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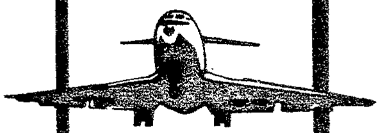

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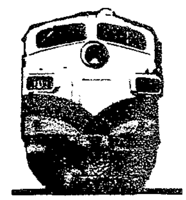
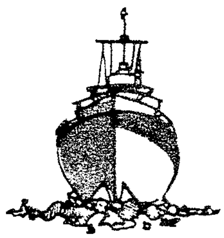
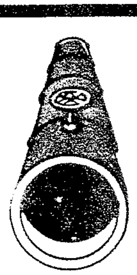


WASHINGTON, D.C. 20594

MARINE ACCIDENT REPORT



UNITED STATES BULK CARRIER MARINE ELECTRIC
CAPSIZING AND SINKING
ABOUT 30 NAUTICAL MILES
EAST OF CHINCOTEAGUE, VIRGINIA
FEBRUARY 12, 1983



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16. Abstract

About 0415 on February 12, 1983, the 605-foot U.S. bulk carrier MARINE ELECTRIC capsized and sank during a storm in the Atlantic Ocean about 30 nautical miles east of Chincoteague, Virginia. Thirty-four persons were aboard. Three persons survived the accident, and the bodies of 24 persons were recovered. The other seven persons are missing and presumed dead. The MARINE ELECTRIC currently is resting in three pieces on the bottom of the ocean in about 120 feet of water; its estimated value, including the cargo was $12 million. An examination of the wreckage indicates that a structural failure occurred either at the No. 2 cargo hold or in the original T-2 bow section.

The National Transportation Safety Board determines that the probable cause of the capsizing and sinking of the U.S. bulk carrier MARINE ELECTRIC was the flooding of several forward compartments as the result of an undetermined structural failure. Contributing to the loss of life was the lack of personal thermal protection equipment for the crewmembers to minimize the effects of hypothermia and inadequate provisions for persons in the water to board the type of inflatable liferaft carried by the MARINE ELECTRIC.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

MARINE ACCIDENT REPORT

Adopted: January 19, 1984

UNITED STATES BULK CARRIER MARINE ELECTRIC CAPSIZING AND SINKING ABOUT 30 NAUTICAL MILES EAST OF CHINCOTEAGUE, VIRGINIA FEBRUARY 12, 1983

INTRODUCTION

This accident was investigated jointly by the National Transportation Safety Board and the U.S. Coast Guard. Public hearings were held in Portsmouth, Virginia, from February 16 to February 24, 1983, March 18 to March 26, 1983, and July 25 to July 28, 1983. This report is based on the factual information developed by the investigation. The Safety Board has considered all facts pertinent to the Safety Board's statutory responsibility to determine the cause or probable cause of the accident and to make recommendations.

The Safety Board's analysis and recommendations are made independently of the Coast Guard. To insure public awareness of all Safety Board recommendations and responses, a summary of all recommendations and responses is published in the Federal Register.

SYNOPSIS

About 0415 on February 12, 1983, the 605-foot U.S. bulk carrier MARINE ELECTRIC capsized and sank during a storm in the Atlantic Ocean about 30 nautical miles east of Chincoteague, Virginia. Thirty-four persons were aboard. Three persons survived the accident, and the bodies of 24 persons were recovered. The other seven persons are missing and presumed dead. The MARINE ELECTRIC currently is resting in three pieces on the bottom of the ocean in about 120 feet of water; its estimated value, including the cargo was $12 million. An examination of the wreckage indicates that a structural failure occurred either at the No. 2 cargo hold or in the original T-2 bow section.

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INVESTIGATION

Events Preceding the Accident

About 2345 1/ on February 10, 1983, the 605-foot-long U.S. bulk carrier MARINE ELECTRIC (see figure 1) departed Norfolk, Virginia, with about 24,800 tons of pulverized steam coal bound for the New England Power Service Company's generating plant in Somerset, Massachusetts. Thirty-five persons were onboard the vessel, including the relief master, a Virginia pilot, the chief engineer, the chief mate, the second mate, the 8 to 12 third mate, the 12 to 4 third mate, the first assistant engineer, the 8 to 12 third assistant engineer, and the 12 to 4 2/ third assistant engineer. The chief mate testified that the entire ship, including the hatch covers, was secured for sea as the MARINE ELECTRIC proceeded out of the harbor. Because of a predicted storm, the chief mate ordered the boatswain (bos'n) and deck utility man, "to put all the dogs 3/ that they could get on around the hatches." The chief mate [later] testified:

> Usually in the coal trade we only put a few dogs on the coamings of the hatches. The hatches were very heavy, and when the hydraulic jacks were released, the hatch panels with wheels set down into a depression in the hatch track, and the wheel was quite a way below the track itself, and made it quite solid. The hatches were very heavy and we did not feel that it was necessary to dog them all the way around.

About 0200 on February 11, the pilot disembarked off Cape Henry, Virginia, and the ship headed to sea. From a position 1 mile east of the Chesapeake light tower, the ship's trackline northbound was 038 1/2° T. (See figure 2.) About 0900, due to the rough sea conditions, the master ordered the ship's speed reduced from 80 rpm (about 12 knots in calm water) to 40 rpm (about 4 knots in calm water). The 8 to 12 third mate testified that during his watch, the winds were from the northeast at force 10 4/ (48 to 55 knots), the seas were from the northeast and 25 to 30 feet high, and green seas were coming over the starboard bow. He said the seas were breaking near the anchor windlass on the forecastle but "the vessel was shipping her water properly. She was getting rid of it easily. It was riding fairly smooth." Other witnesses on the MARINE ELECTRIC testified that, from 1150 to 1350, there were 15-foot seas with 10-foot swells.

About 1320, the master of the 65-foot fishing vessel THEODORA (which was about 30 nmi east of Chincoteague, Virginia) called U.S. Coast Guard (USCG) Station Ocean City, Maryland, and stated that the THEODORA was taking on water, that the vessel's pumps were inoperative, and that he was unsure of his position. The THEODORA had departed Cape May, New Jersey, on the evening of February 10, 1983.

At 1448, the USCG cutter POINT HIGHLAND got underway from the USCG Station at Chincoteague to search for the THEODORA. However, at 1520, a mechanical problem caused the POINT HIGHLAND to return to the USCG station. At 1510, a USCG HH-3F helicopter was launched from Elizabeth City, North Carolina (about 120 nmi southwest of the THEODORA'S position) to search for the fishing vessel and to deliver some portable pumps to the vessel. At 1530, an airborne USCG HC-130 fixed-wing aircraft was diverted to search the area and arrived at the area about 1545. However, limited visibility prevented the aircraft from locating the THEODORA at that time.

1/ All times herein are eastern standard time, based on a 24-hour clock.
2/ These designations refer to the watch stood by the individuals. The 8 to 12 third mate stood the 0800 to 1200 and 2000 to 2400 watch on the bridge.
3/ Mechanical devices to hold the hatch covers in place.
4/ Beaufort scale.

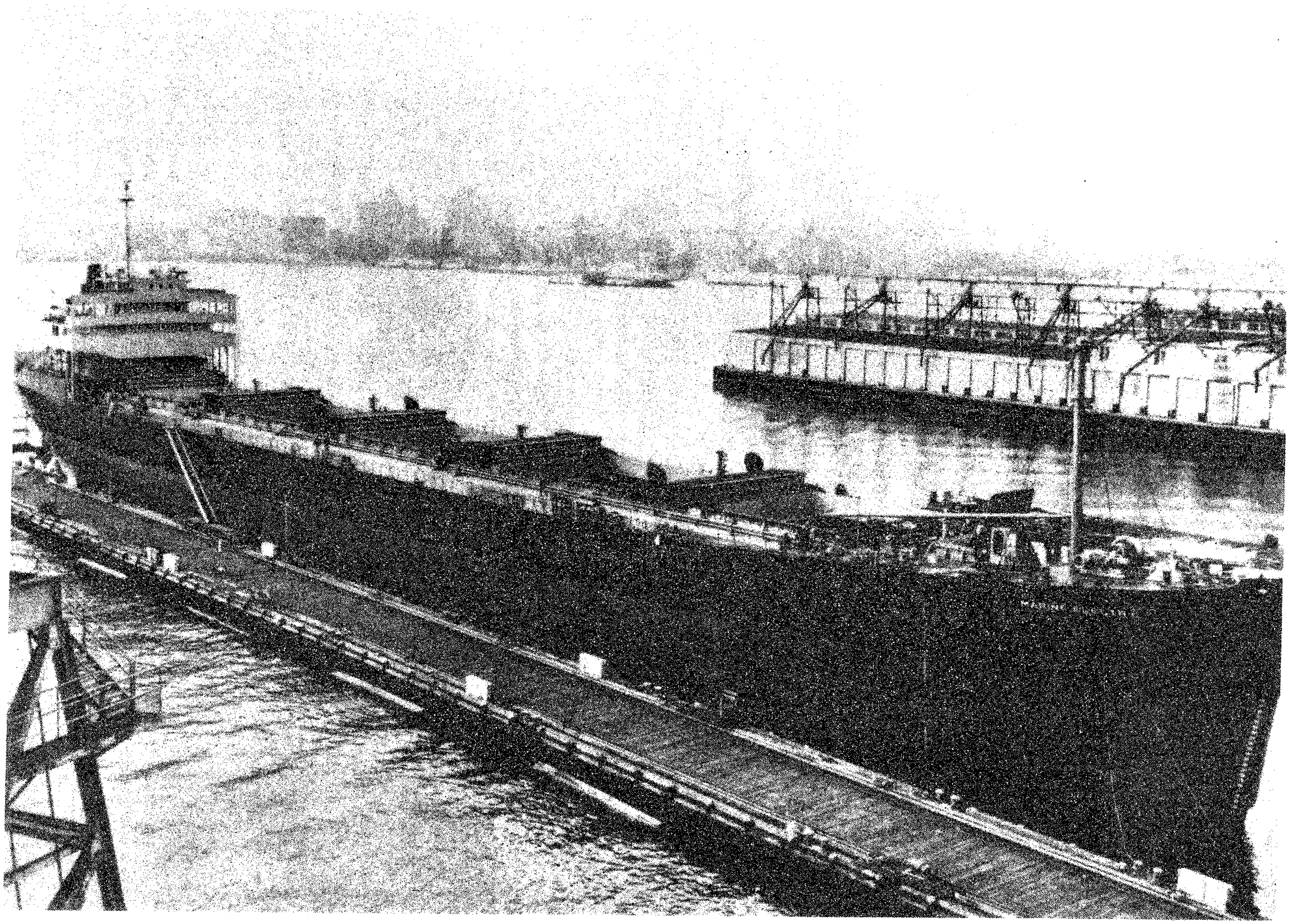

Figure 1.--The U.S. Bulk Carrier MARINE ELECTRIC.

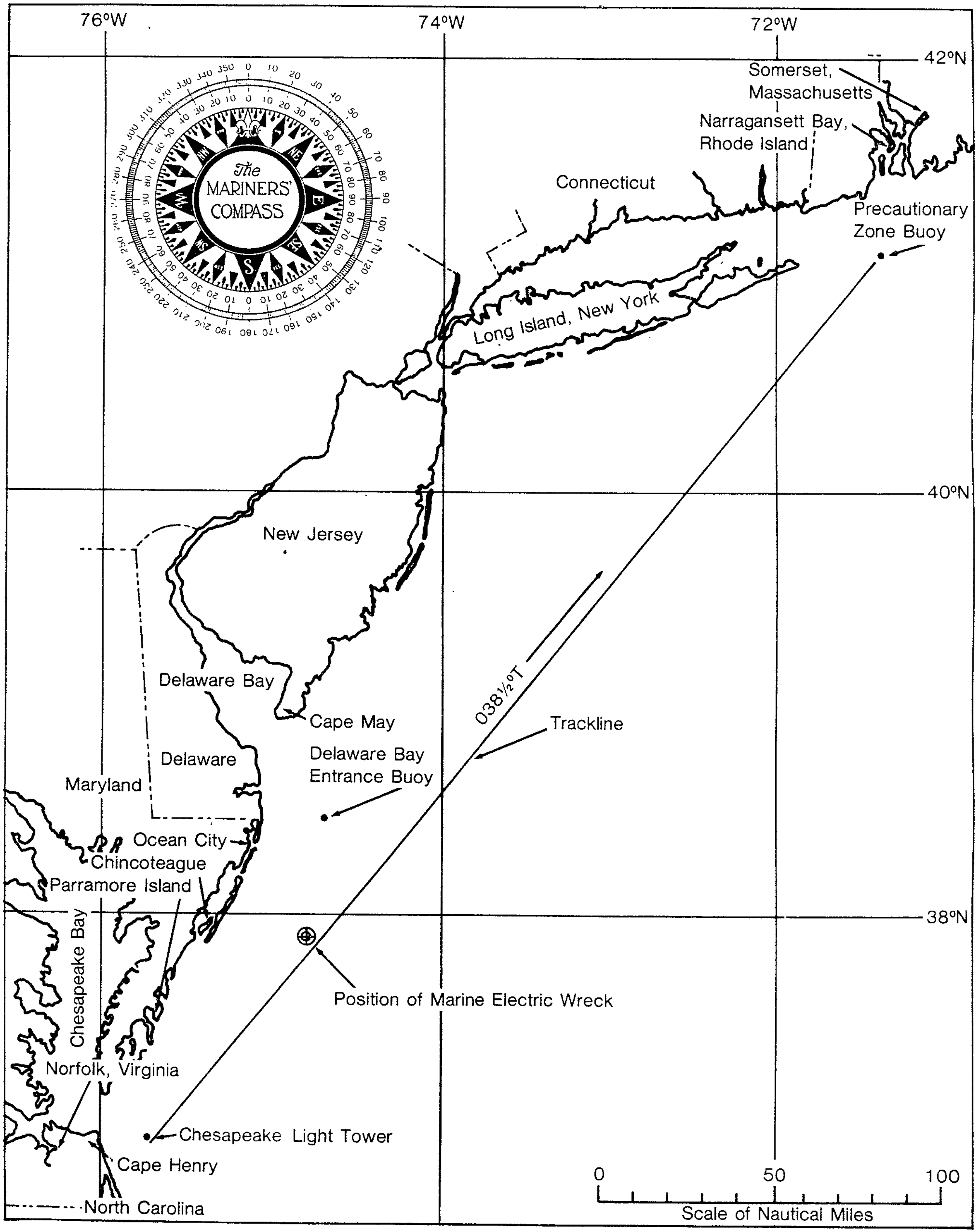

Figure 2.--MARINE ELECTRIC's normal northbound trackline and position of its wreck.

The USCG Station Ocean City then initiated an urgent marine information broadcast which requested that any vessels in the area help to locate the THEODORA. The MARINE ELECTRIC received the broadcast and its master proceeded to help in the search.

An able seaman (AB) aboard the MARINE ELECTRIC stated that the ship had passed the THEODORA about 1530, while he and the chief mate were securing the mooring lines on the stern. The chief mate stated that about 1545, the master told him they were going to turn around to go to the aid of the THEODORA. At that time, visibility was reduced to about 1 to 1 1/2 nmi because of falling snow. At 1600, the master of the MARINE ELECTRIC called the USCG Station at Ocean City on VHF-FM radiotelephone channel 16 and reported that he had located the THEODORA and that the two vessels were at position 37° 54' north latitude, 74° 40.8' west longitude. The USCG Station Chincoteague requested that the MARINE ELECTRIC standby the THEODORA until the POINT HIGHLAND arrived on scene. At 1613, the HC-130 located the THEODORA, and at 1624, the USCG helicopter made visual contact with the THEODORA. At 1651, the master of the MARINE ELECTRIC reported his position as 37° 51.7' north, 74° 47' west and again at 1714 as 37° 50' north, 74° 49' west. At 1724, the POINT HIGHLAND was again underway from Chincoteague. At 1729, the USCG helicopter delivered the portable pumps to the THEODORA and then it returned to Elizabeth City. Before the HC-130 departed the scene, the pilot reported the MARINE ELECTRIC's position as 37° 50' north, 74° 51' west and that both vessels were heading due west.

At 1738, MARINE ELECTRIC's master reported, "I've (sic) having problems out here in this water —weather." At 1744, he reported being on a course of 270° and making about 5 knots over the ground. At 1749, the master reported the MARINE ELECTRIC's position as 37° 50.1' north, 74° 53.6' west and that:

> We are in the midst of a very serious rain squall here. A course of 270 from my present position will put me in trouble. I cannot steer 270.

The USCG requested that the MARINE ELECTRIC continue on the 270° course until the POINT HIGHLAND made a rendezvous with the ship. At 1754, the master of the MARINE ELECTRIC said, "I'll set a course for Chincoteague," which would have been a course of about 270°. However, at 1822, the master of the MARINE ELECTRIC reported:

> I don't know if I'm going to be able to keep on this course. I'm taking an awful beating out here. I'm going to be in trouble myself pretty soon.

The USCG asked the MARINE ELECTRIC if it could maintain its position until the POINT HIGHLAND arrived and the master replied:

> I don't know how I can hold - heave to on this course. I'm rolling, taking water, green water over — over my starboard side, all the way across my deck.

The master of the THEODORA told the master of the MARINE ELECTRIC that he could make the rendezvous with the POINT HIGHLAND (estimated at 2030) without the aid of the MARINE ELECTRIC. At 1825, the USCG radioed the MARINE ELECTRIC that it was free to proceed on its voyage and the master reported, "I'll be going back to my original course." The THEODORA made a rendezvous with the POINT HIGHLAND about 2000 without further difficulty.

The Accident

When the 8 to 12 third mate relieved the watch about 1945, all equipment was functioning properly and the MARINE ELECTRIC was on a course of 040°. The 8 to 12 third mate said the winds were about force 5 (17 to 21 knots) from the north-northeast and that the waves were from the northeast and about 20 feet high. The ship was hove to 5/ and made only 1 1/2 to 2 nmi headway during his watch, although the speed had been increased to 50 rpm (6 knots in calm water) from the 40 rpm set during his previous watch. The waves were not "breaking as heavy on the vessel at that time as they were in the morning." The 8 to 12 third mate said that at the end of his watch, about 2345, he did not notice any change in trim or that the ship had developed any permanent list.

When the AB assumed the lookout watch on the starboard bridge wing about 2350, the MARINE ELECTRIC was on a course of 040°, the seas were 15- to 20-feet high, and the ship's bow was "down a little bit." The AB said that the bow "appeared to be just down a little bit." Between 0100 and 0200 on February 12, the AB was in a standby status and went below to change into dry clothes. About 0150, the AB returned to the bridge and relieved the helmsman. The AB stated that the 12 to 4 third mate and the master were on the bridge and "I think the third mate and the captain there were discussing about the bow a little bit."

About 0230, the master went to the chief mate's room, woke him, and said, "Come up on the bridge, mate... I believe that we were (sic) in trouble... I think she's going--settling by the head." The chief mate went to the bridge looked at the bow, ran down below, got the chief engineer, and returned to the bridge. The chief mate testified, "I took one quick look, and it was apparent that she was [down by the bow]. The seas were staying there. They were not -- the bow was not lifting up properly." At 0251, the master called the USCG Station Ocean City on VHF-FM radiotelephone channel 16 and reported:

> I'm approximately 30 miles from Delaware Bay Entrance and I'm going down by the head, I seem to be taking on water forward. . . . I am a coal carrier, five hatch coal carrier, I am loaded with 23,000 tons of coal. . . we are positively in bad shape. . . positively in bad shape, we need someone to come out and give us some assistance if possible. Our problem is we don't know exactly what our situation is.

At 0254, the master reported, "I'm having my crew muster at the lifeboats"; at 0255, he reported, "I am steering 030, my position is as follows: 37° 51.8' north, 37° 51.8' north, 74° 45.5' west, 74° 45.5' west"; and at 0257, he reported "I'm altering my course to due north to try to head for Delaware Bay Entrance." After the master described the MARINE ELECTRIC and its speed (1.5 knots), USCG Station Ocean City asked, "Are you in any danger of sinking at this time?" At 0308, the master replied, "It's hard to say. . . my bow seems to be going down, we seem to be awash forward, we can't get up there. We don't have any lights to shine up to see what's going on. . . I'm not listing, I seem to be going down by the head fast."

Meanwhile, about 0300, the 8 to 12 third mate was awakened by another crewmember. The 8 to 12 third mate testified that he immediately sensed that the ship was trimmed forward. He donned his lifejacket and reported to the bridge, where he saw "seas covering the forward part of the ship and breaking back to No. 3 hatch. The after

5/ Making bare steerageway.

end of No. 2, the forward part of No. 3." He testified that no emergency alarms were sounded so he did not relieve the watch as required by the station bill in an emergency. The 12 to 4 third mate told him that "at approximately 0115, he felt the bow was sluggish, it was not coming out of the water as much as it had previously." The 8 to 12 third mate said that everyone but the master had donned his lifejacket and that he overheard someone say they were pumping out Nos. 1 and 2 starboard tanks. He also said that the chief engineer believed that "the No. 1 hatch had stove in," but that he could not tell because he said water was covering the No. 1 hatch cover. At that time, the 8 to 12 third mate saw 6 or 7 feet of water on the deck and the ship had a 5° to 8° trim down by the bow. The 8 to 12 third mate helped to ready the starboard lifeboat, gathered and placed liferings on the afterdeck, and cut the Emergency Position Indicating Radio Beacon (EPIRB) free, standing it upright in its box on the port bridge wing.

The AB said that the chief engineer had the lookout shine a tankerman's light 6/ toward the bow and that he heard the chief engineer say that the No. 1 hatch cover was "cracked, or opened, or busted." Also, he overheard the first assistant engineer tell the chief engineer over a hand-held radiotelephone that "he had good pressure on number 1 and 2 starboard." The AB went on to say, "I'm not sure for that. I know it was number 1 positive, but it was the cargo hold or ballast tanks, I don't know." The AB said he overheard the first engineer say "he was getting pressure and all that." The AB then said the first assistant engineer, " called up and asked the chief engineer 'did he want to gravitate from starboard to port', and the captain. . . just said, you know, 'keep pumping'." Shortly afterward, the 12 to 4 third mate relieved the AB at the wheel, and the AB went below to his room, changed to heavier clothing, donned his lifejacket, and returned to the bridge. The chief mate also testified that a third assistant engineer told him, "I'm getting a lot of water out of number one starboard" but later changed his testimony and said that the third assistant engineer said "number one port" and that the first assistant engineer told him, "they were getting water out of No. 2 starboard."

About 0350, the ship was observed to be listing about 5° to starboard. At 0355, the master reported to the USCG that the ship was listing about 5° and was rolling to 14°. At 0403, the master reported to the USCG an 8° list, that they were flooding the port tanks, and that they were pumping the starboard tanks. About 0400, the chief mate went to the bridge, observed a 5° list on the ship's inclinometer, and then went below to the boat deck to standby the starboard lifeboat. About 0410, the master instructed the crew to abandon ship and instructed the AB to proceed to the starboard lifeboat. The chief mate testified that he got the lifeboats and liferafts ready for launching and that when he heard the ship's whistle blow a signal meaning to abandon ship he ordered the crew to launch the lifeboat. At 0414, the master reported to the USCG, "We are abandoning the ship right now, we are abandoning the ship right now."

When the AB reached the lifeboat, it was still hanging from the davits and the crew was trying to pull the boat closer to the rail. The AB tried to help bring the boat in, but at 0415, the MARINE ELECTRIC capsized to starboard throwing the AB and others into the water. The ship was at 37°52'N, 74°46'W.

The 8 to 12 third mate further testified:

> At this time, about 4:10, the radio operator came on the bridge, and he told us that he had received messages from two merchant vessels

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6/ Explosion proof battery powered light used to inspect cargo holds or tanks.

in the area. One was approximately an hour away. One was due on the scene at approximately 8:00 o'clock, 1800 (sic), and it was kind of strange, because on the bridge, everybody kind of let out a sigh of despair. They knew we didn't have that much longer to stay afloat. The ship started to take another list, in addition to the 5 degrees. It went to about 10 degrees starboard. The captain called down to the engineroom -- the captain had the chief call down to the engine - room, I thought, on the sound-powered phones. It may have been on the walkie-talkie. And he wanted the engine secured, the engine stopped, and the engineroom secured. He ordered the engines stopped, and the engineroom evacuated.

At that time, he also told the helmsman, to leave his station, that there was no sense steering her, she wasn't answering up at that time too well.

The helmsman went out to the starboard bridge wing, and I yelled to him to go down the inside passage, that we had too much of a list, he would probably slide right off. The decks at this time weren't ice-coated, but they were slippery with all the salt spray that was on board, plus the list, plus the action of the seas would increase the list to maybe 20 degrees when she rolled on a wave.

The helmsman came back in, went down the inside passage, and directly after that, the master radioed the Coast Guard and said that he thought he was going to lose his vessel, and he was going to abandon ship at that time. The master started to get into his life jacket. I noticed he was struggling a little bit to get into it. And the Coast Guard came back with the transmission they wanted to know what color the lifeboats were. And I just grabbed the mike, and I responded "International orange." And that's all I said on the radio.

And we started out. The master went out the starboard bridge wing and down that way. I went down the inside passage, which takes you by the radio shack and then onto the outside decks.

As I started down the ladder in the inside, I thought I would be a little bit quicker, and I jumped, I would try to catch the second step, and try to jump halfway down, but I missed the steps and fell all the way to the bottom of the ladder.

Just before I was at the top of the ladder, I don't know where I got the walkie-talkie in my hand — I think it was laying on the chart table — but I heard the first engineer call from the engine room, he wanted to know if they wanted the fuel oil pumps secured.

I believe that is what he asked, the fuel oil pumps, and I just responded, "Mike, get the hell out of there. We are going down."

As I jumped down the ladder, as I was falling down the ladder, I dropped the radio, and it smashed at the foot of the stairs, smashed into a lot of pieces, and I was laying there on top of it, and I just thought of getting out of the house. I just wanted tc get outside before she went under.

At that time I didn't think it was going to roll over. I thought she was going to go down straight by the head. I don't think anybody expected it to roll over.

I got outside — right directly outside the radio shack, and I went down one ladder to about seven or eight steps, maybe ten steps, and I came to the spot where we had piled all the life rings. I stopped there, and I started throwing life rings over the side of the ship. I believe it was probably half a dozen life rings setting there, and I think maybe three or four of them made it into the water. The rest hit the overhead and bounced directly back down onto the deck.

It seemed like only seconds after that that I started down the ladder to the boat deck. It is only a short little ladder, down to what they call the stack deck, where the stack is located, and I was watching the lifeboat being launched. The falls were being payed out. The mate was there — the mate was on the forward fall. He was paying it out. And I don't know who was on the after fall, but all of a sudden, the ship just rolled, and I saw the water level start to rise, and before the releasing gear was even released on the lifeboat, the seas picked it up brought it right in front of me up against the stack. And I just watched the ocean level come up and grab me.

As I went into the water, I looked up and I saw the master on his deck, climbing over the railing, trying to get into the water. That is the last time I saw the master. I wasn't in the water with him.

Rescue Efforts

At 0310, the USCG Rescue Coordination Center (RCC) in Portsmouth, Virginia, was notified, and the POINT HIGHLAND was instructed to cease escorting the THEODORA and go to the aid of the MARINE ELECTRIC. At 0316, the MARINE ELECTRIC's master reported, "What has happened is the number one hatch is broke, we're putting pumps on and we have good head pressure on our pumps, we're trying to keep pumping." At 0318, the master reported his position as "37° 52 north, 74° 45.5' west." At 0318, USCG Air Station Elizabeth City, North Carolina, was directed to launch its ready helicopter. At 0330, the master of the U.S. tankship TROPIC SUN which was bound for Delaware Bay and was located about 35 nmi north of the MARINE ELECTRIC's position, called the USCG and offered to assist. At this time, the POINT HIGHLAND was about 35 nmi to the west of the MARINE ELECTRIC. At 0345, the TROPIC SUN changed course from 312° to 192° to go to the aid of the MARINE ELECTRIC.

At 0413, USCG helicopter 1471 departed Elizabeth City. At 0416, the TROPIC SUN reported that it was 24 nmi away from the MARINE ELECTRIC, that it was proceeding at 17 knots, and that the Norwegian tankship BANANGER, was 6 nmi ahead of the TROPIC SUN and also proceeding to the scene at a speed of 13 knots. At 0509, a U.S. Navy Helicopter departed the Naval Air Station, Oceana, Virginia, and a USCG HC-130 departed from Elizabeth City. About 0545, the HC-130, the TROPIC SUN, and the BANANGER arrived on scene. USCG helicopter 1471 recovered three survivors, departed the scene about 0700, and proceeded to Salisbury, Maryland, where at 0738, the survivors were transferred to ambulances and taken to the Peninsular General Hospital in Salisbury. The remaining rescue aircraft stayed at the scene and observed the stern of the MARINE ELECTRIC afloat until 1000 when it disappeared from sight.

Injuries to Persons

Injuries	Crew	Others	Total
Fatal	31	0	31
Serious	0	0	0
Minor/None	3	0	3
Total	34	0	34

Damage to Vessel

The MARINE ELECTRIC sank in about 120 feet of water. On February 15, 1983, the USCG located the wreck of the MARINE ELECTRIC using a fathometer. On February 16, the USCG conducted a side scan sonar survey and a diving survey on the wreck. Portions of the ship were found resting in two pieces on the bottom of the ocean at latitude 37° 52.9' North longitude 74°46.6' West. A third piece was found about June 9, 1983, about 1,800 yards to the south-southeast. Divers found large amounts of coal spread over the ocean floor between the two sections. The value of the MARINE ELECTRIC was estimated at $10 million and the coal at $2 million.

Crew Information

The USCG Certificate of Inspection for the MARINE ELECTRIC required a crew of 21, including a master, a chief mate, a second mate, a third mate, a radio officer, six able seamen, three ordinary seamen, a chief engineer, a first assistant engineer, a second assistant engineer, a third assistant engineer, and three oilers or enginemen. At the time of the accident, in addition to the required crew, the following crewmembers were onboard: an additional third mate, an additional third assistant engineer, a bosun, a chief cook, a steward/baker, two wipers, four utility men, a deck utility man, and an engine cadet. (See appendix A.)

The relief master, 59, had held a valid USCG license as master since 1978 and had served as relief master since February 1980. He first went to sea in 1943, received his third mate's license in 1945, second mate's license in 1947, and chief mate's license in 1949. He had been employed by Marine Transport Lines since 1976 and had served in the capacity of chief mate or master on tankships of a comparable size to the MARINE ELECTRIC. He had served as relief master on the MARINE ELECTRIC from June to September 1982, and again had assumed duty as relief master on February 9, 1983.

The chief mate, 59, had held a valid USCG license as unlimited master since 1981 although he had never sailed as master of a ship. He received his original third mate's license in 1943, his second mate's license in 1944, and his chief mate's license in 1945. From 1952 to 1962, he sailed for a company which operated coal carrying bulk carriers; from 1962 to 1978, he served on various types of ships; and in 1978, he became the permanent chief mate on the MARINE ELECTRIC, a position which he held until the time of the accident. Although the chief mate did not stand any bridge watches, he was second in command of the vessel, and he was responsible for the loading and unloading of the cargo. He was in charge of the deck department and securing the MARINE ELECTRIC for sea. He also supervised the deck maintenance of the vessel, including the hatch covers, cargo holds, and lifesaving equipment.

The chief engineer, 44, had held a valid USCG license as chief engineer, steam and motor vessels of any horsepower since 1974, and he had held the position of chief engineer on the MARINE ELECTRIC since 1980. He received his license as third assistant engineer of steam vessels in 1963, his license as second assistant engineer of steam vessels in 1965, and his license as first assistant engineer of steam vessels in 1969. The chief engineer served concurrently in the capacity of port engineer for Marine Transport Lines while serving as chief engineer and during his 6-month shore time vacation each year. As port engineer, he was responsible for approving all repair requests from the master, the chief mate, or the engine department. He also acted as the marine surveyor for Marine Transport Lines when the MARINE ELECTRIC grounded in July 1981.

Vessel Information

General.--The MARINE ELECTRIC was owned by Marine Coal Transport Corporation and was operated by Marine Transport Lines, Inc. (MTL) of New York, New York. The ship was built in 1944 by Sun Shipbuilding and Drydock Company of Chester, Pennsylvania, and was named MUSGROVES MILLS. Built to the specifications for the U.S. Maritime Administration Design T-2 tankship, the ship was 523 feet long, 68 feet wide, and 39.25 feet deep. It was outfitted with a raised forecastle deck, midship house, and a raised after deck.

In 1962, the ship was converted to a bulk carrier by Bethlehem Steel Company, Shipbuilding Division of East Boston, Massachusetts, and was renamed the MARINE ELECTRIC. The ship was outfitted with a 387-foot midbody built by Bremer Vulkan Schiftbau and Maschinenfabrich of Bremen, Germany. The new midbody section, which met USCG construction standards and the American Bureau of Shipping (ABS) 1961 Rules for Building and Classing Steel Vessels, overcame T-2 tankship design problems by incorporating a riveted deck and bottom crack arrestors. (See figure 3.) The main deck of the new midbody was the same height as the forecastle deck and the after deck, which became a part of the new main deck. The former main deck was redesignated the second deck. The converted ship was 605 feet long, 75 feet wide, and 47.25 feet deep.

The stern section contained an after deckhouse and the machinery spaces. The midship house was moved aft and placed on top of the original after deckhouse. The new midship section contained five cargo holds and five upper and lower wing ballast tanks, port and starboard. Steel hatch covers on 4.5-foot coamings protected each cargo hold. (See figure 3.) The original bow section contained a small dry cargo space with a non-weathertight hatch on the second deck, various storerooms, the forepeak tank, and the port and starboard fuel oil deep tanks. A hinged steel weathertight hatch cover on a 2.5-foot coaming on the main deck protected the dry cargo area. This single panel hatchcover was about 11 feet 3 inches by 15 feet and was original T-2 tanker equipment.

Equipment.--The MARINE ELECTRIC was equipped with MacGregor single pull steel hatch covers. (See figure 4.) Each cover consisted of a number of panels designed to be stowed clear of the hatch opening when in the open position. The No. 1 cargo hatch cover consisted of six panels. The forward and after panels were of similar construction and scantlings. The forward panel was 6 feet 8 inches wide and the after panel was 7 feet 3/4 inch wide. The four intermediate panels between were identical, each being 6 feet 9 1/4 inches wide. The overall dimensions of the hatchcover were 37 feet 10 3/8 inches wide by 40 feet 9 3/ 4 inches long. When the hatch cover was in place, the panels were connected structurally at the seams between panels. The covers of the Nos. 2 through 5 hatches consisted of seven panels each. All the panels on all the hatches

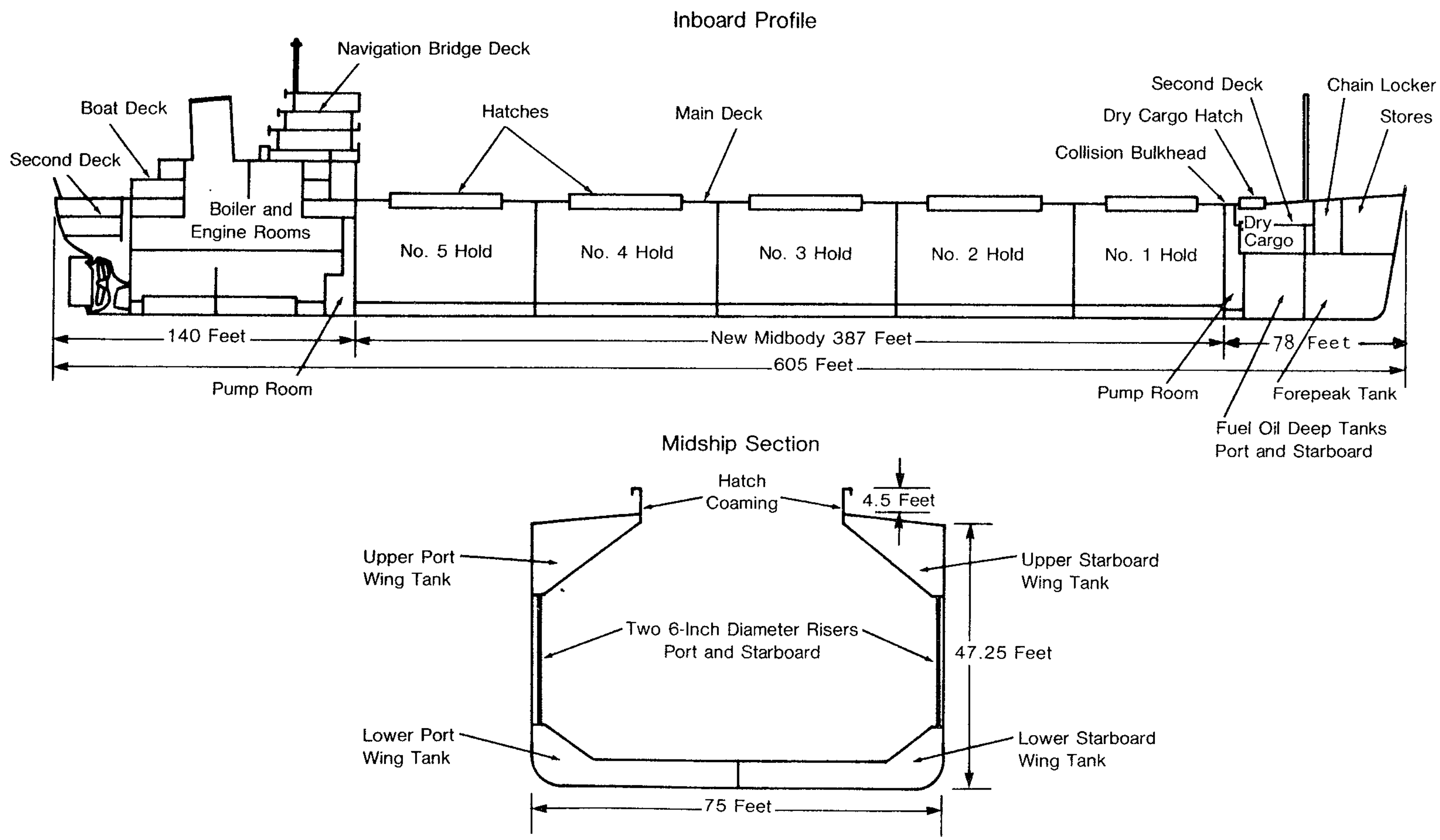

Figure 3.—Inboard profile and midship section of the MARINE ELECTRIC.

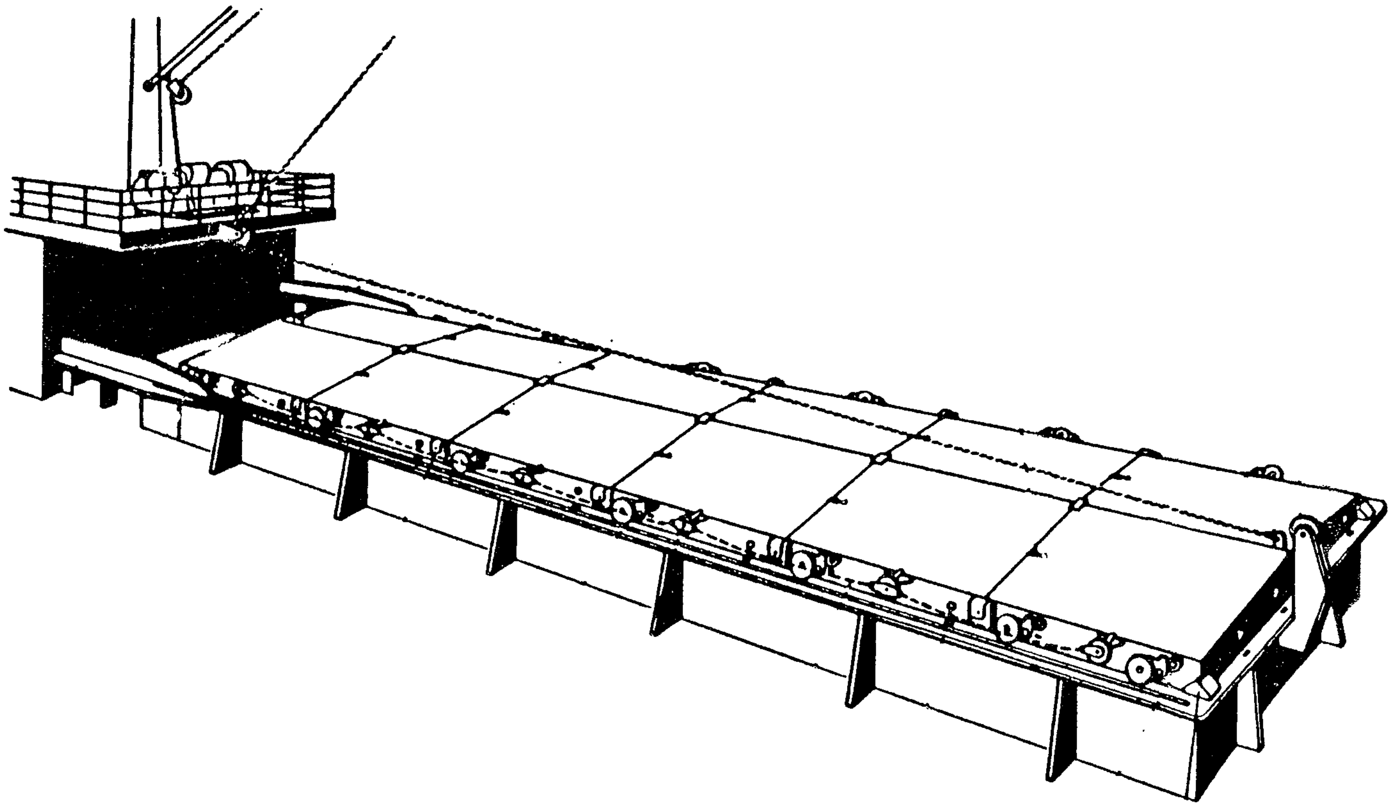

Figure 4.—Typical six-panel hatchcover.

were equipped with traveling wheels to permit rolling of panels into place on the hatch coaming. Weathertightness was achieved by lowering the wheels into recesses in the hatch coaming by releasing a hydraulic jacking system and allowing the weight of the cover to rest on the gasket. Setting quick acting dogs around the periphery of the hatch and installing cross joint wedges between panels completed the hatch closing arrangement.

The No. 1 hatchcover was constructed using 9/32-inch mild steel plate for the forward and after panels and 1/4-inch plate for the four intermediate panels. Each panel was stiffened by a centerline longitudinal girder, two equally spaced transverse stiffeners, and transverse and longitudinal end plates. The centerline longitudinal girder was a built-up T-section with an 18 1/2- by 9/32-inch web and 6- by 1-inch flange. The transverse stiffeners were also built-up T sections with 11/32-inch webs that tapered from 18 1/2 inches at the centerline to 10 13/32 inches at the sides with 6- by 1-inch flanges. The transverse and longitudinal end plates were 0.406 inch tapered flat bars with depth dimensions of 20 5/16 to 11 1/16 inches. The perimeter of the hatchcover was fitted with a gasket and a steel skirt for weathertightness.

When the MARINE ELECTRIC was converted in 1962, the USCG permitted MTL to retain the ship's original sheath screw lifeboat davits with manila rope falls and lifeboats. The original lifeboats, though also retained, subsequently were replaced. The port lifeboat was built in 1966 and the starboard lifeboat in 1964. Both lifeboats were constructed of steel and were located on and boarded from the boat deck, one deck above the main deck. The MARINE ELECTRIC also was equipped with two USCG-approved inflatable liferafts: one manufactured by the B.F. Goodrich Co. in 1977 and the other manufactured by the Switlik Parachute Co. in 1980. The vessel was equipped with a MARTECH Whaler EB-2BW Emergency Position Indicating Radio Beacon (EPIRB) which was last inspected by the Federal Communications Commission (FCC) on June 17, 1982.

The radio room, located one deck below the navigation bridge deck, was equipped with a main transmitter and receiver, an emergency transmitter and receiver, and a single side band radio transceiver. The navigation bridge was equipped with two VHF transceivers, a LORAN-C receiver, two radars, a gyrocompass, and a gyrocompass repeater. An inclinometer was mounted on a transverse bulkhead.

Bilge and Ballast System.--The upper and lower wing ballast tanks in each hold were connected by two 6-inch vertical risers, port and starboard, without valves. The upper ballast tanks were filled by pumping through the port and starboard ballast manifolds into the lower ballast tanks until they were filled and then the water rose through the vertical risers until the upper ballast tanks were full. Water was discharged from the ballast tanks through the piping in the lower ballast tanks using the suction valves in the ballast manifolds. The three original T-2 cargo pumps were used as ballast pumps. New bilge and ballast valve manifolds were installed in the after pumproom. Each wing ballast tank was serviced by a single 6-inch pipe and each cargo hold bilge with a single 4-inch pipe. The port pump serviced the port wing ballast tanks, and the starboard pump serviced the starboard wing ballast tanks although the pumps could be cross-connected. The center pump normally serviced the cargo hold bilges; however, while the MARINE ELECTRIC was in the coal trade the cargo hold bilge wells were covered with steel plates, rendering the system inoperative.

Stability and Loading.--Because the MARINE ELECTRIC was a cargo ship, it was not required by the ABS, the USCG, or any international convention to meet any subdivision or damage stability standard. The ship's collision bulkhead was located about

77 feet aft of the forward perpendicular (FP). (Before conversion, the collision bulkhead was located about 42 feet aft of the FP.) The MARINE ELECTRIC had a USCG-approved trim, stability, and loading manual dated March 1, 1977. In addition, an MTL port captain developed some standard loading conditions in 1977 for use by the master. The permanent master stated that, when he first began carrying coal between Norfolk and Somerset, he would calculate the metacentric height (GM), 7/ which ranged from 2.8 to 3 feet and the stress numeral, 8/ which ranged from 95 to 98 for the loaded portion of the voyage. However, after a while, he stopped performing the GM and stress numeral calculations because they carried the same cargo each voyage and it was difficult to estimate the residual coal that remained aboard after discharging. To reduce the turnaround time of the ship, some coal always was left in the holds upon completion of discharge.

The MARINE ELECTRIC's maximum allowable draft in salt water was 33 feet 11.4 inches. Upon completion of loading about 2300 on February 10, 1983, the chief mate read the MARINE ELECTRIC's draft in brackish water as 34 feet forward, 34 feet 4 inches amidships and 34 feet 8 inches aft. At 1830, he had determined that the fresh water correction was about 4.5 inches, or a mean draft of 33 feet 11.5 inches in salt water. Draft readings are normally accurate to the nearest inch.

Inspections and Repairs.—From February 8 to February 29, 1980, the MARINE ELECTRIC was at Jacksonville Shipyards, Inc., Jacksonville, Florida, for drydocking and routine repairs. During this time, an ABS surveyor conducted a drydocking survey, an intermediate hull survey, a tailshaft survey, a port and starboard boiler survey; commenced the No. 8 special survey of machinery; and witnessed hull gaugings which were later credited toward the No. 8 special survey of the hull. An MTL structural engineer took additional hull gaugings, and USCG inspectors conducted a drydock inspection. Gaugings were not taken of the hatch covers.

While in the shipyard, doubler plates 9/ were installed on the sloping bulkheads of the Nos. 1 port and starboard upper wing tanks (P&S), the No. 2 P&S, the No. 3 P&S, and the No. 5 P&S; all five port and starboard salt water ballast lower and upper wing tanks were examined internally and were tested in the presence of the ABS surveyor and USCG inspector. The lower wing tanks were found to be satisfactory; however, both the ABS surveyor and the USCG inspector issued a requirement that the upper wing tanks be retested at a later time after leaks, which were found in the welds at the doubler plates, were repaired.

The original bow section was examined internally and found satisfactory by both the ABS surveyor and the USCG inspector; however, the ABS surveyor noted that some forepeak bulkhead stiffeners were approaching maximum allowable wastage limits. Ninety-eight doubler plates were installed on panels of all five hatch covers, wasted sections of the hatch coaming on all hatches were renewed, and over 60 hatch holddown bolt clips were renewed or replaced on all five hatches. The hatch covers then were inspected and found satisfactory by the ABS surveyor. Although the new doubler plates on the hatch covers were hose tested with water at 30 psi in the presence of the ABS surveyor, the weathertightness hose test required for an ABS special survey, which requires a hose test of the entire hatch cover with water at 30 psi, was not conducted.

7/ GM is a measure of a vessel's ability to resist overturning forces.
8/ The stress numeral is a measure of a vessel's design stress with 100 representing maximum design stress.
9/ Doubler plates are plates normally of equivalent thickness to the original plating, which are welded over wasted plating in areas where the original plating is not considered to contribute to the longitudinal strength of the vessel.

After departing the shipyard, the MARINE ELECTRIC transported grain between the United States and eastern Mediterranean ports until December 1980. On May 8, 1980, the upper wing ballast tanks were satisfactorily tested in the presence of a USCG inspector in Houston, Texas. Meanwhile both the ABS technical office in New York and the MTL structural engineer were analyzing the ABS witnessed and unwitnessed (i.e., MTL) gauging reports. In a June 16, 1980 letter to MTL, the ABS described the hull plating to be renewed as a result of the ABS witnessed gauging reports. In an October 17, 1981, letter to MTL, the ABS described the bulkhead plating, side shell longitudinals, and transverse frames that would have to be renewed as a result of the unwitnessed gauging reports. Most of the steel to be renewed was in the forepeak tank and in the upper wing ballast tanks.

During November 1980, the MTL structural engineer drew up preliminary specifications for work to be performed on the MARINE ELECTRIC. The specifications included the steel renewals required by ABS and additional structural renewals including extensive plate renewals to the transverse bulkheads in the midship cargo area and twenty 4-foot by 2-foot by 1/4-inch, ten 6-foot by 3-foot by 1/4-inch, and three 41-foot by 2-foot by 1/4-inch doubler plates for the hatch covers. In preparation for the repairs, which were to be performed in Jacksonville, Florida, the New York office of the ABS in December provided its Jacksonville office with a computer printout of the outstanding ABS recommendations on the MARINE ELECTRIC and the structural surveys conducted in February 1980 which could be credited toward the No. 8 special survey of hull and machinery. Included in the printout was the erroneous notation that the hatch covers had been hose tested in February 1980. The ABS report analyst in New York who encoded the February 1980 ABS surveyor's report mistakenly interpreted the surveyor's examination of the MARINE ELECTRIC's hatch cover as including the required weathertight hose testing for a special survey.

The MARINE ELECTRIC was in the Jacksonville Shipyard from December 22, 1980, to February 24, 1981, and was on drydock during the period from January 18 to January 23, 1981. The structural renewals required by ABS as a result of the February 1980 gaugings and the additional structural renewals contained in the MTL specifications were accomplished. An ABS surveyor completed a drydocking survey, an annual classification survey, an annual load line inspection, a No. 8 special survey of the hull, a No. 8 special survey of the machinery, and a cargo ship safety construction survey. In addition to the gaugings taken in 1980, the ABS surveyor required gaugings of the main deck, the transverse bulkheads, the double bottom tank tops, and other critical areas. As a result of these new gaugings and inspections, some main deck plating was renewed, some wing tank sloping bulkhead longitudinals were renewed, and some additional transverse bulkhead plating was renewed beyond that required as a result of the 1980 gaugings. However, the hatch covers were not gauged, and the ABS surveyor was not aware of the work being done to the hatch cover panels because they had been removed from the ship. When the hatch covers were reinstalled on the ship a few days before it left the shipyard, the ABS surveyor inspected the hatch covers and found no deficiencies. He did not conduct a hose test or any other weathertightness test because the computer printout had indicated this had been done in February 1980. Also, the USCG conducted a drydock inspection, which included an examination of the entire structure of the vessel. The USCG inspector stated that he did not witness any repairs to the hatch covers and that he did not conduct any tests of the hatch covers because they are not specifically included in a USCG drydock inspection and the repair work to the hatch covers was done off the ship. The 28 hatch panels from the Nos. 1, 2, 4, and 5 hatch covers were transported to the Bellinger Shipyard, Atlantic Beach, Florida, where extensive renewals to the hatch panel stiffeners were made and new gaskets were installed on each of the panels of the four hatch covers. The repairs to the seven panels of hatch cover No. 3 were accomplished at the Jacksonville Shipyard. In addition, 27 doubler plates were installed at both shipyards on the tops and sides of a number of the hatch cover panels. Two doubler plates were installed on the dry cargo hatch on the main deck at Jacksonville Shipyard.

After departing the Jacksonville Shipyard late in February 1981, the MARINE ELECTRIC transported coal from Norfolk, Virginia, or Baltimore, Maryland, to the New England Power Service Company, until February 1983, except for the periods from August to December 1981, March to April 1982, and June to October 1982, when the MARINE ELECTRIC transported grain from the U.S. and Canada to eastern Mediterranean ports.

Because the hatch covers would not open or close properly after the shipyard repairs, in February 1981, MTL requested that a manufacturer's representative examine the hatch covers and recommend repairs. This examination and subsequent repairs were performed from March 8 to 16, 1981 at Brayton Point, Massachusetts. The manufacturer's representative testified that, in his opinion, despite the repairs, the hatches still were not weathertight; however, he did not hose or chalk test 10/ them. He said that MTL intended to achieve weathertightness by using sealing tape. About the same time, the cross-joint wedges 11/ for all the hatch panels were removed. From June 2 to 8, 1981, the USCG conducted a biennial inspection for certification of the MARINE ELECTRIC. The USCG inspector testified that the examination of hatch covers was made while they were in the open position and because the Hull Inspection Book, dated June 8, 1981, did not contain any comments, the hatch covers must have been satisfactory. The USCG inspector also stated that these were the only MacGregor type of hatch covers that he had ever inspected.

On July 1, 1981, the MARINE ELECTRIC grounded while berthing at the New England Power Service Company pier. Divers conducted a survey in the presence of an ABS representative, a USCG representative, the permanent master, and the chief engineer of the MARINE ELECTRIC. Although the divers found no damage, paint had been disturbed on the bottom plating from the stem aft for about 130 feet on the port side of the hull.

On February 24, 1982, an ABS surveyor in Baltimore, Maryland, accompanied by the MARINE ELECTRIC's chief mate, conducted an annual hull survey, an annual machinery survey, and an annual loadline inspection. All hatch covers, other weathertight closures, and the cargo holds were found in satisfactory condition. Eight days later, on March 4, 1982, at Brayton Point, Massachusetts, an MTL port captain attended the MARINE ELECTRIC to prepare the ship for the carriage of grain and reported numerous wasted holes in the hatch covers. To repair the holes, 84 doublers were installed on the hatch cover panels and four doubler plates were installed on the main deck. On March 20, 1982, new cross-joint wedges for the hatch covers were delivered to the ship; however, they were never installed. On May 9, 1982, a manufacturer's representative again visited the ship because the crew was having difficulty opening the No. 3 hatch cover. The representative recommended replacing the first panel of the hatch cover which had sagged due to severe wastage. (The panel was replaced in November 1982.) On May 29, 1982, an MTL port engineer noted an additional 12 holes in the hatch covers

10/ A chalk test consists of putting chalk on the hatch cover, securing the hatch and then examining the hatch cover knife edge to determine if there are any places where the hatch covers have not made contact with the gaskets.

11/ Mechanical devices to maintain the overlapping edges of the individual panels weathertight.

and 3 holes in the main deck that required repairs, and between June 14 and 18, 1982, doubler plates were installed over the holes by workers at Brayton Point. On June 18, 1982, the USCG conducted a reinspection of the MARINE ELECTRIC and noted no problems with the hatch covers or hull structure. The USCG inspector said that he did not inspect the hatch covers because the crew was "getting ready for their annual loadline survey, and ABS would normally take care of checking those particular hatches and things." However, the next annual loadline survey was not due until February 1983.

During September 1982, MTL prepared preliminary specifications, which included as an item 15 doubler plates for the hatch covers, in anticipation of drydocking and repairs to be performed in February 1983. On November 30, 1982, the manufacturer's representative, who supervised the installation of the new panel on No. 3 hatch cover, wrote a report which contained the following:

> OBSERVATIONS: During a visit to the vessel in March of 1981, I noticed that panels on No. 3 hold were in poor condition, i.e., being distorted and having wasted area on the main beams. They have deteriorated badly in the interim. At present the coamings have holes in the wheel tracks, and are so wasted that there is no strength left to support the [weight] of the panels without further distortion. The coaming compression bar is badly scaled and wasted such that it should be renewed. The falling tracks are likewise weakened, wasted and damaged. The rising tracks have slopes of uneven angles and are distorted; in addition, they are weakened so as to flex and distort easily. The panels themselves are in an even more serious state of decay. The top plates are weak, wasted, buckled and holed in many places. The cross joint wedges are all [missing], which is a serious omission and although the wedges are onboard, the state of the panels is such that extensive welding on them could lead to further rapid deterioration. There are heavy deposits around and on the panels where hatch tape is used. The rubber gasket channels are of an incorrect size (required during past repairs) and do not fit correctly to the adjacent panels. The distortions in the panels are such that fore and aft bowing precludes the side rubber from seating on the compression bar. To compound this problem the side skirts bend inboard and foul the compression bar and transverse sag causes problems at the cross joints and on the coaming back. The panels on the remaining hatches appear to be in a similar condition. A judgment as to the seaworthiness and cargo protection capabilities of these panels must be examined in conjunction with the ship's Classification Society to fully determine their exact state with an eye to the duration of further use, if any.
>
> The panels should be removed, grit blasted and inspected. Those that are salvable should be repaired; those that are not, should be renewed. The coamings should be grit blasted so that wasted and weakened areas can be identified and renewed.
>
> The panels are large, heavy and therefore costly. To replace all 34 at one time and make the corrective repairs to the coamings would require the outlay of a large sum at one time. An alternative would be to carry out the repair one hold at a time, spreading the cost over several voyages.
>
> MacGregor Services intends to present an estimate for both of the above options in due course for your consideration.

On December 2, 1982, an MTL port engineer attended the MARINE ELECTRIC at Norfolk, Virginia, and noted in his report:

> The crew is presently in the process of chipping, scaling, and painting the hatch covers. In this process, the top plating of the covers becomes holed in many cases, especially along the welding of the frame beams, where new beams were welded onto existing plating. Such wasted and holed areas are being temporarily repaired with epoxy cement.
>
> The chief mate was requested to make a record of all such wasted and holed areas, indicating approximate sizes and location for our evaluation and finalizing the relevant items of the shipyard repair specifications.
>
> In reference to the above, the Master stated that Mr. M. Graham of MacGregor indicated to him, in the course of adjusting the new hatch cover panel, that MacGregor might be able to supply a number of hatch cover panels at a low price of approximately $12,000 each, if substantial order was placed. In view of costs already incurred in repairing the hatch covers, such offer, if upheld by MacGregor, is obviously attractive. The next panel that is now recommended to be renewed is the forward one of No. 4 hatch, as it is sagging.

On December 21, 1982, MTL contacted the USCG and requested a deferment of the required drydocking date from February 22, 1983, to sometime between April 1 and 15, 1983, because of an October 1982 request by the New England Power Service Company that the vessel remain in service until April 1, 1983. On December 22, 1982, the USCG conducted a special inspection at Somerset, Massachusetts, to determine if an extension of the drydocking date could be given. The inspection included the bilge and ballast system in the after pumproom, all overboard piping and valves in the engineroom, and shaft alley piping systems. The hull plating and hatch covers were not inspected. The USCG granted an extension of the drydocking date on January 6, 1983, and stated that the drydocking was to be performed during April 1 to 15, 1983.

During December 1982 and January 1983, the MARINE ELECTRIC's chief mate compiled a series of sketches showing 95 wasted areas on the hatch covers which needed repair. The sketches were sent to MTL's New York office in early February. The wasted areas were temporarily repaired with epoxy by the ship's crew to maintain the weathertightness of the hatch covers. On February 2, 1983, the MARINE ELECTRIC sustained a 4- by 1-inch puncture in the side shell plating at the No. 1 upper port wing ballast tank about 6 feet below the main deck as a result of contact with a shoreside bulldozer being lifted aboard by a crane. A cement box was installed in the tank over the damage before the vessel sailed, and the permanent master requested that MTL repair the fracture. The repair was not made and the fracture was not reported to the ABS or the USCG as required.

A review of the MTL records indicated that, during the ship's last drydocking in January 1981 until its sinking on February 12, 1983, numerous repairs had been made to the cargo holds as the result of damage caused during the offloading of coal. MTL considered the repairs temporary and did not report them to the ABS or the USCG. The permanent master, who left the MARINE ELECTRIC on February 9, 1983, testified that even though the ship's hatch covers had some defective dogs, gaskets that needed repair, and panels with temporary epoxy patches, the hatch covers were weathertight when he went to sea. The only exception was the after panel of the No. 5 hatch cover where the permanent master specifically requested that some holes not be patched so the MTL marine superintendent could observe the general condition of the hatch covers when he attended the ship. The chief mate testified that although he had not found any water in the cargo holds at the completion of any of the voyages after January 1981, he believed that the hatch covers were not weathertight because the gaskets were ineffective.

Operations.--The MARINE ELECTRIC's permanent master testified that the chief engineer was in charge of all repairs. The master was not made aware of every repair item, although the MTL operations manual required that the master approve all repairs. This was not done on the MARINE ELECTRIC because in the company's organizational scheme concerning repairs, the port engineer's decision superseded the master's.

The permanent master also testified that during good weather operations, he would instruct the chief mate to put only a few dogs on the hatches when securing for sea, although he did not know specifically how many dogs were needed to make the hatch covers weathertight. He believed that more than 50 percent of the dogs were operable because the chief mate had never reported any problems with the dogs. He further testified that the cargo hold bilges could not be pumped even if plates were not fitted over the bilge wells because coal mixed with water would clog the bilge piping and damage the pumps.

On December 12, 1982, the MARINE ELECTRIC experienced Force 9 (41 to 47 knots) winds from the north-northeast while northbound and fully loaded. The permanent master recalled that during January 1983 the MARINE ELECTRIC had experienced 25-foot seas from the northeast while the ship was northbound in a fully loaded condition although the ship's log does not indicate that fact. He said that at that time, he reduced the speed to about 3 knots, and that the ship met the seas without difficulty. Water was not found in the cargo holds after the cargo was discharged although the permanent master had observed about 6 inches of water over the No. 1 hatch cover and about 1 foot of water over the dry cargo hatch cover during the storm. He stated that, in calm water, full speed, 86 rpm was about 12.5 knots, 50 rpm was 6 knots, 40 rpm was 4 knots, and 20 rpm was 2 knots.

Waterway Information

From a position 1 mile east of the Chesapeake light tower at the entrance to Chesapeake Bay, the MARINE ELECTRIC's normal northbound trackline to the whistle buoy at the center of the precautionary zone at the entrance to Narragansett Bay, Rhode Island, was a course of 038 1/2° T. (See figure 2.) This course took the vessel well outside the 10-fathom curve off the Virginia and Maryland coast. Along the trackline east of Chincoteague, the water depth is between 100 and 130 feet. About 15 nmi west of the trackline and 15 nmi east of Chincoteague, the water depth decreases to about 70 feet.

Meteorological Information

During February 11 and 12, 1983, a storm system moved north off the Atlantic coast of the United States. The system brought high winds, high seas, and some precipitation to the coastal States and offshore waters from south of Cape Hatteras to New England. (See appendix B.) From 0100 to 1900 on February 11, the wind and waves were generally from the northeast. The winds ranged from 20 to 45 knots, and the significant wave heights 12/ ranged from 13 to 25 feet. About 2200 on February 11, the winds began to shift to the north and then the north-northwest and the wave heights began to decrease, and by 0700 on February 12, the waves were from 11 to 16 feet high. A National Oceanographic and Atmospheric Administration (NOAA) buoy located about 18 nmi north-northwest of the MARINE ELECTRIC wreck recorded wave periods ranging from 11 to 14 seconds with wave heights ranging from 13 to 21 feet between 1600 on February 11 and 0400 on February 12.

Medical and Pathological Information

Reports from the Virginia Department of Health Medical Examiner and the Maryland Department of Post Mortem Examiner indicated that 20 of the 24 persons whose bodies were recovered died of hypothermia, the loss of body heat to the water. At the time of the capsizing of the MARINE ELECTRIC, the water temperature was 39° F and the air temperature was 29° F. The cause of death of the other four persons was drowning. The following chart appearing in the U.S. Coast Guard regulations (33 CFR 181.705) shows the effects of hypothermia:

Water Temperature	Exhaustion or Unconsciousness	Expected Time of Survival
(° F)	(Time)	(Time)
32.5	Under 15 min.	Under 15 to 45 min.
32.5 to 40	15 to 30 min.	30 to 90 min.
40 to 50	30 to 60 min.	1 to 3 h
50 to 60	1 to 2 h	1 to 6 h
60 to 70	2 to 7 h	2 to 40 h
70 to 80	3 to 12 h	3 h to Indefinite
Over 80	Indefinite	Indefinite

When the 59-year-old, 5-foot 8-inch, 200-pound chief mate was rescued, he was wearing thermal underwear, a shirt, a cotton sweatshirt, pants, a parka with hood, gloves, stockings, and a watch cap. The 31-year-old, 5-foot 7-inch, 210-pound third mate was wearing leg warmers, blue jeans, a flannel shirt, a down jacket, wool socks, rubber boots, gloves, and a watch cap. The 28-year-old, 6-foot, 220-pound AB was wearing thermal underwear, blue jeans, 2 pairs of socks, a chamois shirt, a parka with hood, work shoes, gloves, and a watch cap. All three survivors were also wearing lifejackets. It is not known exactly how the bodies that were recovered were clothed.

Survival Aspects

After entering the water, the 8 to 12 third mate swam on his back until he came to five other persons hanging onto a lifering: the chief engineer, the 12 to 4 third mate, the radio operator, an ordinary seaman, and the deck utility man. The only survivor of the group of six, the 8 to 12 third mate, testified as follows:

12/ Significant wave height is the average of the highest one-third of the waves, measured from trough to crest.

> . . .I don't know when I started to notice that people weren't on the lifering. I noticed that [the ordinary seaman] wasn't there at one time. An then I turned around and the [deck utility] man wasn't there. Right after there (sic), I called out to [the 12 to 4 third mate], and I asked him how he was doing. He responded that he was okay, that he was cold, he was okay.
>
> I don't know how long [I] was on the lifering before I noticed that the only one there was the chief engineer and the radio operator. The radio operator kept saying he was cold, and he was stiffening up. He kept saying, "I'm cold. I'm cold. Help me."
>
> At that point, I noticed that the chief — the chief, when we went into the water, had his spotlight, and he had been shining it up into the air all this time. I noticed that he wasn't shining it anymore. I thought he might have lost it. So I whacked him on the back of his lifejacket, and there was no response from the chief. And as I hit him, his flashlight floated away from him, and I was able to grab that, and use that as my signal.
>
> Again, I never looked at my watch in the water because I was afraid that I would lose my grip on the ring. So I wasn't concerned with the time element. I kept talking to [the radio operator]. [He] was the last one on the ring with me.
>
> The helicopters arrived, and it seemed like I could see them passing over me two or three times before they spotted us. When they lowered the basket, I turned to tell [the radio operator] that the basket was here, and [he] wasn't on the lifering anymore. It was just myself.
>
> That's when they lowered the basket into the water, and I was able to get in.

The AB who was on watch before the capsizing also swam on his back away from the MARINE ELECTRIC after he entered the water. He found an unopened liferaft floating in the water and inflated the liferaft by putting his feet on the canister and pulling on the inflation line. After inflating, the wind blew the liferaft a short distance away but he was able to swim to it and get in. Four other persons swam to the liferaft, including the second mate and another AB. The AB in the liferaft was not able to assist any of them into the raft. The second mate told him to put over the liferaft's ladder. The AB found the ladder at the other end of the enclosed liferaft and instructed the four persons in the water to go to the other end using the lifeline around the outside of the liferaft; however, none of the persons in the water was able to get into the liferaft. The AB was the only survivor of the five and testified as follows:

> So, after I told him to go on over there. I had to repeat that at least five times, to follow the line around to the other side of the raft, and there's a ladder over there. What the ladder consisted of was, I guess what we call a cargo net. We went over there, and again one of the guys, he grabbed ahold of that, and the other two guys had the life line on one side, and the second mate came around the other side, and

I was trying to get the second mate in, and even with him, with that ladder, we couldn't get it in. He couldn't grab on top. The ladder was flush against the raft, the top of there, and you couldn't reach down and get your hands into anything. I even tried to — I squashed the net up a little bit, and they had a little flap there. I tried to put his hand into there so he could hold onto that and I grabbed something else. And we tried for a long time to get him in. I told him to get a foot hold, see if he could get a foot hold on the ladder. He said he couldn't do it, there wasn't one, or whatever. And so he was really coherent. I was trying to get him in first because he was the most coherent, and he could help me get the other guys in.

Finally we tried every way we could, and I was pulling. Of course, we was all freezing. You know, our hands aren't all that good. It was cold.

And then he put his legs up there, tried to get in that way, and after awhile I had him up to his knees. His knees were on top of the raft and his head was in the water down that way, and I was losing him. That way he was falling asleep and drifting off.

* * * *

So, after I couldn't get them in, and they all — the second mate, he was the first one to drift away. I guess he was struggling. And then after that I went to try to look for something; kept on looking for something to help them with, and then they all started drifting away one by one. Towards the end one of the guys that was hanging onto the ladder, that's when he tried the hardest, and he didn't last too long after that. They would just drift away.

And then I was in the raft. So I just sat back and turned off my dollar and twenty-nine cent flashlight and just waited until I heard the helicopters come, and that's the only noise I heard, you know, after I lost these four guys.

The third survivor, the chief mate, swam away from the ship and came upon the port lifeboat, which was flooded with water up to the bottom of the thwarts (seats), and climbed into the lifeboat. The lifeboat was holed but remained afloat supported by the buoyancy tanks. The chief mate testified as follows:

It was freezing cold up in the air. The sea come over and tried to wash me off. I had a good grip of the brace that holds the part to the side of the lifeboat, so I got back down underneath the water and stayed under there till daylight came.

I kept kicking and thrashing around to keep the circulation. All the time I kept looking out and yelling out, "lifeboat here, come here, lifeboat here," just continued yelling out to keep myself going and maybe someone was there that could come over and I could have helped them. I could have dragged them in very easily, because the boat was only a few inches out of the water. Then I waited and prayed for daylight to come. I never in my life — it must have been another couple of hours until daylight finally came.

When the the first helicopter arrived onscene about 0520, the pilot saw "a great number of lights in the water" one empty liferaft, and another liferaft containing the AB. The pilot lowered a survival basket, which the AB climbed into, and the basket was hoisted into the helicopter. Next, the pilot saw "a group of people in the water" but only one person, the 8 to 12 third mate, was able to climb into the rescue basket. At 0610, the Navy helicopter arrived and lowered a rescue swimmer near the persons in the water. The rescue swimmer placed three persons into the USCG rescue basket, but all three persons were found to be dead when they were hoisted into the helicopter. Shortly afterward, the rescue swimmer began to show signs of hypothermia, and the pilot of the USCG helicopter hoisted him from the water. Other persons in the water were floating face down and showed no signs of life. Meanwhile, the master of the BARRANGER had maneuvered his ship alongside the lifeboat containing the chief mate and had lowered a ladder and net over the side. Crewmen from the BARRANGER climbed down the ladder and net in an attempt to rescue the chief mate but the sea was too rough. USCG helicopter 1471, which had the two other survivors aboard, was called to assist. The helicopter lowered its rescue basket, hoisted the chief mate to the helicopter, and then departed the scene with the three survivors aboard for Salisbury, Maryland. The Navy helicopter departed the scene at 0700.

The POINT HIGHLAND arrived onscene at 0558; the second USCG helicopter at 0623; two U.S. Navy vessels, the frigate USS JACK WILLIAMS, and the replenishment ship USS SEATTLE at 0850; the USCG cutter CHEROKEE at 0926; and the USCG cutter POINT ARENA at 1115. After picking up two bodies, the second USCG helicopter departed the scene at 0817 for Salisbury. The POINT HIGHLAND recovered 16 bodies, and the CHEROKEE recovered 3 bodies. At 1240, the POINT HIGHLAND departed the scene with all 19 bodies aboard and arrived at Chincoteague at 1603. At 1556, the BARRANGER was released from the search and another USCG helicopter arrived on scene. At 1656, the CHEROKEE recovered the MARINE ELECTRIC's port lifeboat, which had contained the chief mate, and deliberately sank the two liferafts. The TROPIC SUN was released at 1739. At 1741, the last USCG helicopter departed the scene, and the USS JACK WILLIAMS and USS SEATTLE were released by the USCG. The POINT ARENA however continued searching for survivors throughout the night until 0400 on February 13. On February 13, a final helicopter search was conducted between 0924 and 1130. The active search was suspended at 1737 when the CHEROKEE departed the scene. Four USCG and U.S. Navy aircraft spent 11.9 hours searching the scene, and USCG, U.S. Navy, and Merchant vessels spent 93 hours searching the scene. The air search extended for a period of 2 days and comprised a total of 28 hours flying time. Seven persons are missing and presumed dead; they are the master, the first assistant engineer, the second assistant engineer, the two third assistant engineers, the engine cadet, and one engineman. There is speculation that some crewmembers may have been trapped in the engineroom when the vessel capsized. On February 16, USCG divers located the hull and tapped on it. It was later determined that they had dove on the bow section when the stern section was located by side scan sonar.

The USCG chief of search and rescue operations for this mission testified that the time between the receipt of the first distress call at 0251 at USCG station Ocean City and RCC Portsmouth being notified at 0310 was spent in determining the MARINE ELECTRIC's actual position. He also testified that the USCG guideline for launching the ready helicopter which is 30 minutes, was exceeded in this case, because the pilot of the first helicopter to depart for the accident scene had to evaluate the severe onscene weather before taking off. When questioned concerning the response time, the pilot stated that he had talked with U.S. Navy weather personnel for some time and that he had ordered the emergency pumps (which normally are carried on the aircraft) removed to allow for additional space for survivors. He also testified that, while he was on scene, he did not detect any EPIRB signals.

Tests and Research

Stability.--The USCG Marine Technical and Hazardous Materials Division in Washington, D.C. performed intact and damage stability calculations 13/ to determine the MARINE ELECTRIC's intact stability when it departed Norfolk, Virginia, on February 10, 1983, and to investigate certain assumed flooding conditions on February 12, 1983. The intact stability calculations showed that the MARINE ELECTRIC departed Norfolk with a GM of 3.5 feet and a positive stability of up to 73° of heel assuming no flooding and that a 40-knot beam wind would have resulted in a 0.5° heel. The USCG required minimum GM is 0.4 foot. For calculating the MARINE ELECTRIC'S intact condition, the depth of the ship at the bow was assumed to be 55.5 feet. To determine the righting moment at any given angle of heel, the righting arm 14/ was multiplied by the displacement of the vessel, or 32,500 long tons. The ship's estimated natural roll period was 13 seconds. (See tables I and II.)

Table I.--Assumed flooding cases.

Case No.	Assumed Flooding	Approximate Bow Freeboard (feet)	Approximate Bow Trim Angle (degree)	Approximate Starboard Heel Angle (degree)
1	Intact	21	0	0
2	Forward dry cargo, stores & chain locker	20	0.2	0
3	All forward spaces except pumproom and forepeak tank	16	0.8	0
4	All forward spaces except pumproom	13	1.2	0
5	Cargo hold No. 1, and forward dry cargo and stores, chain locker and deep tanks	7	2.0	0
6	Cargo hold No. 1, and all forward spaces except pumproom	4	2.4	0
7	Cargo holds Nos. 1, and 2 and all forward spaces except pumproom		ship will capsize	
8	Cargo hold No. 1	16	0.7	0

13/ "Technical Investigation of Stability and Strength Characteristics of the SS MARINE ELECTRIC" October 18, 1983.

14/ The righting arm is a measure of the ship's ability to right itself over a range of heel angles.

Table I.--Assumed flooding cases. (continued)

Case No.	Assumed Flooding	Approximate Bow Freeboard (feet)	Approximate Bow Trim Angle (degree)	Approximate Starboard Heel Angle (degree)
9	Cargo hold No. 2	16	0.5	0
10	Cargo holds Nos. 1 and 2	10	1.4	0
11	Starboard wing tank No. 1	20	0.1	2.0
12	Starboard wing tank No. 2	20	0.1	4.5
13	Starboard wing tanks Nos. 1 and 2	19	0.2	6.0
14	Cargo hold No. 1 and No. 1 wing tanks port and starboard	14	1.0	0
15	Cargo hold No. 1 and starboard wing tanks Nos. 1	15	0.8	2.3
16	Cargo holds Nos. 1 and 2 and starboard wing tank No. 2	8	1.6	4.4
17	Cargo holds Nos. 1 and 2 and wing tanks Nos. 1 and 2 port and starboard	2	2.3	0
18	Cargo hold No. 2 and No. 2 wing tanks, port and starboard	14	0.8	0
19	Cargo hold No. 2 and No. 2 starboard wing tank	15	0.7	4.6

Table I.--Assumed flooding cases. (continued)

Case No.	Assumed Flooding	Approximate Bow Freeboard (feet)	Approximate Bow Trim Angle (degree)	Approximate Starboard Heel Angle (degree)
20	All forward spaces except forepeak and pumproom	11	1.4	0
21	Cargo hold No. 1 and all forward spaces except forepeak and pumproom	5	2.3	0
22	Cargo holds Nos. 1 and 2 and all forward spaces except forepeak and pumproom	-13 (under water)	4.6	0

To perform the damage stability calculation, the USCG considered 21 cases of assumed flooding. (See tables I and II.) The cases were examined to provide logical combinations of assumed flooding which analytically represented the lists and trims observed by the eyewitnesses. The forward pumproom was not included because it was not common with the shell plating. Cases 2 through 19 represent hull damage and cases 20 to 22 represent flooding through the hatch covers. Permeabilities 15/ of 0.98 and 0.95 were assumed for ballast tanks and the compartments forward of the collision bulkhead, respectively. The permeability of the holds laded with coal was determined by laboratory tests conducted by Commercial Testing and Engineering Co. using coal similar to that transported by the MARINE ELECTRIC. The permeability of the hold was determined to be 0.38 and the angle of repose of the coal was 25°. 16/

Table II.--Righting arm after flooding.

Case No.	Maximum Right Arm (feet)	Maximum Righting Arm Range (degree)
1	2.0	73
2	1.8	65
3	1.7	64

15/ Permeability is the amount of space that can be flooded within a compartment or tank. The factor is less than 1.00 to the extent nonpermeable fixtures or materials are present in the compartment or tank.

16/ Angle of repose is the angle between the horizontal plane and the cone slope of the bulk cargo when it is emptied onto this plane. As the angle of repose is exceeded a bulk cargo will begin to shift.

Table II.--Righting arm after flooding. (continued)

Case No.	Maximum Right Arm (feet)	Maximum Righting Arm Range (degree)
4	1.6	64
5	1.1	52
6	0.9	50
7	ship will capsize	
8	1.8	71
9	1.7	69
10	1.4	62
11	1.9	73
12	1.7	73
13	1.4	72
14	1.7	71
15	1.5	70
16	0.8	54
17	0.8	52
18	1.6	70
19	1.2	67
20	1.7	62
21	0.8	47
22	0.1	17

Structural Strength.--The USCG Marine Technical and Hazardous Materials Division in Washington, D.C., also performed structural calculations 17/ to determine the longitudinal strength of the MARINE ELECTRIC, the bending moments, and shear forces experienced on February 11 and 12, 1983, and the strength of the No. 1 cargo hold hatch cover. The longitudinal strength calculations were based on an averaging of the plate gaugings conducted by Southeastern Marine Chemists, Inc. in 1981, and on the original scantlings prescribed by the 1961 Bremer Vulkan T2-SE-A1 Reconstruction Midship Section Plans. (See table III.)

Table III.--MARINE ELECTRIC section modulus*/ comparison table.

	1961 Design Scantlings in^2/-ft	1981 Gauged Scantlings in^2/-ft	1982 ABS Rule Scantlings in^2/-ft
Deck	63,340	58,300	54,260
Bottom	75,090	68,140	54,260

* Section modulus is mathematically defined as the moment of inertia of a ship's midship section about its neutral axis divided by the distance from the neutral axis to the upper deck or bottom plating. The larger the section modulus for a given bending moment, the lower the stresses in the upper deck or bottom plating.

Before the plate and stiffener renewals, the 1981 gaugings showed a 1 to 12 percent wastage throughout the main deck, a 15 to 23 percent wastage of double bottom plating, a

17/ Op. cit p. 25.

1 to 19 percent wastage of plating near the load line, a 5 to 46 percent wastage of under deck longitudinals, a 5 to 23 percent wastage of side longitudinals in hold No. 3, and 9 to 48 percent wastage in the upper ballast tank plating in all holds.

The resultant still water bending moments and stresses for the MARINE ELECTRIC as loaded on February 12, 1983 and based on the February 1981 gaugings were compared to the ABS required values. (See table IV.)

Table IV.--MARINE ELECTRIC still water bending moments and stresses.

	Calculated Values	ABS Maximum Allowable
Bending moment (foot-tons) (sag)	119,200	229,000
Bending stress (psi) (deck)	4,900	*
Shear force (tons) (station 16)	1,090	1,920
Shear stress (psi) (at neutral axis)	3,240	*

*These values are not directly calculable from the ABS rules.

Assuming 15-foot significant waves and a ship speed of 10 knots, or 20-foot significant waves and a ship speed of 8 knots, the approximate loading condition of February 12 head seas, and the 1981 gauged scantlings, the combined calculated still water, wave-induced, hydrostatic and dynamic bending moments and stresses were compared to ABS allowable values. (See table V.) There is no significant difference in these values for slower speeds.

Table V.--MARINE ELECTRIC dynamic bending moments and stresses.

	Calculated Values		ABS Maximum Allowable
	15 ft wave height 10 knots	20 ft wave height 8 knots	
Bending Moment (foot-tons) (sag)	260,700	302,900	560,000
Bending Stress (psi) (bottom)	18,000	19,900	23,100
Shear force (tons) (station 4)	1,900	2,130	3,360
Shear stress (psi) (at neutral axis)	5,650	6,330	15,120

Assuming 20-foot significant waves, a ship speed of 3 knots, and the spaces forward of the collision bulkhead flooded, except for the forepeak and pumproom, the combined calculated still water, wave induced, hydrostatic and dynamic bending moments, and stresses were compared to ABS allowable values. (See table VI.)

Table VI.--MARINE ELECTRIC dynamic bending moments and stresses—after flooding.

	Calculated Values	ABS Maximum Allowable
Bending Moment (ft-tons) (hog)	219,700	560,000
Bending Stress (psi) (bottom)	10,400	23,100
Shear Force (tons) (station 4)	1,680	3,360
Shear Stress (psi) (at neutral axis)	5,000	15,120

The strength of the No. 1 hatch cover of the MARINE ELECTRIC was analyzed using the Graphics-oriented Interactive Finite Element Timesharing System (GIFTS), a general purpose structural finite element program. To determine the effect wastage would have on the strength of the MARINE ELECTRIC's hatch covers, the original scantlings were considered uniformly reduced by 50 percent for a 50 percent wastage case and by 75 percent for a 75 percent wastage case. Results of the analysis indicated that yielding of the hatch cover stiffeners would occur under a static head of water of about 8 feet using the original scantlings, 4 feet assuming 50 percent wastage, and 2 feet assuming 75 percent wastage.

The failure mode of the No. 1 cargo hatch cover and the main deck dry stores hatch cover were analyzed using the theory of plasticity. 18/ The type of structural steels used in the construction of the hatch covers approached the properties of a perfectly plastic material. The analysis for the No. 1 cargo hatch cover indicated that ultimate failure of the plating would occur at static pressure heads of about 29 feet, 8 feet, and 2 feet of water for the as-designed, 50 percent wastage, and 75 percent wastage cases, respectively. The analysis for the dry stores hatch cover indicated that the ultimate failure of the plating would occur at pressure heads of about 43 feet, 11 feet, and 3 feet of water for the as-designed, 50 percent wastage, and 75 percent wastage cases, respectively. All of the analyses were made using an evenly distributed static load. The report stated that to account for dynamic loading due to the waves breaking on the deck, the pressure head necessary to cause a member to yield or fail, in a particular case, should be reduced by one-half. For example, the dynamic load that would cause failure of the No. 1 cargo hatchcover in the as-designed condition using the beam-strip analogy would be 14.5 feet of water.

Wreckage Surveys.—On February 15, 16, and 17, 1983, a USCG inspector conducted an inspection of the MARINE ELECTRIC's lifeboat, which was recovered and brought to Norfolk by the USCG Cutter CHEROKEE after the accident. The information on the builder's plate indicated it was the port lifeboat manufactured by Marine Safety Equipment Corp. in 1966. The inspector noted that the lifeboat had suffered extensive damage, that the mechanical releasing gear had not been tripped, and that the safety pin on the releasing gear was still in place. The preventer bars which controls the falls from prematurely releasing from the gear hooks failed on both ends, allowing the lifeboat to float free. The inspector noted that the forward preventer bar had been damaged during transfer of the lifeboat ashore but the after preventer bar was weak and appeared to have been in that condition for an extended period of time.

From February 21 to 24, 1983, divers contracted by MTL conducted an underwater diving survey of the wreck of the MARINE ELECTRIC. A qualified USCG diver was onboard the diving platform to observe the diving operations. Adverse weather conditions and limited visibility prevented the divers from conducting a complete survey of the wreck. However, divers found the wreck was in two pieces and that the forward section was inverted and listing 15° to its starboard side so that the port rail was 2 to 3 feet off the ocean bottom. A 12- to 14-foot depression was found in the sand under the forward section at the bow. A diver, who swam under the hull to the dry cargo hatch, reported that: the main deck hatch cover was not in place, two dogs were intact, two dogs had sheared off, and there was no trace of the hatch cover. The diver also located the puncture made in the No. 1 upper port wing tank on February 2, 1983, and determined by inserting a length of rod into the hole that the cement box was not in place. The port anchor was housed in the hawse pipe. The bulkwark plate on the bow was torn back about 8 feet.

18/ A theory that assumes yielding of a material under constant stress after it reaches the proportional limit, i.e., the upper limit at which elongation remains proportional to stress.

About 38 feet aft of the bow, divers found a crack in the bottom of the hull at the forward end of the deep tanks. The open crack ran from the turn of the bilge on the port side, across the flat side of the bottom, and up into the starboard side. Across the 12-foot flat side of the bottom of the hull, the opening was about 1 foot wide with the shell plating bent inward for about 1 foot fore and aft of the opening. One diver said that the forward edge of the opening in the flat side of the bottom of the hull had broken in the heat-affected zone adjacent to a transverse weld (which was later corroborated by photographs) and that he could see bent stiffeners inside the opening. The opening continued through the turn of the bilge and ended about 2 feet up the port side. On the starboard side, the opening was about 2 feet wide with ragged edges and continued upward for about 6 feet before opening into a larger hole. The diver was unable to determine the dimensions of the large hole.

Between March 20 and July 19, 1983, MTL also conducted extensive diving and remotely controlled videocamera surveys of the wreck in four phases, the last three of which were witnessed by a Safety Board investigator. Phase 1, conducted between May 12 and May 14, consisted of a sonar survey of the wreck. The sonar survey showed that the MARINE ELECTRIC was lying upsidedown in two sections on a heading of about 040° T. (See figure 5.) The two sections of the wreck were nearly aligned, with the bow section about 225 feet long with its port side about 30° off the ocean floor, and the stern section about 140 feet long with its port side about 40° off the ocean floor. A midship section about 240 feet long was missing.

During phase 2, conducted between May 24 and May 29, a camera equipped remotely-operated, unmanned underwater vehicle was used to make a videotape of the wreck. Divers were also employed to take still photographs and to examine the wreck. The videotape showed that the starboard anchor was missing and that there was a large hole measuring about 40 feet long and 40 feet high on the starboard bow. The hole extended from just forward of the collision bulkhead into the forepeak tank and from the keel to the main deck. The videotape also showed: several sharp punctures in the starboard shell plating aft and above the level of the starboard hawsepipe; a crack in the stem at the 21-foot draft mark and below this level that the stem was bent about 10° to starboard; large cracks in the shell plating on the port side near the 21-foot draft mark; and some smaller fractures near the keel. The port anchor was in place with the devil's claw engaged. The starboard devil's claw was hanging down into the sand, and an unknown length of chain was found hanging down from the starboard riding chock. The shell plating at the No. 1 hold was intact and there were no signs of grounding damage on the bow section. A fairly clean fracture was found around the entire girth of the vessel near the after end of No. 2 hold; however, the starboard side plating could not be observed because only 4.5 feet of starboard side plating above the bilge keel was visible. (See figure 5.) A videotape was made of the entire fracture in the No. 2 hold. No shell plating remained between the aft end of the No. 2 cargo hold and the aft end of the No. 5 cargo hold; however, there was debris. Two sections were thought to still be attached by the starboard main deck plating buried in the sand since a metal detector indicated metal buried in the sand between the two sections. A jagged and irregular break was found at the after end of the No. 5 cargo hold. The break extended into both the aft pumproom and the No. 5 cargo hold with part of the aft No. 5 cargo hold bulkhead remaining. The stern shell plating was intact.

Phase 3, conducted between June 6 and June 13, consisted of a sonar and magnetometer search around the wreck and along known and projected tracklines of the MARINE ELECTRIC. On June 9, the missing 240-foot midship section was found 1,800

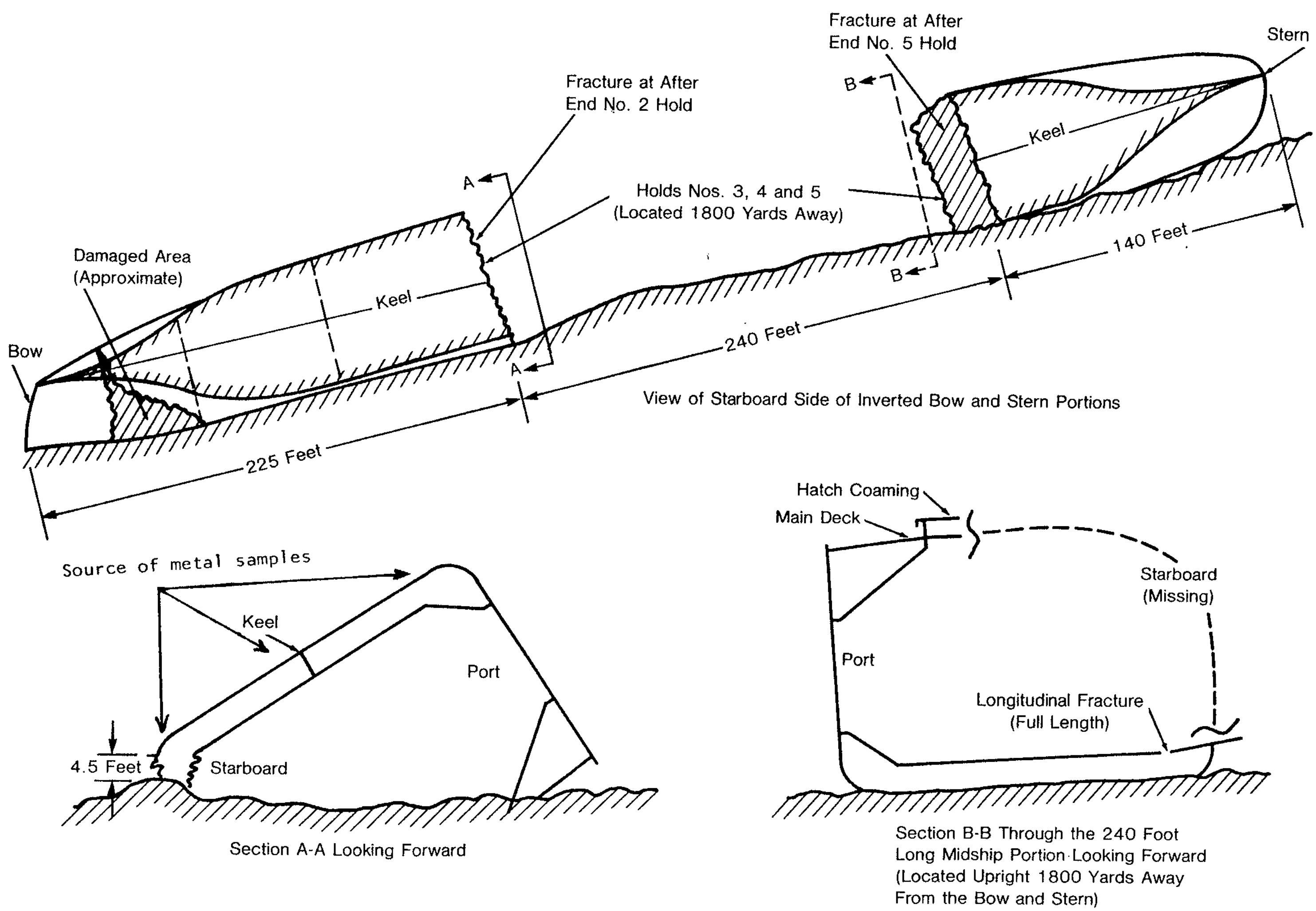

Figure 5.--MARINE ELECTRIC wreckage on ocean floor.

yards at a bearing of 205° T from the main wreck. (See figure 6.) The midship section was upright on a heading of 280° T with the portside intact and the starboard side missing. The starboard anchor was not found, but the starboard devil's claw was removed intact from the bow section, except for the tip of one claw which had broken off. The devil's claw turnbuckle was nearly unscrewed with only a couple of threads showing on the claw end; the threads on the other end were only partially screwed into the turnbuckle. The starboard chain could not be removed because of equipment problems, but four links of chain (later found not to belong to the MARINE ELECTRIC) were recovered from the sand near the stern section.

During phase 4, conducted between June 20 and June 26, a camera equipped remotely-operated, unmanned, underwater vehicle again was used to make a videotape of the wreck. The midship section with cargos holds Nos. 3, 4, and 5 was surveyed. The port side was intact from the ocean floor to about one-third the way across the main deck. The rest of the main deck and the starboard side plating down to the intersection with the starboard lower wing tank were missing. The break on the main deck extended almost parallel to the centerline of the ship. However, at the after end of the No. 5 cargo hold, only a few feet of transverse hatch coaming remained in place while at the forward end of the No. 3 cargo hold, the hatch coaming remaining in place had increased to about 18 feet. The ends of the hatch coamings and deck plating between the hatch opening were twisted and torn. The transverse bulkheads between cargo holds Nos. 2 and 3 and Nos. 3 and 4 were missing, while the bulkheads between holds No. 4 and 5 and No. 5 and the pumproom were partially in place with the port ballast piping and the centerline bilge system manifold attached to the aft bulkhead of the No. 5 hold. A longitudinal gash between 1 and 4 feet wide extended the entire length of the inner bottom plating near the intersection of the lower starboard wing tank inclined plating and horizontal inner bottom plating. Also, the sloping bulkhead was found laying flat on the ocean floor. Debris, including a transverse bulkhead from the midship section, was found between the bow and stern sections and the midship section. A length of chain, consisting of 17 links, was recovered from the starboard side of the bow section by cutting the chain on the forward side of the chain stopper. The port ballast valve manifold was recovered but the starboard ballast manifold was not found. The valves in the port ballast manifold were closed, except for the suction valves to the Nos. 3, 4, and 5 port ballast wing tanks. About 10 hatch covers panels, most of which were inverted and showed little damage, were seen but none were recovered.

During the same period that MTL was conducting surveys, a diver employed by the Master, Mates and Pilots Union made 38 dives on the MARINE ELECTRIC wreck. Although his survey was not as extensive as the MTL survey, his testimony and pictures confirmed the MTL diver's observations. There were no observers present during these dives.

From September 6 to September 10, 1983, the Safety Board and the USCG conducted a diving expedition on the MARINE ELECTRIC to retrieve steel samples from the fracture at the after end of the No. 2 cargo hold. The expedition included a Safety Board investigator and a metallurgist and a representative from MTL. Three pieces of bottom plating were retrieved: one from the starboard side just below the bilge keel, one from the port side just above the bilge keel, and one from the starboard side adjacent to the keel plating. The sampling areas were selected based by a consensus of Safety Board and Parties-In-Interest metallurgists as the area most likely to provide the most information. Specific plates were selected by viewing the videotapes of wreckage and choosing plates which could be identified with certainty.

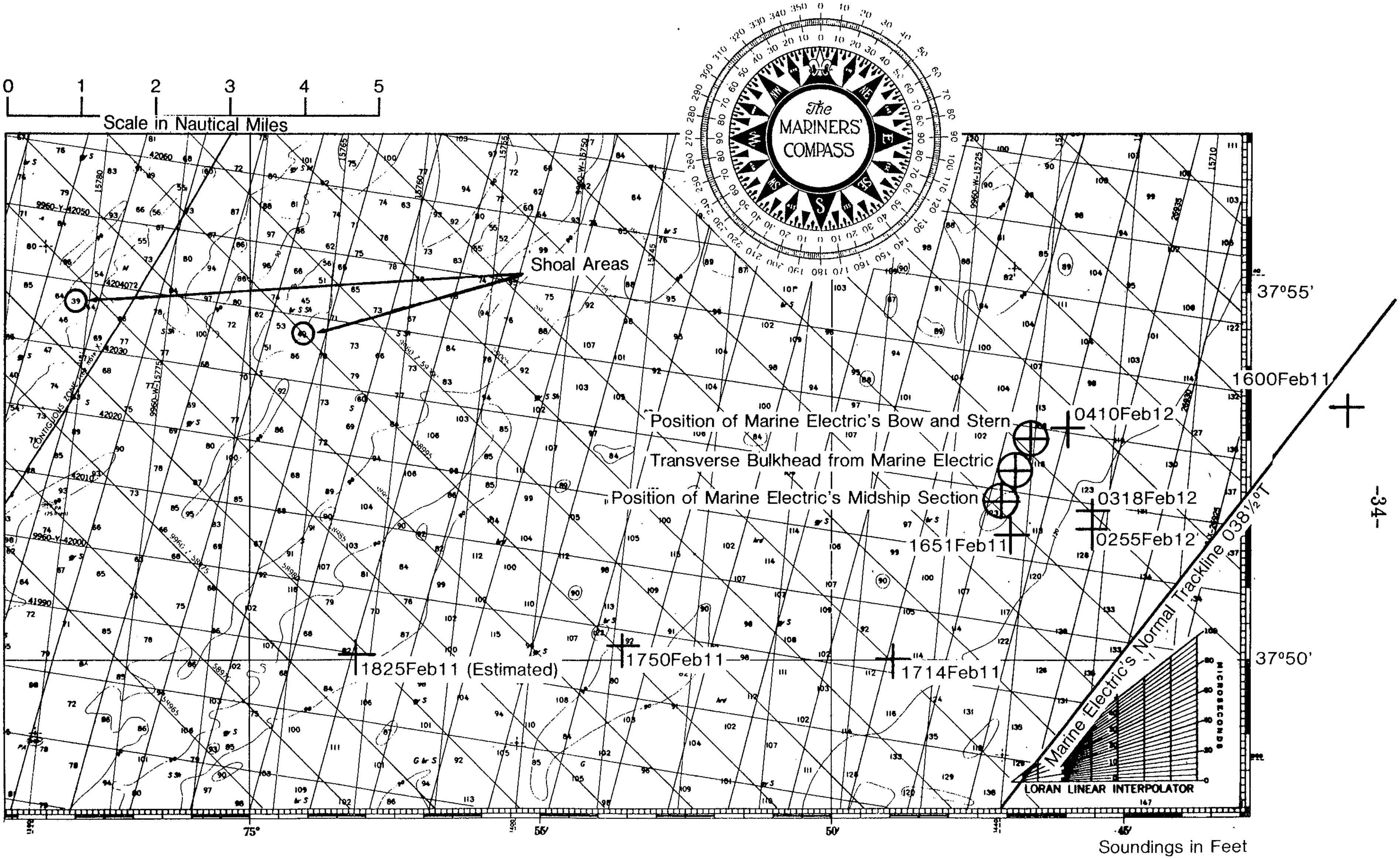

Figure 6.--Section of NOAA Chart 12211, dated July 17, 1982, indicating the MARINE ELECTRIC's position on February 11 and 12, 1983.

Metallurgical Tests and Studies

Samples of the recovered shell plating were brought to the Safety Board's laboratory in Washington, D.C., for evaluation and test preparation. Portions were cut from the steel plate, were identified and photographed, and then were forwarded to the testing laboratories of the National Bureau of Standards (NBS) Fracture and Deformation Division. Test specimens were machined by the NBS Fabrication Technology Division, and Charpy V-notch impact tests, tensile tests, and a chemical analysis then were performed.

The Charpy V-notch test specimens were taken from the metal sample retrieved from the plate next to the keel plating on the starboard side. One tensile specimen was taken from an area next to that from which the Charpy specimens were machined. A second tensile specimen was taken from the outboard end of the same sample. The two tensile specimens were machined in accordance with the American Society for Testing Materials (ASTM) Standard E8-81 for standard 0.500-inch-round tension test specimens with a 2-inch gauge length. Specimens were tested on a Satec Systems, 25,000-kg capacity tensile testing machine. An LVDT extensometer was attached to each specimen during the initial part of the test to record strain. Cross head speed was maintained at 0.02 inch per minute while the extensometer was attached. The speed was increased to 0.06 inch per minute after the extensometer was removed. The results of the tensile tests are given in table VII. The Charpy V-notch impact specimens were machined in accordance with ASTM Standard E23-82. Tests were run on a 264-foot-pound capacity Tinius-Olsen impact testing machine over a temperature range from -35 to +365° F. The results of the impact tests are given in table VIII. The data are listed in the order of increasing temperature. The ductile/brittle transition curve based on the impact test results is shown in figure 7.

Table VII.—Results of Tension Tests.

Specimen	Tensile Strength1/ (psi)	Yield Strength2/ 0.2% Offset, psi	Elongation3/ % in 2 inches	Reduction of Area, %
1	65,500	48,000	33.0	66.6
2	66,500	40,700	35.2	67.0

1/ Values given to the nearest 500 psi in accordance with ASTM Standard E8-82.
2/ Values given to the nearest 100 psi in accordance with ASTM Standard E8-82.
3/ Values given to the nearest 0.2 percent in accordance with ASTM Standard E8-82.

Table VIII.—Results of Charpy V-Notch Impact Tests.

Specimen	Temperature °F	Energy Absorbed (Foot-pounds)	Specimen	Temperature °F	Energy Absorbed (Foot-pounds)
28	-35	4.0	19	110	86.0
2	0	3.5	20	120	71.0
5	10	4.5	21	120	81.0
7	20	5.0	22	130	67.0
11	40	8.5	23	130	71.0
27	40	9.0	14	140	83.5
13	50	23.5	15	140	88.0
1	60	16.0	6	150	106.0

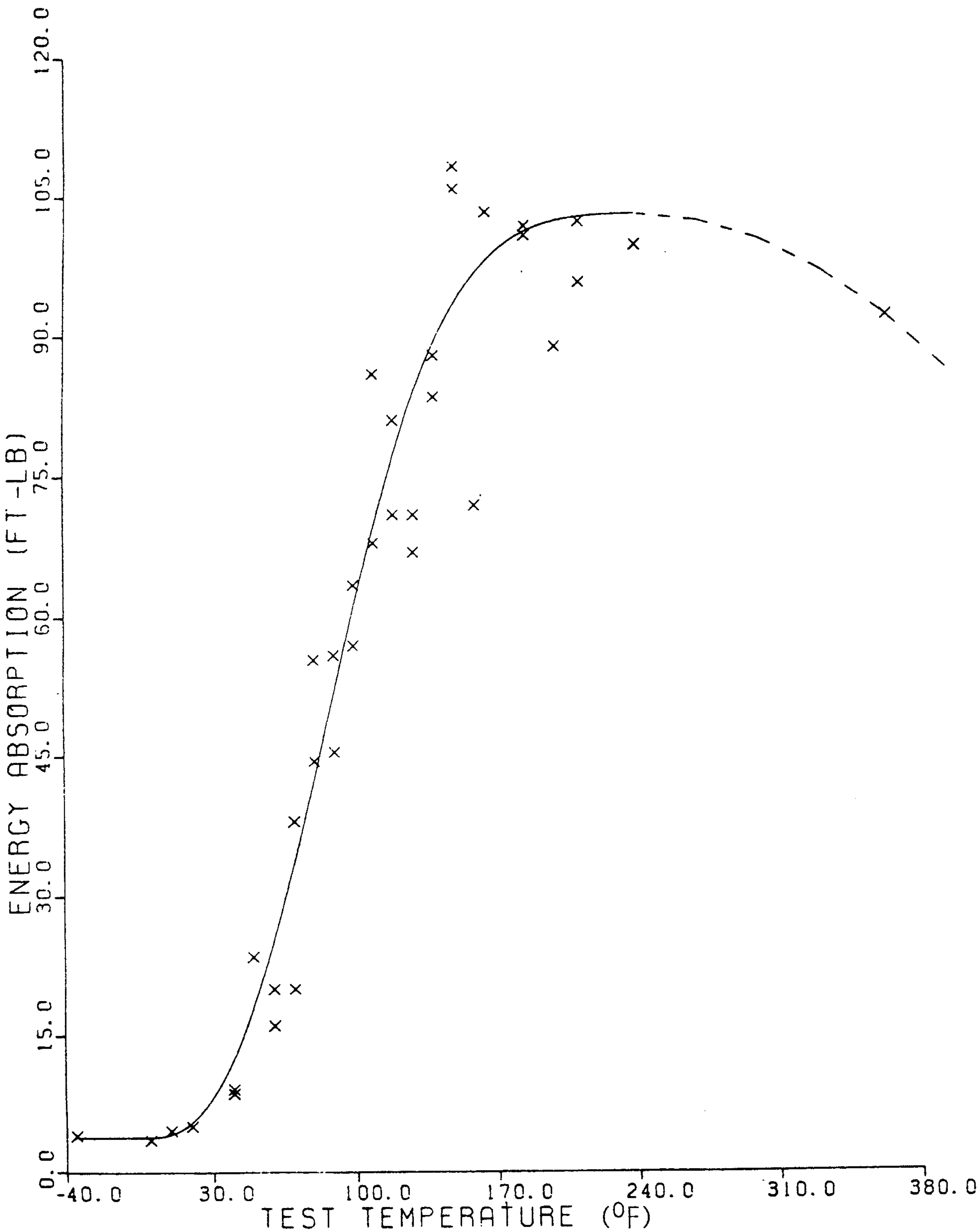

Figure 7.—Charp V-notch transition curve.

Table VIII.—Results of Charpy V-Notch Impact Tests. (Continued)

Specimen	Temperature °F	Energy Absorbed (Foot-pounds)	Specimen	Temperature °F	Energy Absorbed (Foot-pounds)
4	60	20.0	9	150	108.5
3	70	20.0	34	160	72.0
31	70	38.0	12	166	103.5
32	80	44.5	16	185	102.0
33	80	55.5	17	185	101.0
29	90	56.0	35	200	89.0
30	90	45.5	8	212	96.0
25	100	57.0	10	212	102.5
26	100	63.5	36	240	100.0
18	110	68.0	24	365	92.5

A specimen from the inboard end of the plate sample from the starboard side next to the keel plate was analyzed for chemical composition by a commercial laboratory. The sample was analyzed spectrographically for the nine standard elements in low alloy steel. In addition, a tramp element survey was performed to determine the presence of any elements not included in the initial nine element analysis. The results of the chemical analysis are given in table IX.

Table IX.—Results of Chemical Analysis.

Element	Percent by weight
Carbon	0.019
Manganese	0.097
Phosphorus	0.012
Sulfur	0.019
Silicon	0.004
Nickel	0.002
Chromium	0.003
Molybdenum	0.001
Copper	0.005
Tramp element survey (amounts are approximate)	
Aluminum	0.007
Vanadium	0.005 (trace)
Titanium	0.005 (trace)
Tin	0.006
Cobalt	0.008

The results of the NBS tests were forwarded for study and evaluation to the EMTEC Corporation in Oklahoma, a consultant firm engaged by the Safety Board for the Marine Board of Investigation. In addition to providing technical assistance, EMTEC also visually examined the pieces of wreckage and conducted crack-tip opening displacement tests (CTOD) on selected specimens. All results of the testing of the steel plate specimens from the MARINE ELECTRIC indicate that the subject material met the mechanical and chemical requirements set forth in the applicable 1961 American Bureau of Shipping "Rules for the Classification and Construction of Steel Vessels" for class B structural steel. The 1983 ABS rules require Charpy V-notch testing, with an average minimum energy absorbtion of 20 foot-pounds at 32° F. Charpy V-notch tests performed by the National Bureau of Standards revealed that the shell plating had an energy absorption of less than 10 foot-pounds at 32° F. This low value by itself does not necessarily indicate that the steel plate used in the construction of the cargo midbody in 1961 was unsafe. In fact, the deformation in the shell plating in the fractured area at the after end of No. 2 cargo hold indicates that brittle failure was not the cause of the separation of the area in question.

The fracture surfaces were visually examined to determine a possible fracture initiation site. The fractures of each piece of wreckage were examined to determine the direction and type of crack. The examinations indicated that the plating tested may not have been a primary point of fracture initiation.

The fracture-toughness crack-tip opening displacement test conducted by EMTECH indicated that the critical crack size 19/ of the metal tested was 2.5 inches for dynamic loading and 40 inches for slow loading at a temperature of +40° F with a nominal stress level of 20,000 psi.

The piece retrieved from the starboard side just below the bilge keel contained approximately 4 feet of fracture. The aft point of the piece had been deformed inward approximately 90°. Examination of the fracture surfaces on the piece revealed a chevron pattern which indicated that the fracture progressed from starboard to port in this area. Measurement of the plate thickness on the piece gave values ranging from 0.794 to 0.803 inch in most areas. The design thickness of the plate was 0.85 inch.

An examination of the fracture and crack surfaces on the piece retrieved from the starboard side adjacent to the keel plating revealed features which indicated that the predominant direction of cracking in most areas was from the outside of the plate to the inside. This fact and the large amount of deformation found on this piece are consistent with a bending overstress separation for this portion of the hull plate. The thickness was measured in 16 places. The results ranged from a low of 0.7 inch to a high of 0.882 inch. Generally, the lower measured values were recorded from areas which were more heavily pitted. The design thickness of this plate was 0.91 inch.

The piece retrieved from the port side just above the bilge keel was nearly flat. An examination of the piece revealed that approximately one-third of the fracture surface was heavily damaged by postfracture mechanical smearing. One area of the fracture contained a series of three raised metal lips, indicating repeated contact in the area. The unsmeared portion of the break contained features typical of an overstress separation which progressed downward along the side of the ship. Crack branching adjacent to the fracture on the inside of the plate and what appeared to be compression bulging on the outside of the plate indicated that bending forces also played a major role in the separation through this section of the hull. The thickness of this piece was measured at several locations. Measurements ranged from 0.842 to 0.872 inch.

Other Information

U.S. Coast Guard Structural Inspections.--USCG regulations contained in 46 CFR Subchapter I--Cargo and Miscellaneous Vessels state that the biennial inspection for certification shall include an inspection of the structure and that the standards

19/ The maximum crack size that metal could sustain before brittle fracturing occurs.

established by the ABS concerning material and construction of hulls shall be accepted as standards by USCG inspectors except where otherwise provided for in the regulations. In the process of initial certification the USCG accepts as satisfactory structural plans approved by ABS, including those for hatch coamings and covers on weather and watertight decks. Guidance for the inspection of the structure of steel vessels is contained in Volume II--Material Inspection of the Coast Guard's Marine Safety Manual and in Navigation and Vessel Inspection Circular 7-68, Notes on Inspection and Repair of Steel Hulls. Neither publication addresses steel cargo hatch covers directly.

At each biennial inspection for certification, the USCG inspectors are required to record their findings in a Hull Inspection Book (CG 840A) which outlines what equipment and structure should be inspected. Similarly, during a drydock inspection, the USCG inspectors are provided with a Drydock Examination Book (CG 840H) which outlines the structure and hull penetrations that should be inspected and gauged if necessary. Hatch covers are not specifically mentioned in either book. USCG Navigation and Vessel Inspection Circular No. 7-68 also states that local deterioration of steel plating of up to 25 percent may be accepted before replacement is necessary except for bottom plating where 20 percent is the maximum average reduction permitted.

Load Line Surveys.--USCG regulations contained in 46 CFR Subchapter E-Load Lines state that the ABS has been appointed as the prime assigning and issuing authority in the U.S. for the provisions of the 1966 International Loadline Convention. The assigning and issuing authority shall make an initial survey, periodical surveys not exceeding 5-year intervals, and annual surveys. (See appendix C.)

Title 46 CFR 42.15-25(d) states that mild steel pontoon hatch covers should be designed to withstand a load of 358 pounds per square foot if located forward of a point one-fourth of the registered length of the vessel aft of the forward perpendicular and those hatch covers located aft of such a point shall withstand a load of 266 pounds per square foot. The product of the maximum stress thus calculated and the factor 5 shall not exceed the minimum ultimate strength of the material. It also states that covers should be designed to limit deflection to not more than 0.0022 times the span and that the mild steel plating forming the tops of covers should be no less thick than 1 percent of the spacing of stiffeners, or 0.24 inch if that is greater.

American Bureau of Shipping Surveys.--The ABS Rules for Building and Classing Steel Vessels contain the survey and design standards. The rules are republished yearly and reflect changes approved by the ABS technical committees, which include industry and USCG technical experts. The 1961 rules which applied to the MARINE ELECTRIC's conversion did not include a special section for bulk carriers. They provided generally that the collision bulkhead was to be located not less than 0.05L abaft the stem at the load line where L is the distance in feet from the forward side of the stem to the after side of the rudder post at the summer load line. The present ABS rules require the collision bulkhead to be located between 0.05L and 0.08L aft of the stem.

An ABS representative testified that the 1981 ABS surveys conducted aboard the MARINE ELECTRIC were the same as for a newer vessel classed as a bulk carrier by ABS. (See appendix D.) At each special survey (4 to 5 years), steel hatch covers are required to be hose tested or otherwise proven tight. Each special survey becomes more stringent than the last until special survey No. 6 (24 to 30 years after construction). After special survey 6, all special surveys are to be at least as comprehensive as No. 6.

USCG Liferaft Standards.--The U.S. Coast Guard standards for inflatable liferafts (46 CFR 160.051-7(b)(1)) require that a boarding ladder, or equivalent, be provided at each entrance to the raft. In addition, hand holds, or equivalent, are to be provided on both sides of each entrance to assist persons in boarding.

Age of U.S. Flag Fleet.--Of the approximately 850 seagoing vessels in the U.S fleet, over 2,000 gross tons, 27 percent are laid up in the MARAD reserve fleet and are not operating. Of the operating fleet, about 50 percent are 20 years or older and about 28 percent are 30 years or older. The MARINE ELECTRIC was one of 63 existing U.S. vessels that was converted from the 536 U.S. Maritime Administration T-2 Design tankships that were built between 1942 and 1945. Fifteen unconverted T-2 tankships still remain in the U.S. fleet. T-2 tankships and T-2 conversions make up about 11 percent of the operating fleet.

USCG Bilge Piping Regulations.--The USCG marine engineering regulations which applied to the MARINE ELECTRIC regarding bilge piping systems state, in part:

> 46 CFR 56.50 Bilge and ballast piping.
>
> (a)(1) All vessels except unmanned barges shall be provided with a satisfactory bilge pumping plant capable of pumping from and draining any watertight compartment except for ballast, oil and water tanks which have acceptable means for filling and emptying independent of the bilge system. The bilge pumping system shall be capable of operation under all practicable conditions after a casualty whether the ship is upright or listed. For this purpose wing suctions will generally be necessary except in narrow compartments at the ends of the vessel where one suction may be sufficient. In compartments of unusual form, additional suctions may be required.

ANALYSIS

Capsizing

When the 8 to 12 third mate who survived the accident was relieved of the watch at 2345 on February 11, 1983, the MARINE ELECTRIC was hove to heading into 15- to 20-foot seas. At that time, the 8 to 12 third mate did not notice any trim by the bow, any flooding problems, or a starboard list. However, by 0300 on February 12, the ship had developed a 5° to 8° trim by the bow, and 6 or 7 feet of water was flooding the deck near the No. 1 hatch cover. Based on the survivors' testimony and USCG records, about 0350, the MARINE ELECTRIC developed a 5° starboard list which gradually increased until it capsized about 25 minutes later. Trim and stability calculations performed after the accident indicated that to develop a 5° to 8° trim by the bow would have required, at least, flooding the Nos. 1 and 2 cargo holds and most of the spaces forward of the collision bulkhead. A 5° starboard list would have required flooding both Nos. 1 and 2 starboard wing tanks. A 40-knot beam wind would have produced a list of about 0.5°. Flooding the No. 1 starboard wing ballast tank alone would have resulted in a 2.0° heel, and flooding Nos. 1 and 2 starboard wing tanks would have resulted in a 4.5° heel angle.

The 8 to 12 third mate should have been able to note a 1° to 2° port or starboard permanent list even though the ship may have been rolling since the bridge was equipped with a transverse inclinometer. However, a bow trim of up to 3° would not have been as apparent because of the pitching motion of the ship. All three survivors recall overhearing or being informed between 0300 and 0350, that Nos. 1 and 2 starboard ballast tanks were being pumped out. The Safety Board concludes that the engineers were pumping the Nos. 1 and 2 starboard wing tanks; however, it could not determine, based on the survivors' statements, that both tanks, in fact, had flooded. The 5° list at 0350 was probably the result of flooding of the Nos. 1 and 2 starboard wing tanks. As the bow went deeper into water, the MARINE ELECTRIC gradually lost stability, however, the asymmetrical flooding would only have increased the list rather than cause the ship to capsize. The sudden capsizing at 0415 probably was the result of the loss of all positive stability as the bow went deeper under water and not further asymmetrical flooding of the wing tanks.

Flooding

Based on the available evidence and testimony, the Safety Board could not determine the cause of the flooding in the MARINE ELECTRIC's forward compartments; however, there are several possible causes, including (1) grounding damage, (2) hatch cover failure, (3) damage caused by the anchor, and (4) hull structural failure. Each possible cause is discussed separately in the following paragraphs.

Grounding Damage.--From 1600 to 1825 on February 11, 1983, the MARINE ELECTRIC escorted the fishing vessel THEODORA toward Chincoteague, Virginia, while USCG helicopters lowered portable pumps to the THEODORA. Based on tape recorded conversations between the master of the MARINE ELECTRIC and the USCG, and the ship's course and speed from 1714 to 1750, the Safety Board estimated the 1825 position on February 11. (See figure 5.) The nearest shoal area where the water depth is 40 feet or less is about 5 miles from the 1825 position. The tape recordings indicate that the MARINE ELECTRIC maintained a course of 270°T until it was released from escorting the THEODORA at 1825 and resumed its voyage to Somerset, Massachusetts. There was no direct evidence of the MARINE ELECTRIC's course, speed, or position from 1825 to 1945 other than the master's radio transmission that he was "going back to his original course." However, when the 8 to 12 third mate relieved the watch about 1945, the ship was hove to on a course of 040° T and the distance traveled was only 1 1/2 to 2 nmi during his 4-hour watch. The next known position of the MARINE ELECTRIC was reported by the master in the 0255 distress call on February 12. Since the 0255 position is only 2 nmi north of 37° 50'N, the MARINE ELECTRIC's trackline between 1714 and 1825, and about 1.5 nmi west of the original trackline, the Safety Board believes the master of the MARINE ELECTRIC proceeded on an easterly course after leaving the THEODORA and did not ground during this period. When the 8 to 12 third mate relieved the watch at 1945, the MARINE ELECTRIC was close to its normal trackline and almost on its original heading. Since the ship was hove to in a north-northwest wind and probably being set to the southeast, the 0255 position is reasonable even though the ship had been on a heading of 040° T for 7 hours. The videotapes of the bottom of the MARINE ELECTRIC's bow section showed some damage but none indicating that the bow had grounded. Since the two nearest shoal areas were 4.5 to 6 nmi to the north-northwest of the MARINE ELECTRIC's position when it parted company with the THEODORA, since the MARINE ELECTRIC probably steered an easterly course after leaving the THEODORA, and since there were no communications or testimony suggesting a grounding, the Safety Board believes that grounding damage was not a factor in the flooding of the forward compartments.

Hatch Cover Failure.—The MARINE ELECTRIC had at least 21 feet of freeboard at the bow according to the draft of the vessel when it sailed. The three survivors testified that, before midnight on February 11, waves were breaking over the bow and sea water was washing down the deck but that there was only spray on the hatch covers themselves. (The dry cargo hatch had a 2.5-foot coaming and the No. 1 hatch had a 4.5-foot coaming.) Since the height of a wave is measured from the trough to the crest, some water would have come over the bow in 25-foot waves, however, only spray would reach the height of the hatch covers further aft. When the seas subsided to 15 to 20 feet on February 12, water probably did not go over the bow until the loss of some freeboard forward from some internal flooding.

The hatch covers were designed to withstand a static head of 8 feet of water. The calculations performed after the accident showed that even if the No. 1 hatch cover had been 75 percent wasted, it should have withstood a 2-foot head of static water or 1 foot of breaking waves before failure. Similar calculations for the dry cargo hatch showed 1.5 feet of breaking waves would have been required to cause failure of the dry cargo hatch if 75 percent wasted. However, since the hatch covers were raised off the deck and the three survivors did not observe any waves reaching the height of the hatch covers before the forward trim was experienced, a hatch cover failure without preceding flooding is not likely. The hatch covers could have failed later that night when the freeboard at the bow had been reduced as the result of flooding, or the ingress of some water due to faulty gaskets. However, any ingress of water through faulty gaskets during the period in question would probably have been minimal.

When the third mate observed a 5° to 8° forward trim at 0300, the dry cargo hatch and the No. 1 hatch covers were already under water with waves breaking on top of the hatch covers; and either the dry cargo hatch and/or No. 1 hatch cover could well have failed. However, the hatch covers probably did not fail until after some factor reduced the freeboard at the bow, i.e., flooding of some of the forward compartments. Although the MARINE ELECTRIC experienced 20- to 25-foot significant waves on February 11, which decreased to 15- to 20-foot waves on the early morning of February 12, the Safety Board believes that a hatch cover failure was not the initial cause of the flooding of forward compartments.

Damage caused by the anchor.--The underwater videocamera and diving surveys made during May and June 1983 showed that the starboard anchor was missing but there was no indication of whether or not the anchor and chain had released before the ship capsized. Because of the large amount of damage on the starboard side of the older T-2 bow section from the collision bulkhead forward, the Safety Board could not determine the damage which may have been caused by a loose anchor although several sharp punctures in the shell plating aft of and above the starboard hawse pipe may have been caused by the anchor. The devil claw's turnbuckle was found almost fully open which indicated that the claw may have come loose and fallen off the chain during the rolling of the ship; however, the chain stopper (pawl) if properly engaged should have held the anchor in place while the vessel was upright. In addition, brake of the anchor windlass should also have held the anchor. The Safety Board believes it is improbable that the devil's claw, the chain stopper, and the anchor windlass brake all failed while the ship was upright. When the MARINE ELECTRIC capsized to starboard, the devil's claw may have come loose. Since the chain stopper was held in place by gravity, it would open as the ship capsized. The anchor could then have been released if the anchor windlass brake had also failed as the starboard side hit bottom, causing damage on the starboard side of the bow, including the punctures aft and above the starboard hawsepipe.

If the starboard anchor had released and punctured a hole in the bow area while the ship was upright, the forward dry cargo and stores spaces would have flooded progressively over a period of time. However, calculations (case 2, Table I) show that the resulting trim would have been less than 0.5° with 20 feet of freeboard remaining. This reduction in freeboard probably would not have been sufficient to permit waves to roll over the No. 1 hatch cover. If the butterworth covers for the deep tanks and the manhole cover for the forepeak tank had not been secured, or if the anchor had punctured holes in the forepeak and deep tanks, the bow trim would have been increased to 1.2° and the freeboard would have been reduced to 13 feet (case 4, table I), thereby permitting sufficient depth of water to board on top of the No. 1 hatch cover to cause failure. The flooding of the No. 1 cargo hold and all the spaces forward of the collision bulkhead except for the pumproom (case 6, table I) would have reduced the freeboard to 4 feet at the bow. This in turn could have led to the failure of No. 2 hatch cover and the flooding of the No. 2 hold (case 7, table I) and a capsize. However, there is no evidence that the starboard anchor was released while the ship was upright. None of the survivors heard any sounds indicating a loose anchor.

Hull Structural Failure.--None of the above flooding cases explains the testimony that the engineers were pumping the Nos. 1 and 2 starboard wing tanks and possibly the No. 1 port wing tank. It is possible that if the No. 1 cargo hold had flooded, the No. 1 wing tanks could have flooded because of some undetected damage to the wing tank bulkheads within the cargo hold. However, the chief mate did not note any water in the No. 1 or No. 2 cargo hold after the previous ballast voyage when the Nos. 1 and 2 wing tanks were full of water. Had the cement patch in the No. 1 port wing tank failed, water may have entered the No. 1 port wing tank; however, only a small amount of water would have leaked into the port wing tank through this puncture even over a period of hours. A structural failure, opening the No. 2 cargo hold to the sea (case 9, table I), would have resulted in about 0.5° trim and the bow freeboard would have been reduced to about 16 feet. This reduction in freeboard would probably have been sufficient to result in waves breaking over and collapsing the dry cargo and No. 1 hatch covers. If the structural failure continued into the No. 2 starboard wing tank (case 19, table 1), the calculations show that a 4.6° list would have resulted.

The chief mate recalled being informed by different engineers that they were pumping the No. 1 port and No. 1 and 2 starboard wing tanks. However, the engineers may only have been pumping water out of No. 2 starboard wing tank. The positions of the valves found open in the port ballast manifold after the sinking were not consistent with the chief mate's recollection. The position of the valves suggests a last desperate effort to correct the starboard list and bow trim by flooding the after port wing tanks. The starboard heel of about 5° at 0350 may have been the result of the reduced stability from the bow being under water, but this condition would not have explained the reported pumping of water from the wing tanks. With the Nos. 1 and 2 cargo holds, the spaces forward of the collision bulkhead and the No. 2 starboard wing tank flooded, the ship probably would have lost all positive stability and capsized.

The underwater videocamera and diver surveys showed that the hull fractured in the No. 2 cargo hold. Although the hull may have fractured when the ship hit the ocean bottom, a structural failure and flooding in the No. 2 cargo hold shell plating while the ship was on the surface would explain the forward trim. The propagation of this fracture into the No. 2 starboard wing tank also would explain the reported pumping of starboard wing tanks and the starboard list.

It is possible that a structural failure may have occurred on the starboard side of the bow forward of the collision bulkhead. However, evidence of the initiation of such a failure is masked by the large amount of damage in this area. Such a structural failure would have caused flooding of the dry cargo stores and deep tanks forward and would have caused a trim angle of about 0.8° with a resulting freeboard of 16 feet. This could have led to waves breaking over and collapsing the No. 1 hatch cover and allowed the flooding in the No. 1 cargo hold. However, a structural failure in the bow would not explain the need for pumping of the starboard wing ballast tanks.

The Safety Board believes that the most probable cause of initial flooding was a structural failure on the starboard side of the No. 2 cargo hold. Since the structural calculations performed after the accident based on 2-year-old gaugings indicate that the MARINE ELECTRIC's hull strength was within design limits and the stresses and bending moments calculated for the ship as loaded on February 11 and 12 were within design limits, the structural failure probably was the result of a local stress concentration. Local wastage was probably responsible for this stress concentration because the sea state on February 11 and 12 probably was not as severe as many vessels of similar design have experienced in the North Atlantic Ocean where even more severe winter storms are common. The structural calculations show that the longitudinal bending and shear stresses would have been reduced with forward compartments flooded, indicating that a structural failure more likely would have occurred with the ship intact than with forward compartments flooded.

The Safety Board cannot determine why the master did not change the heading of the MARINE ELECTRIC and run before the sea when the adverse bow trim was first reported to him. If the master could have turned the ship safely under the sea conditions, he might have been able to assess the situation forward and to determine the cause of the trim.

With the wreck in three major pieces, it is difficult to determine the sequence of failure. After the ship capsized at 0415, the stern remained afloat for about 6 hours. It could not be determined if the hull was in one piece during the 6 hours. Since the bow and stern sections were found almost in line, the Safety Board believes these two pieces remained joined until the stern section eventually sank. Subsequently, it is hypothesized that the midship section broke free and, because the Nos. 3 and 4 wing tanks apparently were intact, it remained partially buoyant and drifted with the current before coming to rest 1,800 yards to the south-southeast in an upright position after the Nos. 3 and 4 wing tanks flooded. The debris from the MARINE ELECTRIC, found between the bow and stern sections and the midship section, including a main transverse bulkhead from the midship section, probably fell from the midship section as it was carried by the current while in a partially buoyant condition.

Although it is difficult to accurately reconstruct the MARINE ELECTRIC's loading condition at 2345 on February 10, 1983, because of the unknown amount of residual coal from the previous voyage, the Safety Board believes that the ship was loaded correctly. The draft readings provided by the chief mate indicate that the MARINE ELECTRIC was loaded properly and the structural calculations performed after the accident show the stress level in the ship as loaded to have been well within design limits.

Metallurgical Analysis

EMTEC's evaluation of the NBS tests of the recovered material from the wreckage of the MARINE ELECTRIC indicated that all of the recovered wreckage material had exhibited good ductility at the time the vessel was breaking apart. Because the steel plate samples used for testing purposes were taken from the fracture at the after end of No. 2 cargo hold of the cargo midbody of the ship's hull, they provided well defined specimens for the type of physical property determinations and chemical tests that were conducted. It was found that the steel used in the cargo midbody of the MARINE ELECTRIC conformed to the 1961 ABS rules which do not require Charpy V-notch testing; however, under the present rules, which require a minimum toughness of 20 foot-pounds at 32° F, the steel would not be acceptable.

Initial examination of the videotape of the hull fracture through the number two starboard and port wing tanks revealed a large amount of inward deformation of the exterior hull plate along the bottom of the ship. Visual examination of the samples from the bottom of the hull confirmed this deformation, which, in many areas, exceeded a bend angle of 90°. The stresses which caused this damage along the ship bottom were most likely compressive stresses which caused buckling of the hull and the extreme deformation.

The sample piece taken from above the port bilge keel contained much less overall deformation than the other pieces. The deformation that was noted on this piece was adjacent to the fracture surface. The examination of the wreckage material revealed that none of the recovered pieces had failed in a brittle manner.

Examination of the fracture surfaces on the three pieces from the hull indicated that the direction of fracture was downward along the sides of the ship, then across the bottom of the hull. This conclusion points to an initial failure somewhere near the deck of the ship.

The results of the CTOD tests indicated that under slow loading conditions, a very large flaw size (40 inches with a stress level of 20,000 psi) was necessary before brittle fracturing began. However, under specific dynamic loading conditions, the critical flaw size was significantly reduced (2.5 inches with a stress level of 20,000 psi).

Stability

Intact stability calculations performed after the accident showed that the MARINE ELECTRIC had 3 feet more GM than required by USCG regulations, indicating sufficient initial stability for the existing sea conditions. However, the ship's natural roll period of 13 seconds was close to the 11- to 14-second wave periods recorded by a NOAA wave buoy located 18 nmi away. This could account for the severe rolling in quartering seas experienced by the MARINE ELECTRIC while escorting the THEODORA and could be the reason the master asked to be relieved of the escort duty. When the ship returned to its original course but hove to in head seas, the rolling should have been minimized and should not have caused any unusual problems later that night.

Although no specific standard of subdivision is prescribed by the USCG or ABS for cargo vessels similar to the MARINE ELECTRIC, the ABS rules do require certain watertight transverse bulkheads, including a collision bulkhead, which subdivide the ship and limit the progression of flooding. Present ABS rules require the collision bulkhead to be located between 5 and 8 percent of the length aft of the stem; however, the 1961 ABS rules only required that the collision bulkhead be located more than 5 percent aft. The original T-2 design located the collision bulkhead 8 percent aft of the stem, but because of the conversion, the MARINE ELECTRIC's collision bulkhead was located 13 percent aft of the stem. As a result, any bow damage to the vessel would have resulted in greater flooding than is allowed by the present ABS rules. However, the calculations performed after the accident show that the MARINE ELECTRIC probably would not have capsized and sunk with only the spaces forward of the collision bulkhead flooded, indicating that the collision bulkhead served its intended purpose.

The bilge wells in the cargo holds on the MARINE ELECTRIC were covered with steel plates to prevent clogging of the suction piping by the pulverized coal cargo. Regardless of whether the bilge wells were covered with steel plates or by any other method, because of the nature of the cargo, it probably would not have been possible, to pump out the cargo holds if they had flooded. The wing ballast tanks could be dewatered through a separate system. The Safety Board believes that covering the cargo hold bilge wells on the MARINE ELECTRIC with steel plates did not contribute to the accident. However, USCG regulations require a bilge pumping system capable of operation under all practicable conditions. The MARINE ELECTRIC had a bilge pumping system, but it normally was not capable of operation while the vessel was in the coal trade. The USCG should examine the bilge pumping systems of other vessels in the coal trade to evaluate the adequacy of the bilge pumping systems and require that they be modified if they cannot be operated while the vessel is carrying coal.

Older Ships

The MARINE ELECTRIC, which was built in 1944 and converted in 1961, is the second U.S. registered ship built during World War II which has been lost during the last 3 years. In October 1980, the U.S. freighter POET 20/ disappeared in the North Atlantic Ocean about 500 nmi east of Delaware Bay during a severe storm. The POET was converted in 1964 by Bethlehem Steel Corporation Ship Building Division, Sparrows Point, Maryland, from a MARAD Design C-4 troopship built by Kaiser Company, Inc., of Richmond, California, in 1944. Approximately 28 percent of the U.S. operating seagoing fleet is over 30 years old. Although the Safety Board in the last 3 years also investigated the total loss of three major U.S. vessels 21/ less than 10 years old these losses did not raise any questions about the structural integrity of the vessels. The loss of the POET and the MARINE ELECTRIC on the other hand may have involved these factors and raise the possibility that owners, operators, the ABS and the USCG should subject older vessels to more comprehensive inspections. Although the ABS survey requirements increase their scope and depth at each succeeding special survey up to special survey No. 6 (24 to 30 years after construction), there are no additional requirements for vessels over 30 years of age. USCG inspection regulations do not include any special accommodation or have any special requirements based upon vessel age, and the USCG has not issued any standard policy or written guidance for its inspectors to follow when conducting inspections of older vessels.

20/ For more detailed information, read Marine Accident Report--"Disappearance of U.S. Freighter SS POET in North Atlantic Ocean about October 25, 1980" (NTSB-MAR-81-6).
21/ For more detailed information, read Marine Accident Reports--"Sinking of the M/V OXY PRODUCER in the Atlantic Ocean Near the Azores Islands, September 20, 1981" (NTSB-MAR-82-6); "Capsizing and Sinking of the U.S. Mobile Offshore Drilling Unit OCEAN RANGER off the East Coast of Canada 166 Nautical Miles East of St. John's, Newfoundland, February 15, 1982" (NTSB/MAR-83/2); and "Explosion and Fire Onboard the U.S. Tankship GOLDEN DOLPHIN in the Atlantic Ocean, March 6, 1982" (NTSB/MAR-83/7).

The records and testimony of the ABS surveyor and the USCG inspector who attended the 1981 drydocking of the MARINE ELECTRIC in Jacksonville, Florida, showed that a comprehensive ABS special survey No. 8 and USCG drydocking inspection were conducted and that extensive structural renewals were required as a result. The cargo hatch covers, however, were not hose tested or otherwise tested for weathertightness as required by ABS special survey No. 8. The records and testimony of MTL representatives indicated that "regular" repairs had been performed on the MARINE ELECTRIC's cargo hatch covers and cargo holds (to correct damage caused by unloading equipment) and the main deck between hatch coamings. The 1980 and 1981 gaugings indicated that extensive plate and stiffener renewals were required for the hull structure to meet required standards. The structural calculations performed after the accident, which indicated that stresses were within design standards, used average wastage values in determining the longitudinal hull strength of the MARINE ELECTRIC. However, some local areas of wastage may have developed during the 2-year period since the last gaugings were taken which, in the sea conditions on February 11 and 12, 1983, could have led to a local structural failure. The Safety Board believes that the MARINE ELECTRIC's continuous need for structural repairs of the hatch covers, main deck, and cargo holds (which it does not view as "regular" repairs) also indicates that a parallel deterioration of structural strength of the vessel must have been in progress over the preceding 2 years due to wasting of underwater hull plating. The next extensive gaugings would not have been required until 1985. The Safety Board believes that the ABS and the USCG should require extensive gauging of all older vessels every 2 years during the biennial drydocking, rather than every 4 to 5 years at special surveys. If such gaugings are performed during regular drydock periods, the added cost to the owner should be minimal. The Board also believes that the USCG should publish more specific guidelines for USCG inspectors who conduct inspections of older vessels.

Hatch Covers

Closures in the hulls of standard cargo vessels and bulk carriers, like the MARINE ELECTRIC, are required to be watertight up to the freeboard deck, and weathertight above the freeboard deck, which, in the case of the MARINE ELECTRIC, was also the main deck. Weathertight means that in any sea condition significant amounts of water will not penetrate into the vessel while watertight means that the closure is equivalent in strength to the surrounding structure so that water will not penetrate the vessel with the closure under a head of water.

The weathertightness and structural requirements for hatch covers are set out in the Load Line Regulations (46 CFR Part 42). The ABS has been appointed by the USCG as the "assigning authority" for the load line regulations in the United States and it is the entity responsible for assuring compliance with the load line regulations concerning hatch covers. The USCG nevertheless retains an oversight responsibility and is responsible for enforcement of the load line regulations. The ABS ensures that hatch covers meet the load line regulations by approving the design and installation of hatch covers by annually surveying hatch covers and by hose testing hatch covers for weathertightness every 4 to 5 years in the course of special surveys. However, neither the load line regulations nor the ABS rules contain any specific guidance regarding maintaining the structural strength of steel hatch covers or related installations after construction. Testimony and records indicated that the MARINE ELECTRIC hatch covers were not gauged at either the 1980 or 1981 drydocking and that the surveyor attending the ship did not know if the hatch covers still met design standards. The Safety Board believes that the ABS should institute a requirement that its surveyors gauge steel hatch covers at special surveys similar to the requirement for gauging steel hulls and that they compare the results with the original design requirements. The MARINE ELECTRIC hatch covers were not hose tested for weathertightness in February 1981 because the December 1980 ABS computer summary of outstanding survey requirements for special survey No. 8 included the incorrect notation that the steel hatches covers were both examined and hose tested in February 1980. Since the February 12 accident, the ABS has changed its computer format so that there is a separate notation for the hose testing of steel hatch covers for weathertightness.

The Safety Board believes that the MARINE ELECTRIC's hatch covers were capable of being made weathertight when the ship departed Norfolk, Virginia, on February 10, 1983. Although the wastage of the original hatch cover panels was severe and had required numerous doubler plates and epoxy patches to make them weathertight, the chief mate testified that he had never found water in the holds. Moreover, the permanent master testified that the ship had been in a similar storm in January 1983 (the logbooks showed the storm was actually in December 1982) without any water entering the cargo holds. The practice of the master of using only some of the dogs during good weather and the only failure of MTL to replace the cross-joint wedges were not good marine practices and impaired the weathertightness of the hatch covers; however, the hatch covers probably still were capable of preventing the penetration of significant quantities of water into the vessel on February 11 and 12, 1983, since the epoxy would have effectively prevented any leakage through the wasted holes and since the chief mate secured the workable dogs on the hatch covers. The MARINE ELECTRIC had operating problems with its hatch covers when the ship left the Jacksonville shipyard in 1981, but extensive work was performed on the hatch covers over the next 2 years, including the replacement of a panel on the No. 3 hatch. Although the November 30, 1982, report by the manufacturer's representative indicated that the hatch covers and supports were wasted, decreasing the ability of the hatch covers to support a head of water, MTL records showed that repairs to the deteriorating hatchcovers were performed periodically, indicating that MTL recognized the importance of maintaining the weathertightness of the hatch covers. The measures taken probably were sufficient to maintain weathertightness.

Hatch Cover and Hull Inspections

The investigation showed that the inspections of the MARINE ELECTRIC's hatch covers by USCG inspectors were cursory at best. During the USCG drydocking inspection in February 1981, the inspector did not inspect the hatch covers at all because the hatch covers were away from the ship undergoing repairs. During June 1981, the USCG inspected the hatch covers during the vessel's biennial inspection after some repairs recommended by the manufacturer had been accomplished. However, because the hatch covers were in the open position, the USCG inspector could not inspect the hatch covers completely, and he did not conduct any weathertightness tests. He did not require that the hatch covers be closed for these purposes. During June 1982, the USCG inspector reinspected the MARINE ELECTRIC; however, he did not inspect the hatch covers because he believed the ABS would take care of the inspection of hatch covers at the next annual load line survey. Although the USCG has delegated the responsibility of assuring the weathertightness of hatch covers to the assigning authority (the ABS for the MARINE ELECTRIC) of the Load Line Certificate, the USCG still has the overall responsibility for assuring compliance with safety requirements. The USCG needs to provide better guidance to its inspectors regarding their responsibility for insuring compliance with the load line regulations, such as the weathertightness of hatch covers. Moreover, the USCG should consider more comprehensive inspections of older vessels, such as the MARINE ELECTRIC, in respect to fixtures, such as hatchcovers.

The investigation showed that the ABS surveyor conducted a thorough survey of the MARINE ELECTRIC's hatch covers during February 1980, including the hose testing of repairs, but that he did not hose test the hatch covers in their entirety for weathertightness because he was not conducting a special survey. The survey and hose tests were inadvertently recorded as meeting the requirements for a weathertight test so the ABS surveyor in February 1981 conducted an annual inspection of the hatch covers which did not include closing the hatch covers and hose testing for weathertightness. Since the gaskets had been renewed and new doubler plates had been installed, the ABS surveyor would not have readily detected any weathertightness problems with the MARINE ELECTRIC's hatch covers in the open position. However, on February 24, 1982, an ABS surveyor conducted an annual load line survey and found the hatch covers satisfactory, although 8 days later an MTL port captain required that 84 doubler plates be installed. The Safety Board believes that the ABS surveyor should have noted the wasted condition of the hatch covers which required such extensive repairs.

Presently, the ABS does not have any specific guidance for its surveyors regarding the extent of annual load line surveys, and the USCG load line regulations simply state that the annual survey shall be of such scope and extent as to ensure that hatch covers are maintained in an effective condition. The ABS needs to revise its survey standards for annual load line surveys so that extensive wastage of hatch covers can be detected, particularly on older vessels. This may require that surveyors inspect hatch covers both in the open and closed positions during annual load line surveys and that they conduct hose tests for weathertightness more often than at special surveys.

In the 2 year period before the MARINE ELECTRIC sank, the Coast Guard inspected it on four occasions. The first of these was during the ship's shipyard overhaul during December 1980 to February 24, 1981. Although extensive steel plate renewals were made during the period, ABS determined that additional plating, longitudinals, and frames had wasted to the extent that they needed to be renewed and so indicated in its October 17, 1981, letter to MTL. The Coast Guard performed a biennial inspection during the period June 2 to 8, 1981, but did not mention any need for structural renewals. The inspectors may have known that ABS was preparing a list of the structural renewals needed and therefore did not consider making their own list. Although a Coast Guard representative was present during a diver's survey of the MARINE ELECTRIC's grounding on July 1, 1981, this survey was limited to consideration of hull damage and did not examine wastage. The Coast Guard conducted a reinspection on June 18, 1982, and found no problems. MTL had just installed doubler plates on three holes in the main deck, therefore the deck probably was in satisfactory condition. Reinspections are less detailed than biennial inspections, and since local wastage is unlikely to be detected visually unless it is very pronounced, the Coast Guard's satisfactory findings do not insure the hull was in sound condition. The Coast Guard's fourth inspection took place on December 22, 1983, in response to MTL's request for a delay in the ship's scheduled drydocking. This inspection did not include the hull plating or hatch covers inasmuch as its purpose was to ascertain the condition of certain accessible ship piping systems as indicators of the advisability of delaying the drydocking. This of course gave no indication of the condition of the underwater hull plating which is a item during drydock inspections. However, if there had been no request for a delay in the ship's drydocking, the scheduled drydock date of February 22, 1983, would have remained unchanged, which was 10 days after the MARINE ELECTRIC sank. The history of Coast Guard inspections over the 2 year period shows that most of the inspections had limited objectives which did not include, and were not likely to reveal, detection of all but the most severe local hull wastage.

Survival Aspects

The master gave the order to abandon ship about 5 minutes before the ship capsized. When he gave the order, the ship was listing about 8° to starboard and the crew was attempting to correct the list and trim. The metallurgical study of the hull plating indicated that the fracture developed in a ductil manner which would not give any sudden audible warning. The decision of the master not to abandon the vessel while the possibility still existed of correcting the adverse trim and list was correct.

A hasty decision by a master to abandon his vessel prematurely could unnecessarily expose his crew to even greater dangers until, in the master's opinion, the vessel would not remain afloat. A vessel, although severely damaged but afloat, is a safer platform than exposing persons to a winter storm in an open lifeboat. Launching lifeboats and embarking crewmembers is hazardous in rough seas.

The Safety Board considered a number of factors which may have contributed to the large loss of life: (1) the crew abandoned the MARINE ELECTRIC in 39° F water, but was not provided with exposure suits for protection against the cold temperatures that cause hypothermia; (2) only one crewmember in the water was able to board the USCG-approved inflatable liferaft; (3) the lapse of 1 hour after the capsizing before the arrival of the first USCG rescue helicopter; and (4) the USCG regulations which permitted the original lifeboats and davits to be retained after the major conversion in 1962.

In the 39° F water and with the air temperature at 29° F, the survival time of a person in the water without thermal protection was between 30 and 90 minutes depending on the individual's physical condition. Twenty of the 24 persons whose bodies were recovered died of hypothermia. Studies 22/ have shown that the use of exposure suits which provide proper thermal protection can extend an individual's survival time in cold water by several hours. USCG regulations (46 CFR 94.41) currently require each vessel operating on the Great Lakes to carry an exposure suit which provides thermal protection for each person on board.

On September 22, 1978, as a result of its investigation of the sinking of the CHESTER A. POLING 23/ with the loss of one person, the Safety Board recommended that the USCG:

> Require that exposure suits be provided for each crewmember on vessels that routinely operate in areas of cold air or sea temperature. (M-78-65)

On May 19, 1980, the USCG replied that it concurred in the recommendation but that it did not intend to require oceangoing vessels equipped with enclosed lifeboats to carry exposure suits. On July 8, 1982, as a result of its investigation of the capsizing and sinking of the OCEAN RANGER 24/ with the loss of all 84 persons aboard, the Safety Board recommended that the USCG:

22/ Harnett, R. M., O'Brien, E. M., Sias, F. R. and J. R. Pruitt (1979). "Experimental Evaluations of Selected Immersion Hypothermia Protection Equipment," U.S. Coast Guard Report No. CG-D-79-79, October 12, 1979. Hayward, J. S., Lisson, P. A., Collis, M. L. and J. D. Eckeson (1978). "Survival Suits for Accidental Immersion in Cold Water: Design-Concept and their Protection Performance," University of Victoria, January 1978.

23/ For more detailed information, read Marine Accident Report--"Sinking of the M/V CHESTER A. POLING near Cape Ann, Massachusetts, January 10, 1977" (NTSB-MAR-78-7).

24/ Op cit p. 46.

Require that all U.S. mobile offshore drilling units that operate in waters where hypothermia can greatly reduce an individual's survival time carry an exposure suit for each person on board, similar to that required by 46 CFR 94.41-5(c). (M-82-35)

On February 3, 1983, the USCG published a notice of proposed rulemaking in the Federal Register (Vol. 48, No. 24, page 4837) that would require U.S. flag oceangoing and coastwise tank vessels, cargo and miscellaneous vessels, mobile offshore drilling units and oceanographic vessels to be equipped with exposure suits for all persons on board. This rulemaking would include industrial persons on mobile offshore drilling units, such as the OCEAN RANGER, and scientific personnel on oceanographic vessels. Although industrial persons and scientific personnel are not part of the crew, they are employed aboard the vessel and should be provided with exposure suits. However, the requirements would not apply to vessels with totally enclosed lifeboats, except for mobile offshore drilling units, or to any vessel operating in waters between 35° north latitude and 35° south latitude or on the outer continental shelf of the United States in the Atlantic Ocean south of 38° north latitude. The USCG stated that the temperatures in these waters is usually above 60° F and generally does not fall below 57° F. At the time the MARINE ELECTRIC capsized and sank, it was located south of 38° north latitude on the outer continental shelf of the United States, and the water temperature was about 39° F. Therefore, the Safety Board believes that the Coast Guard should reevaluate the temperature analysis it presumably performed in connection with the proposed rulemaking to insure that cold water areas are correctly identified and that vessels operating in such waters are required to carry exposure suits.

Both the OCEAN RANGER and the MARINE ELECTRIC accidents demonstrate that exposure suits should be required even if a vessel is equipped with enclosed lifeboats. The OCEAN RANGER was equipped with enclosed lifeboats, but many persons aboard the drilling rig entered the water before rescue boats arrived on the scene and others entered the water when one of the enclosed lifeboats capsized. Before anyone could enter the open lifeboats on the MARINE ELECTRIC, the ship suddenly capsized, throwing the persons aboard into the cold water. Even if the MARINE ELECTRIC had been equipped with enclosed lifeboats, the crewmembers still would have been thrown into cold water because they never got into the lifeboats. Therefore, whether a vessel is equipped with open or enclosed lifeboats, it should be carry exposure suits for the crew if it operates in cold water.

The proposed USCG regulations do not address inspected passenger vessels. (The provision to permit the substitution of exposure suits for life preservers or other personal flotation devices on uninspected vessels would presumably reach vessels carrying less than six passengers.) The Safety Board believes that the crew of passenger vessels also should be provided with exposure suits to enhance their ability to assist passengers in the water in an emergency before experiencing the effects of hypothermia themselves.

The Safety Board believes that some of the persons aboard the MARINE ELECTRIC might have been saved if they had been wearing exposure suits similar to those required on Great Lakes vessels. A USCG search and rescue helicopter arrived in the area about 1 hour after the MARINE ELECTRIC capsized; however, only three crewmembers were saved. Had the persons aboard the MARINE ELECTRIC been wearing exposure suits as protection from hypothermia, the survival time would have been extended by several hours, thereby increasing their chances for rescue. Although the physical condition and clothing worn by the persons who died from hypothermia was not determined, it is noteworthy that all three survivors, whose ages were 28, 31, and 59, weighed over 200 pounds each and were wearing heavy clothing for insulation.

Since both of the MARINE ELECTRIC's USCG-approved inflatable covered liferafts were deliberately sunk during the search and rescue operation, the Safety Board was not able to identify the manufacturer of the liferaft from which the AB was saved; however, the liferafts were similar in design in that they both had weblike boarding ladders. USCG approved liferafts are required to have a boarding ladder, or the equivalent, at each entrance, and hand holds, or the equivalent, on each side of each entrance to aid in boarding. Although the Safety Board cannot determine why the AB did not find ladders at both ends of the liferaft, it believes more of the persons in the water might have been saved if the location of the liferaft's boarding ladders had been clearly marked and if they had been easier to rig. While the AB was looking for the boarding ladders and trying to rig the one he found, the persons in the cold water were becoming progressively weaker. The Safety Board also believes that even with the early effects of hypothermia the second mate and the others in the water might have been able to enter the liferaft if the hand grabs on the ladder had not laid flat against the liferaft as a result of the weight of the person on the ladder, or if there had been a ramp fitted on the outside of the liferaft for persons in the water to climb onto. Therefore, the Safety Board believes that the USCG should require that the means of boarding new and existing USCG approved liferafts from the water be improved.

The testimony of the surviving third mate and AB indicate that additional crewmembers might have been saved if the USCG rescue helicopter had arrived sooner. The first USCG helicopter arrived at 0520 on February 12, 1983, about 1 hour after the MARINE ELECTRIC capsized about 0415 and 2 hours after the helicopter had been ordered launched. Both the third mate and AB stated that other crewmembers were still alive until shortly before the helicopter arrived, but none survived long enough for the helicopter to rescue them. The USCG in Ocean City, Maryland, was first notified of the MARINE ELECTRIC's distress at 0251 on February 12, when the master reported the ship's position as "approximately 30 miles from Delaware Bay Entrance" and at 0254 as 37° 51.8' north, 74° 45.5' west. This position is near that marked "Position of MARINE ELECTRIC Wreck" on figure 1 while a position 30 miles from Delaware Bay lies on an arc passing through the Delaware Bay Entrance Buoy some 35 miles away. Because of the discrepancy in the two positions, USCG Station Ocean City delayed until 0310 notifying the USCG RCC in Portsmouth, Virginia, while the MARINE ELECTRIC's position was verified. After evaluating the situation at 0318, RCC Portsmouth directed USCG Air Station Elizabeth City, North Carolina, to launch its ready helicopter. The USCG criterion for launching a ready helicopter is that it should be launched within 30 minutes after receiving orders; however, the helicopter did not take off for 55 minutes. The pilot testified that he had a lengthy conversation with weather personnel to evaluate the onscene weather conditions and also that he had ordered the emergency pumps removed from the helicopter so more persons could be carried. The extra time used by the pilot to verify the MARINE ELECTRIC's position and his lengthy weather briefing probably accounted for the delay. Although some persons may have been saved if the USCG helicopter had arrived sooner, the Safety Board believes the USCG pilot's precautions were reasonable and that he reached the scene without undue delay given the severe weather conditions.

The U.S. Navy rescue swimmer risked his own life in attempting to save crewmembers from the MARINE ELECTRIC. Unfortunately, none of the persons he put in the rescue basket survived. The USCG presently does not have the capability of putting a swimmer in the water to aid persons in the water to enter a rescue basket. In a letter 25/ to the Commandant from the House Subcommittee on Coast Guard and Navigation recommended that the USCG personnel be trained in rescue swimming. In a November 10, 1983, letter the Acting Commandant responded favorably to the Subcommittee's recommendation, pointing out that in spite of the cost, such a program "has merit" and would produce a "substantial return." The inability of survivors to participate in their own rescue due to the debilitating effects of hypothermia was illustrated in two other accidents 26/ investigated by the Safety Board. Because the Safety Board's findings in those accidents as well as the February 12, 1983, accident were similar, we urge the USCG to consider the use of rescue swimmers in search and rescue cases, especially those involving cold water where hypothermia can limit a person's ability to aid in his own resuce, and to implement the Subcommittee's recommendation as soon as possible.

Under USCG regulations, the MARINE ELECTRIC was allowed to retain its original lifeboats and davits despite the fact it underwent a major conversion. The ship's davits were sheath screw boom-type davits with manila falls. This type of davit requires at least two men to operate and takes about four times as long to rig out for embarkation as compared to one man with the more modern gravity type davits with wire falls. Current regulations require winches with wire rope falls for lowering and raising lifeboats and one motorized lifeboat for a vessel similar to the MARINE ELECTRIC although sheath screw davits still are permitted. Since the lifeboats on the MARINE ELECTRIC were ready for embarkation when it capsized, the Safety Board believes that the limitations of the 40-year-old equipment did not contribute to the loss of life. Nevertheless, the Safety Board believes that davits should be updated. As a result of the collision between the USCG Cutter BLACKTHORN and the U.S. tankship CAPRICORN 27/ on September 11, 1980, the Safety Board recommended that the USCG:

> Require all U.S. merchant vessels over 1,600 gross tons to be equipped with at least one motor lifeboat on each side and gravity davits throughout. (M-80-79)

On August 13, 1982, the USCG replied in part:

> The Coast Guard does not concur with this recommendation. Grandfathering provisions are provided for in regulations so "existing" vessels may continue to operate when new regulations become effective. The impact of new requirements on industry and the public in general must be weighed against the advantages of enforcing new regulations on existing vessels. Vessels that have been operating safely and in compliance with existing regulations, statutes, and international conventions for years should not be put out of business or caused undue hardship due to promulgation of new regulations. However, safety should not be unduly compromised by the monetary impact on the marine industry or the difficulty in retrofitting existing vessels.

25/ Congressional Record - House, November 15, 1983, Pages H9889, H9890.
26/ Marine Accident Report--"Capsizing and Sinking of the U.S. Mobile Offshore Drilling Unit OCEAN RANGER off the East Coast of Canada 166 Nautical Miles East of St. John's, Newfoundland, February 15, 1982" (NTSB/MAR-83/2); and Aircraft Accident Report--"Air Florida, Inc., Boeing 737-222, N62AF, Collision with 14th Street Bridge, near Washington National Airport, Washington, D.C., January 13, 1982" (NTSB-AAR-82-2).
27/ For more detailed information read, "Marine Accident Report—Collision of USCG BLACKTHORN AND U.S. tankship CAPRICORN, Tampa, Florida, January 28, 1980" (NTSB-MAR-80-14).

On April 13, 1983, the Safety Board classified the recommendation as "Closed--Unacceptable Action."

During its investigation of the disappearance of the U.S. freighter POET in October 1980, the Safety Board became aware that the type of EPIRB (MARTECH Whaler EB-2BW) aboard the POET when it disappeared had a history of malfunctions as a result of maintenance problems arising out of the replacement of its battery. On May 12, 1980, the FCC reported a 25 percent failure rate of the water activated switch on the MARTECH Whaler EB-2BW EPIRB's which were inspected. In an August 13, 1980 letter, the FCC advised MARTECH, Inc. of the need to modify its service manual for this type of EPIRB. On July 14, 1981, the Safety Board recommended that the FCC:

> Monitor the failure rate of the MARTECH Whaler EB-2BW Emergency Position Indicating Radio Beacon's water-activated switch, and require a design change if the present unacceptable failure rate continues. (Class II, Priority Action) (M-82-52)

On January 11, 1982, the FCC replied in part:

> MARTECH was asked to modify its service manual to correct this problem and has complied with the Commission's request. We anticipate that use of this new procedure will prevent failure of the switch due to replacing the battery. Should any further failures be detected as a result of our ship station inspection program, appropriate corrective action will be taken.

On August 19, 1982, the Safety Board classified recommendation M-81-52 as "Closed--Acceptable Action."

The MARINE ELECTRIC was equipped with a MARTECH Whaler EB-2BW EPIRB when it sank on February 12, 1983, but no signal was heard from the EPIRB by rescue personnel. The EPIRB had been inspected by the FCC on June 17, 1982, and the surviving third mate testified that, before the MARINE ELECTRIC capsized to starboard, he stood the EPIRB upright in its box on the port bridge wing. The Safety Board believes that the MARINE ELECTRIC accident indicates there may be a continuing problem with the MARTECH Whaler EB-2BW EPIRB and that the FCC should study a design change to the MARTECH Whaler EB-2BW EPIRB to improve its maintainability and reliability.

CONCLUSIONS

Findings

1. On February 12, 1983, the MARINE ELECTRIC capsized and sank in position 37° 52'9" North Latitude, 74°46'6" West Longitude about 30 nautical miles east of Chincoteague, Virginia, after its forward compartments flooded.

2. The MARINE ELECTRIC had sufficient intact stability before flooding to withstand the wind and sea conditions it experienced on February 11 and 12, 1983.

3. The MARINE ELECTRIC may have stayed afloat longer if the master had turned the ship and run before the seas when he first was notified of the unexplained trim by the bow.

4. The MARINE ELECTRIC did not ground while escorting the THEODORA.

5. The MARINE ELECTRIC's No. 1 hatch cover failed but not until some other structural failure had occurred, causing a significant trim by the bow due to flooding.

6. The MARINE ELECTRIC was loaded correctly when it left Norfolk, Virginia, on February 10, 1983.

7. The blocking of the bilge suctions in the cargo holds with steel plates did not contribute to the accident.

8. The MARINE ELECTRIC's hatch covers probably were weathertight when the ship left Norfolk, Virginia, on February 10, 1983.

9. The American Bureau of Shipping did not test the weathertightness of the MARINE ELECTRIC's hatch covers at the last special survey in February 1981 as required by ABS.

10. Other than not hose testing the cargo hatch covers at the last special survey, the American Bureau of Shipping surveys in February 1980 and February 1981 of the MARINE ELECTRIC were satisfactory.

11. The American Bureau of Shipping annual survey in February 1982 did not detect the extensive wastage which existed on the MARINE ELECTRIC's hatch covers at that time.

12. Subsequent to the February 24, 1981, hull gaugings, the Coast Guard structural inspections were limited in scope and were unlikely to have found any but the most severe areas of localized hull wastage.

13. The U.S. Coast Guard does not provide its inspectors with adequate guidance on their responsibilities for the inspection of items, such as the weathertightness of hatch covers, covered by the Load Line Regulations, which are administered by ABS.

14. The U.S. Coast Guard does not provide its inspectors with adequate written guidance for the inspection of vessels over 20 years of age.

15. Although they do not require more frequent gaugings of older vessels, the ABS rules for special surveys generally provide for stricter inspections on older vessels.

16. The hull of the MARINE ELECTRIC was constructed of steel material which met the mechanical and chemical requirements as set forth in the applicable 1961 American Bureau of Shipping "Rules for the Classification and Construction of Steel Vessels" for Class B structural steel.

17. The U.S. Coast Guard and the American Bureau of Shipping could enhance the safety of older vessels by requiring gauging of vessels over 20 years of age at more frequent intervals.

18. The American Bureau of Shipping does not have adequate procedures for determining the structural strength of steel hatch covers after the hatch covers have been in service for a long period of time.

19. The crew of the MARINE ELECTRIC was not provided with adequate protective equipment for abandoning ship in the cold environment, which contributed to the death of 20 persons from hypothermia.

20. The boarding ladders and hand grabs on the U.S. Coast Guard-approved liferafts were not adequate for their intended purpose and prevented several crewmembers from successfully boarding the liferafts.

21. Although the earlier arrival of the U.S. Coast Guard rescue helicopter probably would have saved some lives, the Coast Guard responded reasonably timely under the severe weather conditions. The additional time required to launch the ready helicopter was used in evaluating the severe weather conditions and to verify the reported position of the MARINE ELECTRIC.

22. The use of rescue swimmers by the U.S. Coast Guard during search and rescue operations would improve its capability of recovering survivors especially when the effects of hypothermia limit the ability of survivors to aid in their own rescue.

23. The sheath screw boom-type davits with manila falls installed on the MARINE ELECTRIC, although more difficult to use than modern gravity davits, did not contribute to the loss of life.

24. The Federal Communications Commission needs to take further action to assure the reliability of the MARTECH Whaler EB-2BW EPIRB.

25. The master correctly decided not to abandon the vessel while the possibility still existed of correcting the adverse trim and list.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the capsizing and sinking of the U.S. bulk carrier MARINE ELECTRIC was the flooding of several forward compartments as the result of an undetermined structural failure. Contributing to the loss of life was the lack of personal thermal protection equipment for the crewmembers to minimize the effects of hypothermia and inadequate provisions for persons in the water to board the type of inflatable liferaft carried by the MARINE ELECTRIC.

RECOMMENDATIONS

While the investigation of this accident was in progress, the National Transportation Safety Board made the following recommendations on July 18, 1983:

--to the U.S. Coast Guard:

Conduct a design study to determine the adequacy of existing boarding systems of U.S. Coast Guard-approved inflatable liferafts regarding the marking of the location and ease of rigging of boarding ladders or equivalent, and the ability of persons in the water, including those wearing exposure suits, to use the boarding ladder and hand holds or equivalent, and require design changes encompassing both new and existing liferafts found to have inadequate boarding systems. (Class II, Priority Action) (M-83-50)

Status: No response

Reevaluate the water temperature analysis underlying the Coast Guard's proposal to exempt vessels operating between 35° north latitude and 35° south latitude and on the U.S. outer continental shelf in the Atlantic Ocean south of 38° north latitude from being required to carry exposure suits, and modify the proposal as appropriate to limit the exemption to those areas where the water is above 60° F throughout the year. (Class II, Priority Action) (M-83-51)

Status: No response

Require that exposure suits be provided for each crewmember, scientific personnel, or industrial person on tank vessels, passenger vessels, cargo and miscellaneous vessels, mobile offshore drilling units, offshore supply vessels, small passenger vessels, and oceanographic vessels that operate in areas where the water temperature is below 60° F. (Class II, Priority Action) (M-83-52)

Status: No response

--to Marine Transport Lines, Inc.:

Provide an exposure suit for each person on board all its vessels that operate in waters where hypothermia can greatly reduce an individual's survival time, similar to that required by 46 CFR 94.41-5(c). (Class II, Priority Action) (M-83-53)

Status: Open — Acceptable Action.

--to the American Institute of Merchant Shipping:

Recommend to its members that they provide an exposure suit for each crewmember, all scientific personnel, and all industrial persons on board their vessels which operate in waters where hypothermia can greatly reduce an individual's survival time, similar to that required by 46 CFR 94.41-5(c). (Class II, Priority Action) (M-83-54)

Status: Open — Acceptable Action.

--to the Council of American-Flag Ship Operators:

Recommend to its members that they provide an exposure suit for each crewmember, all scientific personnel, and all industrial persons on board their vessels which operate in waters where hypothermia can greatly reduce an individual's survival time, similar to that required by 46 CFR 94.41-5(c). (Class II, Priority Action) (M-83-55)

Status: No response

As a result of its investigation, the National Transportation Safety Board made the following recommendations:

—to the U.S. Coast Guard:

Provide written guidance to U.S. Coast Guard inspectors regarding the inspection of vessels over 20 years of age, including specific structural gauging, equipment renewal, and testing requirements. (Class II, Priority Action) (M-84-5)

Require that structural gaugings of vessels be conducted at 2-year intervals after a vessel reaches 20 years of age. (Class II, Priority Action) (M-84-6)

Provide written guidance to U.S. Coast Guard inspectors specifying their responsibility for the inspection of items, such as the weathertightness of hatch covers, that have been delegated to the American Bureau of Shipping under the Load Line Regulations. (Class II, Priority Action) (M-84-7)

Evaluate the design of the bilge pumping systems in the cargo holds of U.S. flag bulk carriers in the coal trade similar to the MARINE ELECTRIC to determine if the systems are compatible with the cargo and require modifications if necessary to those vessels which do not comply with U.S. Coast Guard regulations (46 CFR 56.50-50) that they may be operable under "all practicable conditions." (Class II, Priority Action) (M-84-8)

—to the American Bureau of Shipping:

Require that structural gaugings of vessels be conducted at 2-year intervals after a vessel reaches 20 years of age. (Class II, Priority Action) (M-84-9)

Require that steel weatherdeck hatch covers be gauged at all special surveys. (Class II, Priority Action) (M-84-10)

Require its surveyors to examine hatch covers for wastage during all annual load line surveys. (Class II, Priority Action) (M-84-11)

—to the Federal Communications Commission:

Require a design change to the MARTECH Whaler EB-2BW Emergency Position Indicating Radio Beacon to improve its maintainability and reliability. (Class II, Priority Action) (M-84-12)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ G. H. PATRICK BURSLEY
Member

/s/ DONALD D. ENGEN
Member

/s/ VERNON L. GROSE
Member

January 19, 1984

APPENDIXES

APPENDIX A

PERSONNEL INFORMATION

Regular Master

James K. Farnham, age 56, first went to sea in 1943 and received his third mate's license in 1945, his second mate's license in 1947 and his chief mate's license in 1967. From 1950 to 1966 he was employed by Bath Iron Works, a shipyard in Maine, as a deck officer, harbor pilot, and docking master in addition to service as a ship's expediter. He returned to sea in 1966 and received his master's license in 1969. After serving as chief mate and master for various companies, he joined Marine Transport Lines and was assigned to the MARINE ELECTRIC as chief mate in February 1975. He was appointed master of the MARINE ELECTRIC in September 1978, and has served in that position until the present except for vacations. It was during his vacation that the MARINE ELECTRIC capsized and sank.

Relief master

Phillip Corl, 59, (deceased) first went to sea in 1943 and received his third mate's license in 1945, his second mate's license in 1947 and his chief mate's license in 1949. He had been employed by Marine Transport Lines since 1976 and had served in various capacities until receiving his master's license in 1978. Subsequent to 1978 he served as either master or chief mate aboard tankships of a comparable size to the MARINE ELECTRIC until June 1982 when he was assigned to the MARINE ELECTRIC as relief master. He was relief master until September 1982, and came aboard as relief master on February 9, 1982.

Chief Mate

Robert M. Cusick, age 59, started going to sea in 1941 and received his third mate's license in 1943, his second mate's license in 1944 and his chief mate's license about 1949. He has sailed continuously ever since. He has served on various bulk carriers in the coal trade since 1952 except for a four year period from 1962 to 1966 when he worked aboard a small research vessel. In 1977, he joined the MARINE ELECTRIC as second mate for six months and then as permanent chief mate in 1978 his capacity at the time of the casualty. He received his master's license in 1981 but has never served in that capacity.

Third mate (12-4 watch)

Richard Roberts, (deceased) graduated from the U.S. Merchant Marine Academy in 1979 and had a third mate's license. No further biographical data is available.

Third mate (8-12 watch)

Eugene F. Kelly, age 31, graduated from the Massachusetts Maritime Academy in 1975 and received a third mate's license in the same year. He first worked aboard offshore supply vessels in the Gulf of Mexico. In 1978, after receiving his second mate's license, he sailed on various vessels, mostly tankers, until joining the MARINE ELECTRIC on January 20, 1983, as third mate.

Chief Engineer

Richard Powers, 44, (deceased) received his third assistant engineer's license of steam vessels in 1963, his second assistant engineer's license of steam vessels in 1965 and his first assistant engineer's license in 1969. In 1974, he received his chief engineer's license for steam and motor vessels. While serving as chief engineer, he also served as port engineer for Marine Transport Lines, and was responsible for approving all repair requests for the MARINE ELECTRIC.

APPENDIX B

METEOROLOGICAL INFORMATION FEBRUARY 11 and 12, 1983

The following are the analyzed surface conditions off the Virginia Capes at 0100*, February 11, off Parramore Island, Virginia at 0400, February 11, and in the vicinity of the accident from 0700, February 11 through 0700 February 12, at 3 hours intervals:

February 11, 1983

0100

sky	:	overcast
visibility	:	3 to 5 miles
weather	:	light rain, light snow, fog
air temp.	:	38° F.
sea temp.	:	unknown
wind	:	northeast 25 to 35 knots
sea	:	17-22 feet (**)

0400

sky	:	overcast
visibility	:	5 to 7 miles
weather	:	light rain and fog
air temp.	:	39° F.
sea temp.	:	unknown
wind	:	northeast 18 to 23 knots
sea	:	13 to 18 feet

0700

sky	:	overcast
visibility	:	1/2 to 2 miles
weather	:	light rain and fog
air temp.	:	37° F.
sea temp.	:	39° F.
wind	:	east-northeast 25 to 35 knots
sea	:	15 to 20 feet

1000

sky	:	overcast
visibility	:	1/2 to 2 miles
weather	:	light rain and fog
air temp.	:	37° F.
sea temp.	:	39° F.
wind	:	northeast 30 to 40 knots
sea	:	20 to 25 feet

* All times used herein are eastern standard, based on the 24 hour clock.
** All sea states are significant wave heights.

February 11, 1983

1300

sky	:	overcast
visibility	:	1/2 to 2 miles
weather	:	light rain and fog
air temp.	:	36° F.
sea temp.	:	39° F.
wind	:	northeast 35 to 45 knots
sea	:	17 to 22 feet

1600

sky	:	overcast
visibility	:	1/2 to 1 miles
weather	:	light rain and fog
air temp.	:	36° F.
sea temp.	:	39° F.
wind	:	northeast 35 to 40 knots
sea	:	17 to 22 feet
wave period	:	11 seconds*

1900

sky	:	overcast
visibility	:	1 to 3 miles
weather	:	moderate drizzle and fog
air temp.	:	35° F.
sea temp.	:	39° F.
wind	:	north-northeast 30 to 35 knots
sea	:	17 to 22 feet
wave period	:	12 seconds

2200

sky	:	overcast
visibility	:	1 to 3 miles
weather	:	moderate drizzle and fog
air temp.	:	31° F.
sea temp.	:	39° F.
wind	:	north 30 to 35 knots
sea	:	15 to 20 feet
wave period	:	14 seconds

* Wave periods and significant sea heights were recorded by NOAA buoy from 1600, February 11 until 0500, February 12, 1983.

February 12, 1983

0100

sky	:	overcast
visibility	:	4 to 6 miles
weather	:	moderate drizzle and fog
air temp.	:	30° F.
sea temp.	:	39° F.
wind	:	north-northwest 23 to 28 knots
sea	:	15 to 20 feet
wave period	:	14 seconds

0400

sky	:	overcast
visibility	:	4 to 6 miles
weather	:	None
air temp.	:	29° F.
sea temp.	:	39° F.
wind	:	north 30 to 35 knots
sea	:	13 to 18 feet
wave period	:	14 seconds

0700

sky	:	broken to overcast
visibility	:	5 to 7 miles
weather	:	None
air temp.	:	28° F.
sea temp.	:	39° F.
wind	:	north-northwest 25 to 30 knots
sea	:	11 to 16 feet

APPENDIX C

LOAD LINE REGULATIONS

§ 42.07–35 American Bureau of Shipping as an assigning authority.

(a) The American Bureau of Shipping, with its home office at 45 Broad Street, New York, N.Y. 10004, is hereby appointed as the prime assigning and issuing authority under the provisions of Articles 13 and 16(3) of the 1966 Convention and as directed by sections 3 of the load line acts. In this capacity the American Bureau of Shipping is empowered to assign load lines, to perform surveys required for load line assignments, and to determine that the position of and the manner of marking vessels has been done in accordance with applicable requirements.

§ 42.09–15 Surveys by the American Bureau of Shipping or assigning authority.

(a) *General.* Before issuing a certificate or placement of load line marks on a vessel, the assigning and issuing authority shall make an initial or periodic survey of the vessel as required by this subchapter. A load line survey report shall be made, reflecting information and facts based on initial surveys, including required and special elements as may be deemed necessary by the assigning authority or the Commandant.

(b) *Initial survey.* An initial survey shall be made before the vessel is put in service or the first time the assigning authority is requested to survey a vessel. The survey shall include a complete examination of its structure and equipment insofar as required by the applicable requirements in this subchapter. This survey shall be such as to ensure that the arrangements, materials, scantlings, and subsequent placement of load line marks fully comply with applicable requirements.

(c) *Periodical survey.* A periodical survey shall be made at intervals not exceeding five (5) years from an initial or previous periodic survey. The survey shall be similar to the initial survey insofar as extent and purpose are concerned.

(1) If the load line marks are found to be correct for the condition the vessel is then in, the assigning and issuing authority shall issue a new load line certificate, valid for such time as the condition of the vessel then warrants but in no case for a period of longer than 5 years. If, after a survey has been passed, a loadline certificate can not be issued before the current certificate expires, the current certificate may be extended by an endorsement in accordance with the requirements contained in § 42.07–45(d). This endorsement of the assigning authority shall be placed on the back of the certificate, as shown on the forms in Subpart 42.50. However, if there have been alterations which affect the vessel's freeboards, such extension shall not be granted. This prohibition is the same as in Article 19(2) of the 1966 Convention.

(2) The periodical survey, including certificate extension or reissue, for a vessel holding an international load line exemption certificate for more than one voyage, shall be the same as for any other vessel covered by this section except for load line marks. However, other conditions specified in the exemption certificate shall be verified.

(d) *Annual surveys for endorsements.* Vessels subject to initial and periodic surveys shall have annual surveys, within 3 months either way of the certificate's anniversary date. The annual surveys shall be made by and prove satisfactory to the assigning and issuing authority prior to executing the required annual endorsements on load line certificates or exemption certificates. The scope shall be as defined in § 42.09–40 and such as to ensure that the applicable load line marks are found to be correct for the condition the vessel is then in.

§ 42.09–25 Initial or periodic survey requirements for all vessels.

(a) Before a survey may be completed, the vessel shall be placed in a drydock or hauled out. The surveyor shall be given complete access to all parts of the vessel to ensure that the vessel complies with all applicable requirements.

(b) The surveyor shall examine on all vessels the items, etc., listed in this paragraph to determine if in satisfactory condition and meeting applicable requirements in this subchapter.

(1) Cargo hatch coamings, covers, beams and supports, gaskets, clamps, locking bars, tarpaulins, battens, cleats and wedges of hatches on exposed freeboard, quarter and superstructure decks, and elsewhere as may be necessary.

(2) Structure of the vessel, coamings, closures, and all means of protection provided for openings, such as for ventilators, companionways, machinery casings, fiddleys, funnels, enclosed superstructures on the freeboard deck (and their end bulkheads) or equivalent protective deck houses, openings in the freeboard and superstructure decks, and significant openings at higher levels in the vessel.

(3) Transverse watertight subdivision bulkheads, as fitted, including any openings therein and closures for such openings. They shall be examined throughout their vertical and transverse extent.

(4) All air-pipe outlets, their closures, all scuppers, and all sanitary discharges in the vessel's sides, including nonreturn valves installed.

(5) The main and auxiliary sea inlets and discharges in the machinery space, and elsewhere if existent, and the valves and controls for these items.

(6) All gangways, cargo ports, and airports, including dead covers or other similar openings in the vessel's sides and their closures.

(7) All guardrails, bulwarks, gangways, and freeing port shutters, including securing devices, and bars.

(8) All eye plates or similar fittings for timber (or other) deck-cargo lashings, including the lashings, sockets for uprights and protective devices as may be necessary for ventilators and steering arrangements.

[CGFR 68-60, 33 FR 10056, July 12, 1968, as amended by CGFR 68-126, 34 FR 9013, June 5, 1969]

§ 42.09-30 Additional survey requirements for steel-hull vessels.

(a) In addition to the requirements in § 42.09-25, the surveyor of the assigning authority shall examine the items, etc., listed in this section, to determine if in satisfactory condition and meeting applicable requirements in this subchapter.

(b) When the vessel is in drydock, the hull plating, etc., shall be examined.

(c) The holds, 'tween decks, peaks, bilges, machinery spaces, and bunkers shall be examined to determine the condition of the framing, etc.

(d) The deep tanks and other tanks which form part of the vessel shall be examined internally.

(e) If a double bottom is fitted, the tanks normally shall be examined internally. Where double bottom and other tanks are used for fuel-oil bunkers, such tanks need not be cleaned out, if the surveyor is able to determine by an external examination that their general condition is satisfactory.

(f) The deck shall be examined.

(g) Where, owing to the age and condition of the vessel or otherwise, the surveyor deems it necessary, the shell and deck plating may be required to be drilled or other acceptable means used, in order to ascertain the then thickness of such plating.

§ 42.09-40 Annual surveys.

(a) Relative to §§ 42.09-15(d) and 42.09-20(c), the assigning and issuing authority shall make an annual survey of each vessel holding an appropriate certificate issued under this subchapter.

(b) The annual survey shall be of such scope and extent so as to ensure:

(1) The maintenance in an effective condition of the fittings and appliances for the:

(i) Protection of openings;

(ii) Guardrails;

(iii) Freeing ports; and,

(iv) Means of access to crew's quarters.

(2) That there have not been alterations made to the hull or superstructure which would affect the calculations determining the position of the load line marks.

(c) The assigning and issuing authority shall report on the annual survey made to the owner of the vessel.

APPENDIX D

EXCERPTS FROM ABS SURVEY REQUIREMENTS

45.1.12 Drydocking Survey

a *Interval* An examination of each classed vessel is to be made in dry dock at intervals not exceeding two years. For vessels operating in salt water for less than six months each year, the maximum interval is not to exceed three years. Proposals for alternate means for providing underwater inspection equivalent to Drydocking Survey will be considered. Consideration may be given to any special circumstances justifying an extension of the interval.

b *Parts to be Examined* The vessel is to be placed in dry dock or upon a slipway and the keel, stem, stern frame or stern post, rudder and outside of plating are to be cleaned and examined together with appendages, the propeller, exposed parts of the stern bearing assembly, rudder pintle and gudgeon securing arrangements, sea chests, strainers and their fastenings. The stern bearing clearance and rudder bearing clearances are to be ascertained and reported upon.

45.3 Annual Surveys—Hull

45.3.1 Parts to be Examined

At each Annual Survey between Special Surveys the vessel is to be generally examined and placed in satisfactory condition as necessary. The survey is to include the following:

a All accessible parts of the steering arrangements, including the steering machinery, quadrants, tillers, blocks, rods, chains, telemotor or other control transmission gear, and brakes.

b Sluice valves, doors in watertight bulkheads and vessel's sides, closing appliances in enclosed superstructure bulkheads and for air vent and sounding pipes including pressure-vacuum valves and flame screens.

c Coamings and closing arrangements of ventilators to spaces below the freeboard deck and into enclosed superstructures, hatchway coamings, tarpaulins, hatch covers, and all their supports.

d All accessible parts particularly liable to rapid deterioration.

e Exposed machinery casings, guard rails and all other means of protection provided for openings and for access to crew's quarters.

f Freeing port doors in bulwarks of enclosed wells in freeboard and superstructure decks are to be examined and their hinges put in good order; fittings for securing shutters are not to prevent the shutters from opening in the event of a substantial amount of water coming aboard.

g The holds and 'tween decks of vessels engaged in the dry bulk-cargo trade, at each Annual Survey after Special Survey No. 3.

h Where readily accessible, a general external examination is to be made of the exposed cargo containment and handling system including the supporting and positioning arrangements, hatches, access arrangements, tank penetrations, insulation where fitted, and adjacent hull structure, of independent cargo tanks other than LNG/LPG tanks which are covered in 45.23. Fixed insulation need not be removed unless deemed necessary by the attending Surveyor.

45.3.2 Special Load Lines
Where vessels have timber, tanker or special load lines, an examination is to be made of the structural arrangements, fittings and appliances upon which such load lines are conditional.

45.3.3 Position of Load Lines
The Surveyors are to satisfy themselves at each Annual Survey that no material alteration has been made in the hull, superstructures or means of closing openings in superstructures which affects the position of load lines.

45.5 Intermediate Surveys

45.5.1 Salt Water Ballast Tanks

a *Unprotected Tanks* At a survey approximately two years after entering service and after each subsequent Special Survey, at least two tanks within the length of the cargo space used primarily for salt water ballast, are to be examined internally. Conditions found are to be considered as representative of all such tanks.

b *Protected Tanks* At a survey approximately two years after entering service and after each subsequent Special Survey, the Surveyor is to determine to his satisfaction that the corrosion control in tanks used primarily for salt water ballast is effectively protecting the structure.

45.5.2 Tankers
At a survey approximately two years after the Special Survey No. 1 and after each subsequent Special Survey has been credited in addition to the parts outlined in 45.3.1, the following are to be examined, placed in satisfactory condition and reported upon.

a Pump rooms, cargo and stripping pumps, and associated valves and piping and cargo piping on deck.
b Vent piping together with pressure-vacuum valves and flame screens.
c Where considered necessary by the Surveyor, the cargo piping may be subjected to a pressure test or the thickness is to be ascertained or both.
d Electrical equipment and cables in pump rooms and areas adjacent to cargo tanks as far as practicable without undue disturbance of fixtures. The insulation resistance of these circuits is to be measured.
e The Surveyor is to satisfy himself that no alterations to cargo or vent piping or electrical equipment has been carried out without proper approval.

At a survey approximately two years after the Special Survey No. 3 and after each subsequent Special Survey has been credited, in addition to the parts outlined above and in 45.3.1, some of the cargo tanks are to be examined internally and placed in satisfactory condition and reported upon.

45.5.3 Dry-cargo Vessels
At a survey approximately two years after the Special Survey No. 4 and after each subsequent Special Survey has been credited, in addition to the parts outlined in 45.3.1, some of the holds are to be examined internally and placed in satisfactory condition and reported upon.

45.7 Special Periodical Surveys—Hull

45.7.1 Special Periodical Survey No. 1

Special Periodical Survey No. 1 is to include compliance with all Annual Survey requirements, and the Surveyors are to satisfy themselves, by examination in position, that all means of protection to openings are in good condition and are readily accessible. Effect also is to be given to the following requirements.

a The vessel is to be placed in dry dock or upon a slipway and all items of 45.1.13b are to be examined.

b The rudder is to be examined and lifted when required and the gudgeons rebushed. The condition of carrier and steadiment bearings and the effectiveness of stuffing boxes are to be ascertained when the rudder is lifted.

c Particular attention is to be given to overboard discharges, ash chutes, and all other openings in the shell, casings being removed so that a proper examination can be made.

d The holds, 'tween decks, deep tanks, cargo tanks, peaks, bilges and drain wells, engine and boiler spaces, and coal bunkers are to be cleaned out and the surfaces of the framing and plating are to be cleaned and examined.

e All watertight bulkheads are to be examined.

f Close ceiling in holds and coal bunkers of single-bottom vessels is to be lifted to the extent of at least two strakes on each side (one strake being at the bilge) and all portable hatches in holds and the flooring plates in machinery spaces are to be removed for internal examination of the bottom framing and plating.

g The cement or other composition on the inner surface of the bottom plating is to be carefully examined and sounded to ascertain if it is adhering satisfactorily to the plating.

h Where a double bottom is fitted, the tanks and cofferdams are to be thoroughly cleaned out and examined internally; sufficient ceiling is to be lifted from the double bottom to enable the Surveyor to satisfy himself as to the condition of the tank-top plating, and if necessary, all ceiling is to be removed for cleaning and coating the top plating. All ballast tanks are to be cleaned and examined internally. Requirements for tanks which are used exclusively for permanent ballast, and are fitted with an effective means for corrosion control, will be specially considered.

i Independent oil tanks in machinery spaces are to be externally examined and, if considered necessary, tested under liquid head.

j Where double-bottom and other tanks are used primarily for heavy oil fuel or exclusively for light oils, the gas freeing and internal cleaning and examination may be waived, except for the fore-and-after peak tanks, provided that, upon a general external examination of the tanks, the Surveyor finds their condition to be satisfactory.

k Double-bottom, deep, ballast, peak, and other tanks are to be tested with a head of liquid to the highest point that liquid will rise under service conditions. The testing of double bottoms and other spaces not designed for the carriage of liquids may be omitted provided an internal examination is carried out together with an examination of the tanktop and, in the opinion of the Surveyor, testing may be waived. For deep tanks designed and used for the carriage of liquid cargoes, an alternate means of testing may be approved, provided the Surveyor is satisfied with the internal and external condition of the tanks and associated structure.

l The Surveyor is to see that a thick steel plate is securely fixed below each sounding pipe for the rod to strike upon, in all dry places and in those tanks which are accessible for internal examination.

m The decks are to be examined and deck compositions are to be examined and sounded, but need not be disturbed if found to be adhering satisfactorily to the plating.

n The hawse pipes are to be examined. Anchors and chain cables are to be examined if they are ranged and the required complement and condition verified.

o The efficiency of hand pumps or other drainage arrangements for end spaces is to be tested.

p In insulated cargo spaces all limbers and hatches are to be removed and the plating examined.

q Steel cargo hatch covers not fitted with tarpaulins are to be hose tested or otherwise proven tight.

r Load line marks are to be checked and recut or painted as required.

s In any part of the vessel where wastage is evident, the Surveyor may require gauging of the affected parts.

t The requirements of 45.7.1t1 through 8 apply to independent cargo tanks other than those on liquefied gas carriers (see 45.23). The following items are to be examined insofar as applicable.

1 *Cargo Tanks* An internal examination is to be made of all cargo tanks including internal mountings and equipment. The tanks are to be thoroughly cleaned and cleared of gas before inspection, and every precaution is to be taken to insure safety during examination.

2 *Cargo Tank Supports and Hull Structure Fittings* Foundations, chocks, sway braces, keys, and anti-flotation arrangement are to be examined.

3 *Cargo Tank Venting Systems and Liquid-level Indicators* Venting systems for the cargo containment system are to be examined. All relief valves are to be opened, examined, tested, and readjusted as necessary. Liquid-level indicators are to be proven in order. Where a proper record of continuous overhaul and retesting of individually identifiable relief valves is maintained, consideration will be given to acceptance on the basis of opening, internal examination, and testing of a representative sampling of valves including each size of each type of relief valve in use, provided there is logbook evidence that the remaining valves have been overhauled and tested since the crediting of the previous Special Survey. The testing and setting of relief valves may be carried out in place or after removal.

4 *Cargo Handling Systems* All piping, machinery, and equipment for loading, unloading, venting, compressing, refrigerating, liquefying, heating, or otherwise handling the cargo are to be generally examined. All quick-closing and emergency shutoff valves in the cargo piping systems are to be examined and tested.

5 *Insulation Removals* Insulation is to be removed in way of any distorted or otherwise suspect part in the cargo containment system and elsewhere as required by the Surveyor. Insulation may be required to be removed to carry out any of the previous items at the discretion of the Surveyor.

6 *Gauging* Where there is evidence of corrosion, the plating or structure of the independent tank is to be gauged by nondestructive means to determine the thickness.

7 *Tightness Test* Tanks, other than independent pressure tanks, are to be tested with a head of liquid to the overflow or by an alternative method meeting the approval of the attending Surveyor. In certain designs water should not be used as the test liquid as it may overstress or contaminate the tank.

8 *Independent Pressure Tanks* Independent pressure tanks, complying with the requirements of Section 32, are to be hydrostatically, hydropneumatically, or otherwise pressure tested at each Special Survey. This requirement may be modified at alternate Special Surveys (Nos. 2, 4, 6, etc.) if the internal and external survey of such pressure vessels indicates no evidence of leakage, distortion, or wastage. The test pressure is to be 1.25 times the maximum allowable relief valve setting (MARVS) which corresponds to the maximum allowable working pressure of the independent tank.

45.7.2 Cleaning and Testing of Tanks in Tank Vessels

In vessels intended for the carriage of oil or liquid chemicals in bulk, the tanks are to be thoroughly cleared of gas and cleaned before inspection, and every precaution is to be taken to insure safety during inspection. Some means are to be provided for reasonable access to the upper parts of the cargo tanks as required for examination of suspect areas. Where fitted, anodes and their attachments are to be examined. The bulkheads at the ends of cargo-tank spaces are to be tested with a head of liquid up to the top of the expansion trunk or by an alternative method meeting the approval of the attending Surveyor. The Surveyor is to be satisfied as to the tightness of the remaining cargo-tank bulkheads.

45.7.3 Special Periodical Survey No. 2

Special Periodical Survey No. 2 is to include compliance with all requirements for Special Periodical Survey No. 1 and with those which follow:

a Close ceiling in vessels with a single bottom is to be lifted to an extent which permits all material below the ceiling to be properly examined; in vessels with double-bottom tanks sufficient ceiling and flooring is to be lifted to enable the Surveyor to satisfy himself as to the condition of the material in tank tops, bulkheads, tunnels, side framing and piping.

b All double-bottom and other tanks and cofferdams are to be thoroughly cleaned, gas freed, and examined internally. In cases where double-bottom tanks are used primarily for heavy oil fuel or exclusively for light oils, if upon external examination of bottom and side shell plating in conjunction with examination of the tank top plating the Surveyor finds the condition of the plating satisfactory, the cleaning and gas freeing of the double-bottom oil tanks may be waived. Likewise the cleaning, gas freeing, and internal examination of other tanks (excluding the peak tanks) used for oil fuel may be waived if, upon external examination of bottom and side shell plating in conjunction with examination of the tank top plating, the Surveyor finds the condition of the plating satisfactory.

c A thorough examination is to be made of the deck, shell, and other main scantlings in order to determine the general condition of the structure; and the thicknesses of these members are to be determined to the extent deemed necessary after a review by the Hull Technical Staff. Where corrosion preventive arrangements have been adopted, satisfactory evidence of continued effectiveness is to be verified.

d Plating, in way of airports especially, is to be examined. In this and any other part of the structure where wastage is evident, the Surveyor may require holes to be drilled in order to obtain the actual thickness of material.

e The anchor cables are to be ranged and examined together with anchors, chain locker, and holdfasts. Chain cables are to be renewed in cases where it is found that the links have been so far worn that their mean diameter is 12% below the original required nominal size.

f Where structural alterations to the vessel have had the effect of so increasing the equipment requirements as to bring the vessel into a higher numeral, the original chain cables may be used until their mean diameter has been reduced 12% below the nominal diameter of the larger cable required by the higher numeral.

g For tankers, all items listed in 45.5.2 are to be examined.

45.7.4 Special Periodical Survey No. 3

Special Periodical Survey No. 3 is to include compliance with all requirements for Special Periodical Survey No. 2 and with those which follow.

a Close ceiling, spar ceiling, and wood lining is to be removed in sufficient quantity to enable the Surveyor to satisfy himself as to the condition of the structure underneath such ceiling and lining. Casings in the holds and platform plates in the machinery spaces are to be removed as required by the Surveyor. The vessel is to be made sufficiently free from rust inside and out in order to expose for examination the framing and plating, together with discharge, scupper, air, and sounding pipes.

b When the vessel is thus prepared, the outer and inner surface of the shell plating and the framing, floors, brackets, reverse bars, keelsons, girders, tank-top plating, engine and boiler seatings, shaft tunnels, thrust and shaft stools, beams, watertight bulkheads, rivets, stringers, and decks are to be examined and found or placed in good condition.

c The thicknesses of the shell and deck plating and such other parts of the vessel as are liable to excessive corrosion are to be determined; where a material reduction from the required scantlings is found to have taken place, the structure is to be dealt with as found necessary by the Surveyor.

d In the case of vessels carrying oil in bulk, the thicknesses of the shell, deck, and other main scantlings are to be determined.

e All double bottoms, cofferdams, and other tanks are to be thoroughly cleaned, gas freed, and examined internally. In the case where double-bottom tanks are used primarily for heavy oil fuel or exclusively for light oils, a foreward double-bottom tank is to be thoroughly cleaned, gas freed, and examined internally and, if found satisfactory, the cleaning and gas freeing of the remaining fuel-oil double-bottom tanks may be waived, provided that, upon a general external examination of the tanks, the Surveyor finds their condition satisfactory. Likewise, the cleaning, gas freeing, and internal examination of other tanks (excluding the peak tanks) used for oil fuel may be waived if, after a general examination, the Surveyor finds their condition satisfactory.

f Where sidelights are fitted, the condition of the plating in way of same is to be ascertained and, in way of cabin accommodations the lining may, in the first instance, be removed so that the Surveyor may judge as to the condition of the hull at those parts and, if upon such examination it be considered necessary, additional lining is to be removed.

g When spaces are insulated in connection with refrigeration, the limbers and hatches are to be lifted and enough lining is to be removed from all spaces to enable the Surveyor to satisfy himself as to the general condition of the plating and framing in way of the insulation.

h The plating of all independent cargo tanks (shell, heads, and domes) is to be gauged by nondestructive means to determine the thickness. At subsequent Special Periodical Surveys special consideration will be given to modifying this requirement upon prior application from owners.

45.7.5 Special Periodical Surveys Nos. 4 and 5

These surveys are to be at least as comprehensive as Special Periodical Survey No. 3 with special attention being given to the condition and thickness of material liable to corrosion. The thicknesses of the shell, deck and other members which have not previously been ascertained are to be determined, having regard to the degree of wastage previously indicated by a review of the records of the vessel. All double bottoms, cofferdams, and other tanks are to be thoroughly cleaned, gas freed, and examined internally. In the case where double-bottom tanks are used primarily for heavy oil fuel or exclusively for light oils, one double-bottom tank forward, one in vicinity of amidships, and one aft is to be thoroughly cleaned, gas freed, and examined internally and, if found satisfactory, the cleaning and gas freeing of the remaining fuel-oil double-bottom tanks may be waived, provided that, upon a general external examination of the tanks, the Surveyor finds their condition satisfactory. Likewise, the cleaning, gas freeing, and internal examination of other tanks (excluding the peak tanks) used for oil fuel may be waived if, after a general examination, the Surveyor finds their condition satisfactory.

45.7.6 Special Periodical Survey No. 6

This survey is to be at least as comprehensive as Special Periodical Survey No. 4 and in addition at least one double-bottom tank in way of each cargo hold is to be thoroughly cleaned, gas freed where oil is carried and examined internally. The actual scantlings of the vessel are to be ascertained by the Surveyor and reported in detail to the Committee.

45.7.7 Special Periodical Surveys Subsequent to No. 6

These surveys are to be at least as comprehensive as Special Periodical Survey No. 6. The requirements for gaugings of the scantlings are to be specially considered after a review of the record of the previous gaugings.

45.9 Annual Surveys—Machinery

A general inspection of engines, boilers, steering machinery, windlass and fire-extinguishing apparatus required for Classification as outlined in Section 39 is to be made during each year of service.

45.11 Special Periodical Surveys—Machinery

45.11.1 Correlation with Hull Special Surveys

Main and auxiliary engines of all types are to undergo Special Periodical Survey at intervals similar to those for Special Surveys on the hull, in order that both may be recorded at approximately the same time. In cases where damage has involved extensive repairs and examination, the survey thereon may, where approved by the Committee, be accepted as equivalent to a Special Periodical Survey.

45.11.2 Parts to be Examined

At each Special Periodical Survey effect is to be given to the following requirements.

a All openings to the sea, including sanitary and other overboard discharges, together with the cocks and valves connected therewith, are to be examined internally and externally while the vessel is in dry dock; and the fastenings to the shell plating are to be renewed when considered necessary by the Surveyor.

b Pumps and pumping arrangements, including valves, cocks, pipes, and strainers, are to be examined. Nonmetallic flexible expansion pieces in the main saltwater circulating system are to be examined internally and externally. The Surveyor is to be satisfied with the operation of the bilge system, including an internal examination of the emergency bilge suction valve. Other systems are to be tested as considered necessary.

c Shafts (except the tail shaft), thrust bearings, and lineshaft bearings are to be opened for examination.

d The foundations of main and auxiliary machinery are to be examined.

e Evaporators and other unfired pressure vessels necessary to the vessel's operation are to be opened for examination, gauged if considered necessary, and associated relief valves intended for working pressure above 3.5 kg/cm^2 (50 psi) are to be proven operable.

f Examination of the steering machinery is to be carried out, including an operational test and checking of relief-valve settings, and the machinery may be required to be opened for further examination as considered necessary by the Surveyor.

g Reduction gears are to be opened as considered necessary by the Surveyor in order to permit the examination of the gears, gear teeth, spiders, pinions, shafts, and bearings.

h An examination of the fire extinguishing apparatus required for Classification as outlined in Section 39 is to be made in order that the Surveyor may satisfy himself as to its efficient state.

45.11.3 Engines and Turbines

a In addition to the foregoing requirements, turbine blading and rotors, cylinders, pistons, valves, condensers, and such other parts of main and auxiliary machinery as may be considered necessary, are to be opened up for examination. At Special Periodical No. 1 only, for vessels having more than one main propulsion ahead turbine with emergency steam crossover arrangements, the turbine casings need not be opened provided approved vibration indicators and rotor position indicators are fitted and that the operating records are considered satisfactory by the Surveyor. An operational test of the turbines may be required if considered necessary by the Surveyor.

b Exhaust steam turbines, gears, and clutches are to be opened and examined together with the shaft tapers in way of internal couplings of driving shafts.

c Main steam piping is to be examined, and where considered necessary by the Surveyor, sections may be required to be removed for examination. Alternatively, for installations operating at temperatures not exceeding 427C (800F), hydrostatic tests to $1\frac{1}{4}$ times the working pressure may be accepted. Copper pipes are to be annealed before the test. Where considered desirable by the Surveyor, the thickness is to be ascertained to determine the future working pressure.

45.11.4 Internal-combustion Engines

a In addition to the foregoing applicable requirements, cylinders, cylinder heads, valves and valve gear, fuel pumps, scavenging pumps, and superchargers, pistons, crossheads, connecting rods, crankshafts, clutch, reversing gear, air compressors, intercoolers, and such other parts of the main and auxiliary machinery as are considered necessary are to be opened out for examination. Parts which have been examined within twelve months need not be examined again except in special circumstances.

b Air reservoirs are to be examined and their relief valves proven operable. If air reservoirs cannot be examined internally they are to be gauged by nondestructive means or hydrostatically tested.

45.11.5 Examination During Overhaul

On all occasions of overhaul or adjustment, facilities are to be provided for the Surveyor to examine the parts opened; in the event of defects being discovered, such other parts as may be considered necessary are to be opened and examined.

45.11.6 Examination at Shorter Intervals

If it be found desirable, upon inspection, that any part of the machinery should be examined at shorter intervals than specified above, it will be necessary for Owners to comply with the Committee's requirements in this respect.

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