in the harbor. We are now in the process of acquiring a fire/rescue boat through the Federal Excess Property Program. Incidently, we also have an active underwater rescue unit within the Fire Service...."

On May 3, 1983, the Safety Board responded:

> The work done to produce the Virgin Islands Fire Service Emergency Operations Plan is appreciated. The Safety Board is concerned, however, that the problems identified in its report on this accident do not appear to be addressed by the new plan. We had hoped to generate cooperative activity between the Virgin Islands Government, the Federal Emergency Management Agency (FEMA) and the U. S. Coast Guard (USCG) that would have produced a true blueprint for effective inter-agency response to a major ship fire in the Virgin Islands....We urge you to collaborate with representatives of the USCG and FEMA to develop a comprehensive contingency plan for marine disasters in the Virgin Islands. We understand that the USCG and FEMA are willing to cooperate with you in this matter. We hold Safety Recommendation M-80-115 in an "Open—Acceptable Action" status pending further response.

On February 8, 1993, the Safety Board stated:

> On August 6, 1992, the National Transportation Safety Board inquired about the efforts that have been or are being made to implement Safety Recommendation M-80-115....Our records show that we have not received any further correspondence since March 1983, regarding this recommended action. Therefore, Safety Recommendation M-80-115 has been classified "Closed—Unacceptable Action—No Response Received.

The Safety Board concludes that a need still exists for the Government of the U. S. Virgin Islands to develop a fire contingency plan that ensures a rapid response with adequate firefighting resources to a major shipboard fire in any port or terminal within the U. S. Virgin Islands. The Safety Board continues to believe that the Government of the U. S. Virgin Islands should cooperate with the U. S. Coast Guard in developing such a plan.

CONCLUSIONS

Findings

1. Fatigue was not a factor in the chief engineer's performance on the day of the accident. Drugs, including alcohol, were not a factor in this accident.

2. The engineer's decision to make a temporary repair to the lubricating oil strainer was logical given his perception of the vessel's electrical capacity.

3. The diesel generator probably would not have had problems with the engine jacket water overheating and the electrical loads could have been transferred to the diesel generator without affecting the ship's operations or its speed.

4. The regular and the replacement chief engineer had opportunities during the 4 months that the SEAL ISLAND was at sea and in port to shut down the generator's steam turbine so that a proper and permanent repair could be made to the turbogenerator's strainer.

5. The chief engineer's decision to change a clogged element in the lubricating oil strainer was reasonable and logical.

6. Changing the strainer without a device in place to restrain the upward movement of the control valve was poorly thought out and created a hazard that ultimately led to the fire.

7. The maintenance policies, procedures, and practices of Atlantis Agency at the time of the accident were adequate.

8. The initial response by the ship's crew was timely and proper.

9. Had the lubricating oil strainer been shielded from the turbine casing, the oil may not have struck the hot turbine casing and ignited, and the deaths, injuries, and property damage might have been avoided.

10. The escape of the fireman and the machinist from the SEAL ISLAND engineroom was, in part, the result of their familiarity with the vessel and the training that they had received at shoreside firefighting schools.

11. The number of emergency escape breathing apparatus in the SEAL ISLAND engineroom were insufficient; their place of stowage was not readily accessible to facilitate escape from the engineroom.

12. Escape from the SEAL ISLAND engineroom was largely a matter of luck for two crewmembers who were near exits when the fire started, and for the third engineer, who was nearly trapped in the lower engine control room.

13. Fire drills held on the SEAL ISLAND were less than adequate to prepare personnel to escape from the engineroom.

14. The safety of shipboard engineering personnel would be significantly improved if engineroom fire and escape drills were held.

15. The Incident Command System was not executed as designed.

16. The lack of a dedicated radio frequency compromised the effectiveness of the command exercised by the IC.

17. The HOVIC fire brigade personnel were inadequately trained in shipboard firefighting.

18. The HOVIC emergency plan was not adequate because it did not address response to shipboard fires.

19. A need still exists for the Government of the U. S. Virgin Islands to develop a fire contingency plan that ensures a rapid response with adequate firefighting resources to a major shipboard fire in any port or terminal within the U. S. Virgin Islands.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the fire on board the SEAL ISLAND was the chief engineer's failure to recognize the risks introduced by the temporary repair to the turbogenerator oil strainer. Contributing to the loss of life were the suddenness and severity of the fire, the inability of the electrician to use the control room emergency escape hatch, and the lack of fire and escape drills in the vessel engineroom.

RECOMMENDATIONS

To the U.S. Coast Guard:

Propose to the International Maritime Organization that all ships be required to maintain readily accessible emergency breathing apparatus to facilitate escape from the engineroom. (Class II, Priority Action) (M-95-54)

Propose to the International Maritime Organization that periodic engineroom fire and escape drills be specifically required on board all ships. (Class II, Priority Action) (M-95-55)

Propose that the International Maritime Organization develop a standard for engineroom fire and escape drills that will include, at a minimum, how to locate and don breathing apparatus and how to find and use emergency exits in simulated fire conditions. (Class II, Priority Action) (M-95-56)

Propose to the International Maritime Organization that all modes of fire pump starting systems, including electric, hydraulic, and pneumatic, be tested during fire and boat drills. (Class II, Priority Action) (M-95-57)

Propose to the International Maritime Organization that all vessels be required to install spray shields around lubricating and fuel oil strainers. (Class II, Priority Action) (M-95-58)

To the Governor of the U.S. Virgin Islands:

Cooperate with the U. S. Coast Guard in developing a fire contingency plan that ensures a rapid response with adequate firefighting resources to a major shipboard fire in any port or terminal within the U. S. Virgin Islands. (Class II, Priority Action) (M-95-59)

To Hess Oil Virgin Islands Corporation:

Conduct a risk assessment to identify resources necessary to develop a comprehensive shipboard firefighting plan and revise the HOVIC emergency response plan accordingly. The assessment should identify, at a minimum:

(1) the marine technical expertise needs (M-95-60);

(2) the duties and responsibilities of the emergency response team and other agencies (M-95-61); and

(3) the names, addresses, and telephone numbers of agencies that can provide necessary resources. (Class II, Priority Action) (M-95-62)

To the National Petroleum Refineries Association:

Inform member refineries that operate marine oil transfer facilities of the circumstances in the NTSB investigation report of the SEAL ISLAND accident. (Class II, Priority Action) (M-95-63)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JAMES E. HALL
Chairman

ROBERT T. FRANCIS II
Vice Chairman

JOHN A. HAMMERSCHMIDT
Member

JOHN J. GOGLIA
Member

December 12, 1995

APPENDIX A
INVESTIGATION AND HEARING

Investigation

The National Transportation Safety Board was notified of this accident by the U.S. Coast Guard on October 8, 1995. Four investigators from the Safety Board's Washington, D.C., headquarters were dispatched to the scene.

This accident was investigated jointly by the Safety Board and the Coast Guard under the authority of section 304(a)(1)(E) of the Independent Safety Board Act of 1974 and in accordance with 49 CFR 850 (Coast Guard-NTSB Marine Casualty Investigations). The Coast Guard invited the Government of Liberia to participate in the investigation, in accordance with the IMO Resolution A.637 (Co-Operation in Maritime Casualty Investigations). The Government of Liberia accepted the invitation and a representative participated fully in all aspects of the investigation.

This report is based on factual information obtained during the investigation and on additional analyses made by the Safety Board. The Safety Board has considered all facts in the investigative record that are pertinent to its statutory responsibility to determine the cause or probable cause of the accident and to make recommendations. The Safety Board has made its analyses and recommendations independently of the Coast Guard.

Hearing/Deposition

The Safety Board did not conduct a public hearing in connection with this accident. Because of the severity of injuries to many of the witnesses, Safety Board investigators took their depositions while they were hospitalized. The Board conducted in-person depositions with witnesses in New York, New York, Livingston, New Jersey, and Jacksonville, Florida, and telephone depositions with witnesses in California, St. Croix, the U.S. Virgin Islands, and Italy.

APPENDIX B

CREW INFORMATION

Master — Pasquale Buonarotti was 45 years of age at the time of the accident and was most recently licensed as a master of ocean-going vessels of any gross tonnage by the Republic of Liberia on June 19, 1992. His license was endorsed to show qualification as a radar observer. The master had completed training courses in firefighting, survival and rescue, first aid, tanker safety, and bridge resource management. He was not injured in the accident.

Chief Engineer — Mario Pontarelli was 45 years of age at the time of the accident and was most recently licensed as a chief engineer on steam and motor vessels of any KW propulsion power by the Republic of Liberia on August 19, 1992. He was graduated from an Italian nautical school and went to sea in 1973. He became a chief engineer in 1987 after working for Atlantis for 3 years as a second engineer. He had worked primarily aboard the SEAL ISLAND for about 10 years. He had completed training courses in firefighting, survival and rescue, and first aid.

First Engineer — Antonio Marchese was 49 years of age at the time of the accident and was most recently licensed as a chief engineer on steam and motor vessels of any KW propulsion power by the Republic of Liberia on December 18, 1992. He had completed training courses in firefighting and survival and rescue. He suffered fatal injuries as a result of the accident.

Third Engineer — Francesco Spada was 29 years of age at the time of the accident and was most recently licensed as a first assistant engineer on steam and motor vessels of any KW propulsion power by the Republic of Liberia on July 6, 1994. He had not attended training courses in firefighting, survival and rescue, first aid, or tanker safety at the time of the accident. He suffered serious injuries as a result of the accident.

The six unlicensed engineroom crewmembers listed below were documented by the Republic of Liberia. According to Atlantis, all had previously attended various training courses in firefighting.

Electrician	De La Cruz, Dante	(Fatal Injuries)
Chief Fireman	Alado, Roberto	(Serious Injuries)
Fireman	Divinagracia, Primitivo	(Serious Injuries)
Machinist	Padasas, Ariel	(Serious Injuries)
Machinist	Surmieda, Nomer	(Fatal Injuries)
Wiper	Pedrina, Darwin	(Serious Injuries)

APPENDIX C

TURBOGENERATOR AND DIESEL GENERATOR SERVICE HISTORY

December, 1992 -- ABS Special Surveys (detailed examinations) were conducted of the SEAL ISLAND's hull and equipment while the tankship was in drydock at Dubai. An electrical generator specialist reported that both generators were disassembled, examined, overhauled, and re-assembled. In accordance with ABS testing requirements, the generators were test run at 80 percent full power (turbogenerator 1080 kw/diesel generator 750 kw) and operated satisfactorily.

A Hedemora Diesel representative performed maintenance and repairs to the diesel generator's 12-cylinder diesel prime mover. After the (salt water) lubricating oil cooler, and the fresh water (cylinder, jacket water) cooler were disassembled, cleaned, and re-assembled with new gaskets, the engine was test run under load. The cooling water medium used for the diesel's lubricating oil and jacket water coolers was the very warm sea water of the Persian Gulf. All engine temperatures and pressures were within specifications. Circulating cylinder jacket (fresh water) cooling water carried heat away from around the cylinders and all exhaust temperatures were within the manufacturer's specifications.

A Stal-Laval turbine service technician examined the steam turbine prime mover of the turbogenerator, and reported that the turbine casing, nozzle plate, diaphragm stages, rotor, bearings, pinion and bull (reduction) gears, speed governor, and servo governing system were either in or placed in satisfactory condition and that the turbogenerator tested to ABS class requirements.

Technicians determined that the circuit breakers and electrical protective devices met ABS and SOLAS requirements.

April, 1993 -- Atlantis management contracted a manufacturer's technical specialist to examine the turbine problems reported by the chief engineer. The chief engineer had reported that the turbogenerator, which was rated at 1,350 kw , would not accept electrical loads above 820 kw. The contract specialist repaired the turbogenerator's turbine speed governor. The unit was started and accepted loads up 1050 kw, which was all the load that the ship could provide with the electrical equipment that was available at the time. The contract specialist then conducted test loads of 200, 400, 600, 800, and 1000 kw and compared the load carrying characteristics of the 1993 tests with the original load carrying characteristics recorded in 1973. The contractor found that the new readings were almost identical to the original readings. Further, he observed no governor speed control hunting during the load tests. The contractor's reports states that the turbine governor had sufficient load control to accommodate an additional 300 kw above the maximum test load of 1050 kw.

February, 1994 -- ABS annual surveys were conducted of the SEAL ISLAND while the vessel was in drydock at Cadiz, Spain, during January and February 1994. A turbine service

APPENDIX D

EXAMINATION OF THE OIL STRAINER AND ASSEMBLY COMPONENTS

Safety Board technicians examined the strainer casing and the fabricated assembly components, including the screw-jack, cup, and strongback.

The screw-jack base, which rested on the top of the lubricating oil sump tank, was fabricated from a pipe flange. A 5-inch-long threaded stud was placed into the pipe flange, which held the stud upright. A small steel plate about 1.5-inch square was welded to the end of the stud to support the cup.

The cup was fabricated from a 2-inch-long, 3-inch-diameter round brass bar stock that was machine grooved around the edge to form a 0.25-inch lip that would accommodate an O-ring. The 2.375-inch-diameter middle area of the brass bar stock was bored out about 1.25 inches to accommodate the lower end of the directional flow control valve and to contain leaking oil.

The 19-inch-long strongback was fabricated from 2-inch flange angle iron. Three holes were drilled along one flange of the angle iron: one in the center, and the other two at each end. The center hole accommodated the passage of the top (neck) of the directional flow control valve through the strongback, and allowed the strongback to rest directly on the valve's shoulder. A hole at each end of the strongback accomodated a 4-inch-long threaded stud that was welded to a clamp.

Each clamp was fabricated from 7.5-inch-long angle iron cut to fit the rounded shape of the strainer casing. When nuts were installed and tightened on the clamp studs, the angle iron (clamp) would be pulled up against the underside of the basket cover flange and the iron strongback would be pulled down. When in place, this assembly prevented the directional control flow valve from rising upward out of the strainer casing.

Examiners found the lower securing pin of the directional control flow valve pushed in, which allowed the directional control valve to move upward out of the strainer casing. The directional control valve was easily removed from the strainer casing. The upper O-ring had not been found on scene in the engineroom. The Safety Board did not find the upper O-ring during laboratory examination of the valve. Investigators removed the lower O-ring from the directional control valve, examined it microscopically, and found it to be in good material condition. The O-ring was open ended, and showed no indications of glue.

END

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