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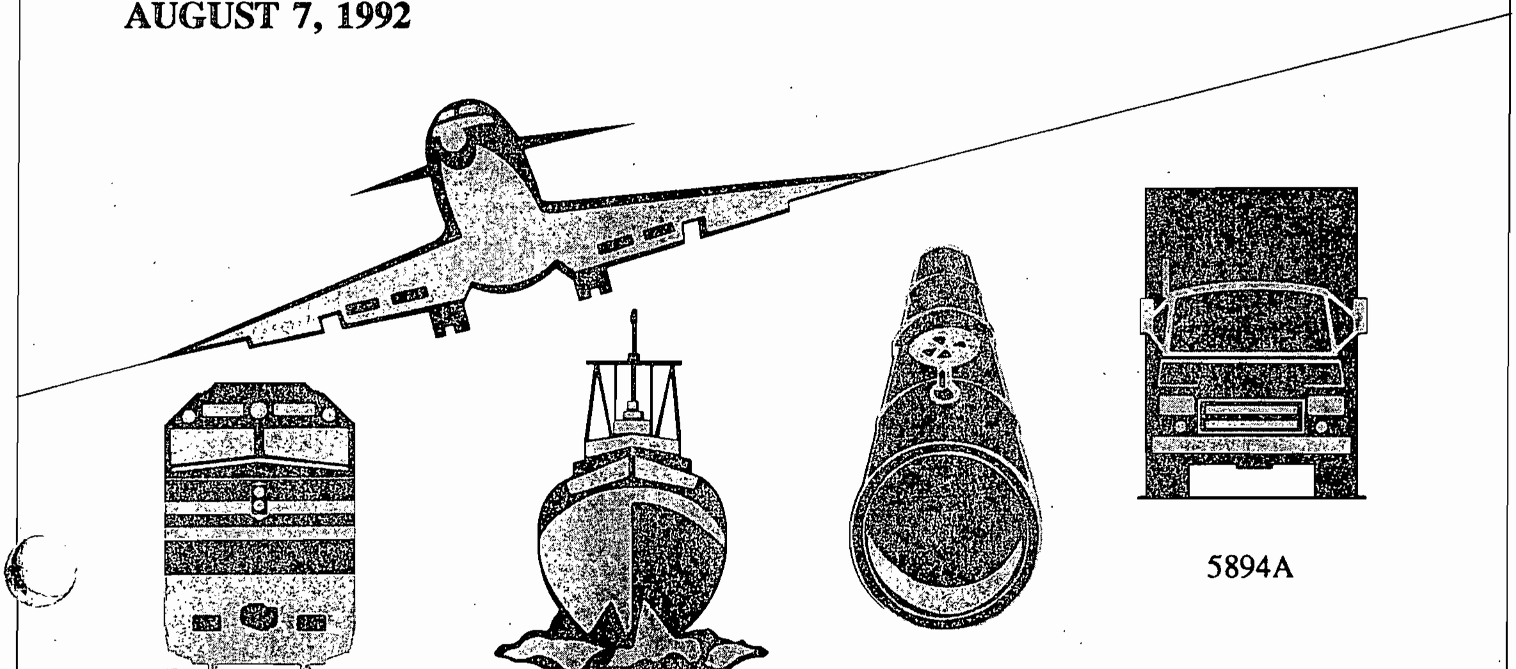
NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

MARINE ACCIDENT REPORT

GROUNDING OF THE UNITED KINGDOM PASSENGER VESSEL RMS QUEEN ELIZABETH 2 NEAR CUTTYHUNK ISLAND VINEYARD SOUND, MASSACHUSETTS AUGUST 7, 1992



5894A

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NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

MARINE ACCIDENT REPORT

ADOPTED: MAY 25, 1993

NOTATION 5894A

On August 7, 1992, the United Kingdom passenger vessel RMS (Royal Mail Ship) QUEEN ELIZABETH 2 was outbound in Vineyard Sound, Massachusetts, when the vessel grounded about 2 1/2 miles south of Cuttyhunk Island. No injuries or deaths resulted from this accident. However, damage was significant; temporary and permanent repairs cost about $13.2 million. In addition, the total revenue lost for the period before the vessel returned to service on October 2, 1992, was estimated at $50 million.

In this report the following safety issues are discussed: the adequacy of shipboard communication; the adequacy of bridge resource management; the adequacy of squat information; the adequacy of navigation chart survey information; the adequacy of Coast Guard instructions to field personnel for drug and alcohol testing of personnel involved in accidents; and the adequacy of shipboard evacuation procedures for disabled passengers.

As a result of its investigation, the Safety Board made recommendations addressing these issues to the U.S. Coast Guard, Department of Transportation, National Oceanic and Atmospheric Administration, Cunard Lines, Ltd., and to State pilot commissions.

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EXECUTIVE SUMMARY

On August 7, 1992, the United Kingdom passenger vessel RMS (Royal Mail Ship) QUEEN ELIZABETH 2 was outbound in Vineyard Sound, Massachusetts, when the vessel grounded about 2 1/2 miles south of Cuttyhunk Island. No injuries or deaths resulted from this accident. However, damage was significant; temporary and permanent repairs cost about $13.2 million. In addition, the total revenue lost for the period before the vessel returned to service on October 2, 1992, was estimated at $50 million.

The National Transportation Safety Board determines that the probable cause of the grounding of the QUEEN ELIZABETH 2 was the failure by the pilot, master, and watch officers to discuss and agree on a navigation plan for departing Vineyard Sound and to maintain situational awareness after an unplanned course change. Contributing to the accident was the lack of information available on the QUEEN ELIZABETH 2 about how speed and water depth affect the ship's underkeel clearance. The safety issues discussed in this report are as follows:

- Adequacy of communication among the master, the pilot, and the bridge watch regarding the ship's navigation plan, including speed and trackline.
- Adequacy of bridge resource management.
- Adequacy of information available to the master and the pilot of the QUEEN ELIZABETH 2 about the reduction in underkeel clearance that occurs as speed increases.
- Adequacy of the survey information on National Oceanic and Atmospheric Administration navigation charts.
- Adequacy of Coast Guard instructions to field personnel for drug and alcohol testing of personnel involved in accidents.
- Adequacy of shipboard evacuation procedures for disabled passengers.

As a result of its investigation, the Safety Board made recommendations addressing these issues to the U.S. Coast Guard, Department of Transportation, National Oceanic and Atmospheric Administration, Cunard Lines, Ltd., and to State pilot commissions.

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GROUNDING OF THE UNITED KINGDOM PASSENGER VESSEL RMS QUEEN ELIZABETH 2 NEAR CUTTYHUNK ISLAND, VINEYARD SOUND, MASSACHUSETTS, AUGUST 7, 1992

INVESTIGATION

The Accident

On August 7, 1992, at 2158, the 963-foot-long United Kingdom (U.K.) passenger vessel RMS QUEEN ELIZABETH 2 (QE2) grounded on a rocky shoal south of Cuttyhunk Island, Massachusetts. The vessel, which was carrying 1,824 passengers and 1,003 crewmembers, was leaving Vineyard Sound, off the northwest coast of the island of Martha's Vineyard (The Vineyard). (See figures 1 through 3.)

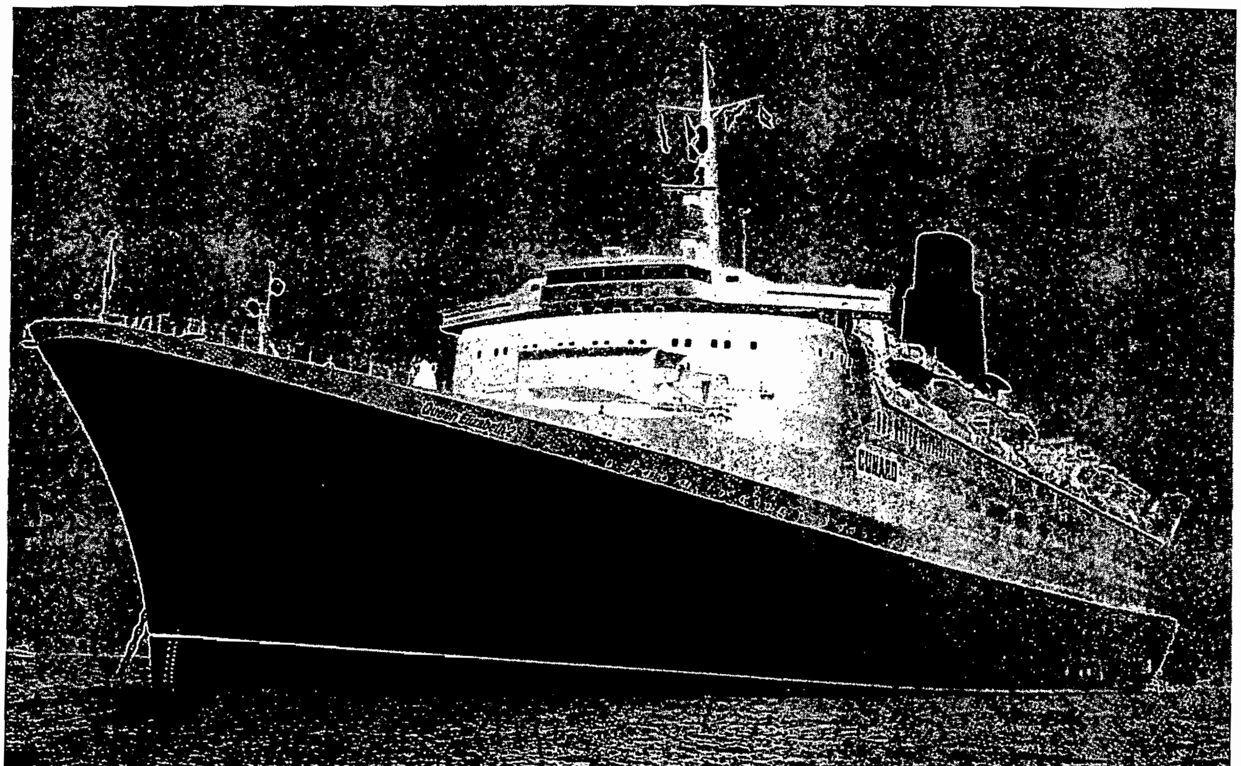

Figure 1.--United Kingdom passenger vessel
RMS QUEEN ELIZABETH 2 at anchor off Oak Bluffs.
(Photograph courtesy of Timothy M. Brown.)

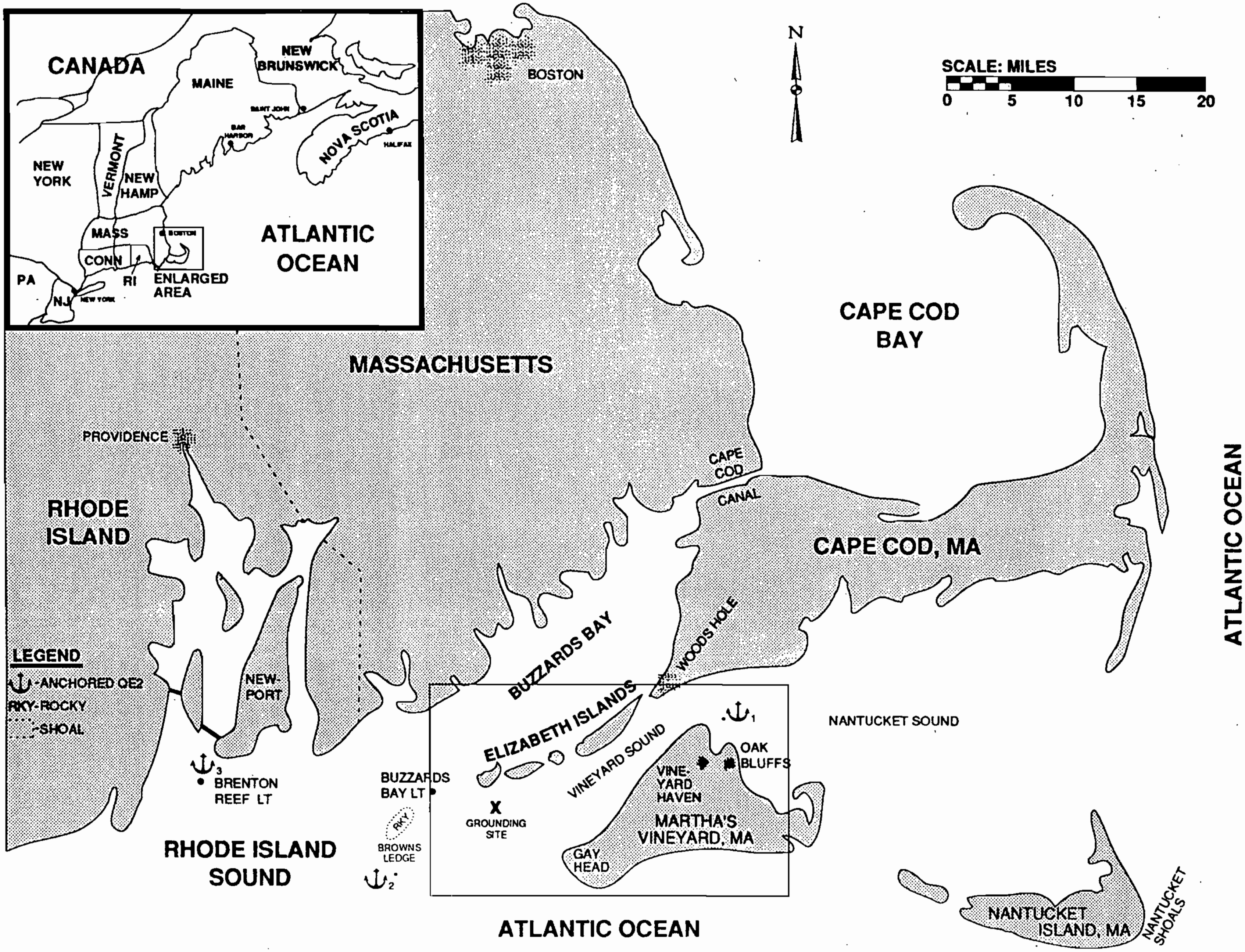

Figure 2.--Accident site.

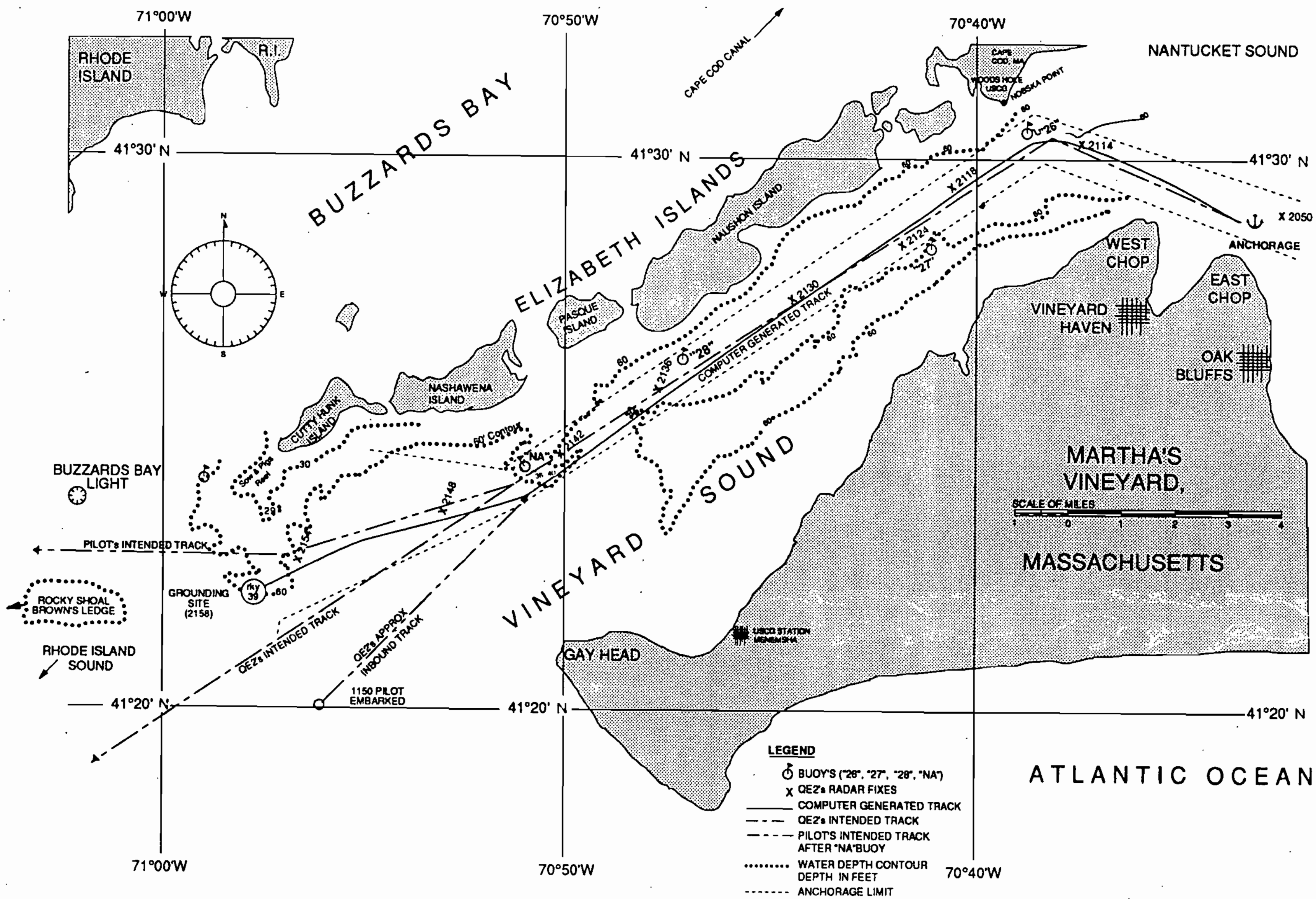

Figure 3.--Accident site (larger scale).

The vessel had departed from the anchorage near the town of Oak Bluffs at 2050. The scheduled departure time was 2000, but due to a delay in boarding the returning passengers, the vessel sailed about 50 minutes late. Initially, the master had the conn and used the main engines and the bow thrusters to turn the vessel to the proper heading before turning the conn over to a Massachusetts State pilot, the same pilot who had guided the vessel into Vineyard Sound earlier that day. The pilot testified that after the anchor was raised, "There was, as I recollect, a small discussion about what time we would make the pilot station and if we could run at a good speed. And the courses were fairly self-explanatory. We would primarily follow...the inbound passage." Regarding the outbound passage, the master stated that after the ship's navigator[1] laid out the trackline for exiting Vineyard Sound, he approved it. He was not aware of the pilot's plan to alter course at the "NA" buoy and pass north of Brown's Ledge shoal to get to the pilot's disembarkation point.

In addition to the master and the pilot, the navigating bridge of the QE2 was staffed by the scheduled 8-12 (0800-1200, 2000-2400) bridge watch consisting of a first officer (senior watch officer), a second officer, a quartermaster, and a helmsman. The helmsman, who was assigned to steer the vessel, took his orders directly from the pilot. No language difficulties were reported between the pilot and the navigation watch on the bridge.

Both of the vessel's radars were in operation. The forward radar was available for use by the master and the pilot, while the after radar was used by the second officer to fix the vessel's position. Two of the vessel's three echo sounders[2] were operating. The nonoperating unit was equipped with an analog readout and located in the wheelhouse; both operating echo sounders had recorders and were located in the chart room. The steering control was set on manual and both hydraulic steering engine pumps were operating.

As the QE2 left the Oak Bluffs anchorage, it proceeded at slow speeds because of small boat and ferry traffic in the area. When the master asked the pilot about speed restrictions in Vineyard Sound, the pilot replied that there were none other than maneuvering through traffic. At approximately 2115, the vessel rounded West Chop at the north end of The Vineyard, leaving buoy "26" close to starboard. After local marine traffic had cleared sufficiently, the ship's speed was increased from 15 to 18 knots. Based on the vessel's positions as plotted by the second officer from 2114 until 2124, the Safety Board calculated the vessel's average speed at 17.5 knots.

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[1]The ship's navigator was a first officer not on duty at the time of the accident. The officers of each bridge watch could make course adjustments to the navigator's original trackline as necessary.

[2]An echo sounder or electronic depth sounder is an instrument that indicates water depth below the bottom hull plating. The water depth is determined by transmitting and receiving a signal at the speed of sound through water (about 1,483 meters per second or about 4,800 feet per second). The signal is transmitted toward the sea floor from a device in the ship's bottom hull plating, which also receives the signal "echo" from the sea floor. The echo sounder measures the elapsed time between transmitting and receiving the signals to compute the water depth. It is also called a fathometer, which is a brand name for certain commercial echo sounders.

The master's standing orders required the bridge watch to frequently fix the position of the vessel on the navigation chart of the area, particularly when in pilotage waters. The second officer obtained ranges and bearings using prominent land masses adjacent to the waterway that could be readily observed on radar and identified on the chart. The vessel's position was plotted every 6 minutes for convenience in calculating speed. The master stated that the second officer was to advise him only if the vessel appeared to deviate to any extent from the trackline that the ship's navigator had drawn on the charts and that the master had approved. When the navigator plotted the courses in and out of Vineyard Sound, he used the information in the *British Pilot Book*,[3] a publication containing information similar to that found in the *U.S. Coast Pilot*.[4] He stated that the publication recommended that vessels proceeding in and out of Vineyard Sound should pass southeast of the "NA" buoy. Using the information found in the *British Pilot Book*, the navigator plotted a trackline on British Admiralty (BA) chart 2456 that was clear of the 36-foot depth near the "NA" buoy but passed over the 40-foot sounding 1/2 mile east-southeast of the buoy.[5] He plotted the trackline well south of the 10-fathom (60-foot) contour line, which enclosed the rocky area that had a 39-foot depth sounding, about 2 1/2 miles south of Cuttyhunk Island or about 1 mile south of Sow and Pigs Reef. The navigator said that he also placed marks on this shoal and others to indicate that the person using the chart should "be aware of this area."

After leaving the anchorage and until 2148, the vessel's positions were plotted on National Oceanic and Atmospheric Administration (NOAA) Chart 13233, as well as on BA Chart 2456. After 2148, the positions were plotted on BA Chart 2890. According to the ship's navigator, the BA charts were preferred over the U.S. charts in U.S. waters because the British Notice to Mariners, which was readily available, referenced the BA charts by number. However, the NOAA charts were also used because they were drawn to a larger scale than the BA charts of the area.

The pilot testified that after he made the turn at buoy "26," he set the course of the vessel at 237° per gyrocompass. He recalled that there was negligible gyro error.[6] He adjusted the base course as needed in increments of a degree or two to "make the buoys that I wanted." Although the navigator had laid out a trackline on the charts that had been approved by the master, the pilot indicated that he preferred to pilot by his own method, testifying that "I had

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[3]*British Pilot Book--East Coast of the United States Pilot*, Crown Copyright Stationary Publication NP-68, volume I, 7th edition, May 23, 1975, and supplement no. 10-1991, November 30, 1991.

[4]*United States Coast Pilot, Volume 2--Atlantic Coast: Cape Cod to Sandy Hook*, Coast and Geodetic Survey, National Ocean Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 26th edition, 1992.

[5]The vessel's draft had been calculated earlier at 32 feet 4 inches forward and 31 feet 4 inches aft. The master testified that draft configuration was the result of his instructions and stated that the vessel handled better with a 1-foot trim forward.

[6]All courses are assumed to be true unless otherwise noted.

in my own mind my own practice of proceeding out of Vineyard Sound." He used buoys primarily and also radar from time to time to verify his position. When the pilot was asked by investigators if he had any input on the navigator's trackline, the pilot replied, "I did not consult the navigator or the ship's charts as to what courses he was laying down versus what I was to use on the outbound passage."

After the traffic had cleared, the master asked the pilot whether he objected to increasing the speed and "run[ning] at something of 24 knots outbound." The pilot first testified that he thought it was acceptable and later that he concurred with the request, and at 2124, the speed was increased accordingly. When the master was asked during testimony if the fast passage upset him or his officers he replied: "Oh, none whatsoever, sir, no. As you say, we are experienced in it." Based on the fixes plotted on the chart by the second officer from 2136 to 2158, the Safety Board calculated the average speed of the vessel to be about 24.6 knots. The master stated that to make the scheduled arrival in New York, it would be necessary to average a speed of 25 knots. He wanted to increase speed as soon as possible to avoid using any higher speed to make the schedule, although the higher speeds were available. The master testified that normal sea speed of the QE2 in the North Atlantic Ocean was 28.5 knots.

At 2144, the QE2 passed the "NA" buoy located about two-thirds of the way out of Vineyard Sound and 3.2 miles north of Gay Head on the western end of The Vineyard on a heading of 235°. With the buoy abeam[7] to starboard, the pilot altered course to the right to 250°. He testified that he intended to maintain that course until he was approximately 2 miles south of the southwestern end of Cuttyhunk Island and then steer 270° to where he would disembark. (Analysis of the course recorder trace indicated a course of 255°.) The pilot had not told the master or the watch officers of this course change, nor of his intent to alter course to 270° when the southwestern point of Cuttyhunk Island was bearing north.

At 2148, after the vessel steadied on the new course, the second officer plotted the position of the vessel on BA chart 2890 and projected a 255° trackline ahead. The pilot's trackline differed from that previously drawn on the chart by the ship's navigator. The second officer, noticing that the extended 255° trackline crossed over a shoal area approximately 7 1/2 miles ahead in Rhode Island Sound north of Brown's Ledge, informed the first officer, who in turn informed the master. The master told the first officer to tell the pilot that he would rather pass further south of Sow and Pigs Reef and toward the original trackline as marked on the ship's charts by the navigator. Shortly before 2154 (the exact time of the course alteration was not noted in the Arrival and Departure Log[8] by the quartermaster nor were any other course changes

[7]At 90° from the vessel's heading.

[8]The QE2's Arrival and Departure Log is an unofficial document from which the Official Deck Logbook is written. In it are noted the time and description of significant events, such as the return of passenger launches, heaving the anchor, and passing buoys. Major engine maneuvers along with the vessel's gyrocompass headings are also recorded here.

ordered by the pilot noted therein),[9] the pilot complied and the vessel's course was changed to 240°. The master testified "...it just seemed the best thing to do was to go south out of the way." The second officer plotted the 240° course trackline from the 2154 position toward the ship's navigator's original trackline.

After the second officer drew the 240° course trackline on the chart, he noticed that the line passed over a 6-1/2 fathom (39-foot) sounding but was not concerned because he was aware that the draft of the QE2 was 32 feet 4 inches. He said nothing to the pilot or to the senior officers on the bridge. The master was not aware of the 39-foot sounding on the chart until after the accident. The pilot stated that he "had in his mind" that the 39-foot sounding was in the area. The pilot said that he did look at the new (240°) trackline and saw that it passed clear and south of Brown's Ledge. The master also looked at the chart. According to the pilot, the predicted height of the tide during the passage out of Vineyard Sound was approximately (+)1.5 feet. Both the master and the pilot testified that they considered passing over the 39-foot sounding with a (+)1.5-foot tide not to be a problem. The pilot stated that he was using 40 feet as a minimum depth when navigating the QE2 through the area.

At 2158, the QE2 experienced severe vibrations that were felt throughout the vessel. Bridge personnel recalled two separate periods of shaking and rumblings. The master recalled that the bridge equipment rattled and shook in a manner similar to that experienced in rough seas. As the second vibration was ending, the master ordered the vessel stopped. The first officer brought the pitch control levers to the zero position, which immediately reduced the vessel's headway. The master testified that the first two reasons for the vibrations that immediately came to mind were a collision with another vessel or a machinery failure; the third and only remaining possibility was a grounding. The pilot at first suspected a mechanical failure, such as losing a propeller. The master called the engineroom and spoke with the staff chief engineer, who assured him that no mechanical difficulties existed. He asked the first officer, who was also keeping lookout, about the possibility of a collision with another vessel. The first officer replied that no other vessels were around. Only then did the master and the pilot conclude that the vessel must have grounded. The master immediately ordered the engineers to check the double-bottom tanks[10] for flooding.

As soon as they felt the vibrations, the staff captain, the chief officer, and the senior first officer reported to the bridge. The master ordered the chief officer to check all compartments aboard the QE2 for damage or flooding. After several minutes, the staff captain made the first of several announcements over the ship's public address system concerning the vibrations; at this time, he told the passengers and crewmembers that the vessel had gone over shallow water and

[9]Although the QE2 was equipped with a course recorder, both the gyrocompass heading and the time were set incorrectly. It was determined that the time factor was about (-)8 minutes in error and the course factor was about (+)24° in error.

[10]Double-bottom tank describes the watertight space between the ship's exterior bottom hull plating and the tanktop/inner-bottom plating.

was experiencing shallow-water effect. While the vessel was checked for damage, the master and the pilot discussed where the vessel had been at the time of the severe vibrations. The navigation chart was checked for depth in the area surrounding the 2158 position.

Because the QE2 eventually lost steerageway[11] and was drifting, the master ordered dead slow ahead on the pitch controls, a speed of approximately 4 knots, to maintain the heading of the vessel. He considered the speed to be safe while damage assessments were being made. The pilot concurred with the maneuver, stating that they should endeavor to stay to the south of Brown's Ledge because the Coast Guard would probably order the vessel to anchor, and he wanted to be in a position to comply.

Meanwhile, the QE2's damage control procedures began. An engineering officer and a deck officer went to the safety control room, where the remote tank-level gauges for the double-bottom tanks were located. An engineering officer went to the emergency generator room in case the ship's electrical power had been affected. The ship's damage control officer reported to the bridge with the ship's plans to coordinate damage assessments and keep the master informed. The remainder of the deck officers came to the bridge and made themselves available for any assignment.

The first damage reports came from the engineroom. Several of the double-bottom tanks that had been empty were now filled with water under pressure. The preliminary assessment of the damage revealed that 4 of the 36 double-bottom tanks were open to the sea, including a forward ballast tank, a fresh water tank, an empty fuel oil tank, a fuel oil overflow tank, and a cofferdam.[12] The tanktop in No. 3 cargo hold showed evidence of bulging upward. As a precaution, wood braces were installed between ship structural members and the tanktop plating by the damage control team. (For more detailed information on damage, see the Wreckage section.)

The pilot advised the master that the accident should be reported to the U.S. Coast Guard and offered to communicate with them. The accident was reported at 2237, after a preliminary damage assessment had been made. After evaluating the information, personnel from Coast Guard Group Wood's Hole, Massachusetts, instructed the master at 2255 to anchor and await the Coast Guard's boarding party. At 2332, the QE2 anchored in Rhode Island Sound approximately 11.5 miles west-southwest of Gay Head and about 20 miles southeast of Newport, Rhode Island. At 2348, the No. 11 lifeboat was launched, and an inspection was made around the vessel to check for traces of oil that might have leaked from a damaged empty fuel oil overflow tank.

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[11]A rate of forward movement sufficient to cause a vessel to change direction in response to rudder movement.

[12]The void space separating two compartments.

Within 45 minutes of the initial notification to the passengers over the public address system, the master announced that the vessel had grounded, was in no danger, and at the request of the Coast Guard would remain at anchor at least until early morning. He then told the passengers to get a good night's sleep and that he would talk to them in the morning.

Coast Guard Response.--The pilot reported to the Coast Guard that the QE2 had sustained bottom damage and that vessel personnel smelled oil. The QE2 had 923,454 gallons of fuel oil on board when it grounded, and the potential existed for the loss of 38,500 gallons of fuel oil from a possibly damaged double-bottom fuel oil overflow tank. A helicopter from Coast Guard Air Station Cape Cod and a utility boat from Coast Guard Station Menemsha, The Vineyard, were immediately ordered to the scene to assess the situation. Shortly thereafter, at least five Coast Guard vessels and personnel from the Coast Guard Marine Safety Detachment (MSD) Cape Cod, Massachusetts (a subunit of the Marine Safety Office Providence, Rhode Island), were ordered to the QE2. The MSD personnel were sent to assess vessel damage, assess oil pollution potential, and initiate the accident investigation. At 0201 on August 8, the MSD team boarded the QE2. Prior to boarding, the MSD boarding officer recorded the draft at 32 feet 4 inches forward and 31 feet 5 inches aft and noted that the vessel had no list. At 0549, a Coast Guard cutter rigged 1,000 feet of oil containment boom around the stern of the QE2 to collect any oil that might leak from the damaged hull. The MSD boarding officer estimated that about 50 gallons of residue fuel oil had leaked from an otherwise empty tank that had been ruptured as a result of the grounding. Coast Guard vessels stood by the QE2 from shortly after notification of the grounding until it arrived in Boston, mainly to control vessel traffic, to clean up any oil pollution, to observe passenger transfer, and to be ready in case the condition of the QE2 deteriorated.

Passenger Transfer Ashore.--Because of the damage to the QE2, Cunard decided to transfer all passengers ashore in Newport, Rhode Island. From Newport, they were to be transported by bus to Providence and then by train to New York City, where the cruise had originally been scheduled to end. About 1530 on August 8, after an underwater hull survey ordered by Cunard Lines, Ltd., was completed, 555 passengers were transported to Newport on a small passenger vessel. The vessel made only one trip. At 1725, because no other commercial vessels were available, the master requested permission from the Coast Guard to shift the QE2 closer to Newport and anchor to facilitate the transfer of the remaining 1,269 passengers. The request was granted, and the vessel moved to an anchorage about 4 miles from Newport. At 2006, after anchoring about 0.7 miles north of Brenton Reef Light Tower (Brenton Reef Light), the QE2 used five of its launches and was able to hire two local small passenger vessels to transfer the passengers ashore. By 0220 on August 9, all passengers were ashore. At 0355, the QE2 got under way for a shipyard in Boston, Massachusetts, escorted by a Coast Guard cutter and two commercial tugs. The vessel arrived in Boston at 1155 on August 10 without further incident, where it was drydocked for survey and temporary repairs.

Events Preceding the Accident

Oak Bluffs was the last scheduled port of call on a cruise that commenced in New York on August 3 and included Bar Harbor, Maine; St. John, New Brunswick; and Halifax, Nova Scotia. The QE2 departed Halifax at 1820 on August 6 and passed east of Cape Cod, east and south of Nantucket Shoals,[13] and south of The Vineyard. About 1145 on August 7, the QE2 arrived about 5 miles west of Gay Head on the western end of The Vineyard to meet the pilot boat. At 1150, the pilot boarded the vessel for the trip into Vineyard Sound. Originally, arrangements had been made to meet the pilot's launch in an area west of Buzzards Bay Entrance Light Tower (Buzzards Bay Light), about 4 miles west of Cuttyhunk Island; however, because the weather that day was favorable, the master of the QE2 requested that the pilot board south of the entrance to Vineyard Sound to avoid the shoal area south of Sow and Pigs Reef when entering Vineyard Sound, and the pilot agreed.

When the pilot arrived on the bridge of the QE2, the master recognized him as having piloted the vessel the previous year into Newport, Rhode Island. The pilot also stated that he had studied the local chart of the area prior to piloting the QE2 to refresh his memory. The pilot said that he was already familiar with the handling (maneuvering) characteristics of the vessel, having been aboard a year earlier. When the pilot boarded the QE2 off Gay Head, he said he was given "a sheet that had the full list of all the pertinent particulars that I was concerned with [pilot card]." The pilot stated that in general, he wanted to know the draft of the vessel (as recorded in the ship's log); vessel characteristics, including length and breadth; and whether the engines, the bow thrusters, and the radar were operating properly. The master did not remember whether it was at the time of the pilot's boarding or during the passage towards the anchorage that he asked the pilot where he "wanted to leave the vessel when we come out that evening." The master stated that the pilot showed him a location on the chart "roughly between Buzzards Bay Tower [Buzzards Bay Light] and Brenton Reef Tower [Brenton Reef Light]."

The master and the pilot agreed on the navigation speed for the passage through Vineyard Sound to the anchorage. As the vessel proceeded toward Vineyard Sound, the speed was increased to 18 knots, then slowed to 15 knots further into the sound; after that, the vessel operated at various speeds while approaching the anchorage at Oak Bluffs. According to the pilot, the vessel's passage into Vineyard Sound was routine. Although the pilot had suggested an alternative position closer to Oak Bluffs for the convenience of the passengers, the vessel anchored about 1330 in a position close to that previously determined by the master (see figure 3). While the vessel was anchored off Oak Bluffs, the passengers were ferried ashore in the vessel's launches. The pilot remained aboard the vessel while it was anchored because he was to pilot the vessel out of Vineyard Sound when it departed that evening.

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[13]Nantucket Shoals is the collective name for the numerous broken shoals that lie southeastward of Nantucket Island, making this one of the most dangerous parts of the United States for ships.

Injuries

No injuries or fatalities occurred during the grounding of the QE2 or during the transfer of passengers ashore.

Damage

The cost of repairs to the ship was approximately $5 million for the temporary repairs and $8.2 million for the permanent repairs, according to Cunard Lines, Ltd. The total loss of revenue during the out-of-service period of the vessel was estimated at $50 million by *Lloyd's List International*, a maritime industry publication. The QE2 was returned to service on October 2, 1992.

Pilot and Crew Information

The QE was staffed by certificated British deck and engineering officers, while the crew's ratings were multinational.

Pilot.--The pilot of the QE2 graduated from the U.S. Merchant Marine Academy, Kings Point, New York, in 1965. After graduation, he sailed for commercial steamship companies, and from 1970 until about 1973, he upgraded his licenses and obtained various pilotage endorsements for New England waters. He joined the Northeast Marine Pilots Association in 1976 after serving as a Panama Canal pilot for 14 months. Since joining the association, he had been involved in one accident in which a 40,000-ton tanker struck a pier in New York under strong tide and wind conditions. The accident, which occurred in 1989, resulted in minor damage. He was issued a master's license by the U.S. Coast Guard in December 1973 for steam or motor vessels of any gross tons, oceans; this license was last renewed on October 5, 1988, for 5 years. He also received a Pilot's Commission from the State of Massachusetts in November 1989 for District 3, which includes the waters of Vineyard Sound.

Between 1200 and 1530 on August 4, he piloted a naval vessel from Newport to sea. His last assignment before piloting the QE2 was piloting a vessel from Boston to Block Island. He worked from 1300 on August 5 to 0045 on August 6 and returned home about 0300 on August 6, leaving almost the entire day and evening for rest. The pilot did not indicate that the rest he received prior to piloting the QE2 was insufficient. He awakened about 0600 on August 7 and boarded the QE2 about noon for the voyage up Vineyard Sound to the anchorage off Oak Bluffs. After the vessel anchored at Oak Bluffs, the pilot remained on board the QE2 and went to lunch on the Lido Deck. After lunch, the pilot spent the time before departure reading, walking about the ship, and relaxing. The pilot was on the bridge when the ship commenced heaving anchor.

Master.--The master held a master's Certificate of Competency for Foreign-going Steamships, issued by the Department of Transport, United Kingdom (U.K.), in July 1960. His last 5-year renewal was in April 1988.

The master had been in command of Cunard vessels since January 1982. Prior to serving as master on the QE2, he was master of the CUNARD PRINCESS and the CUNARD COUNTESS. The master first joined the QE2 in 1968, moving up through the ranks as a second officer, junior first officer, intermediate first officer, senior first officer, chief officer, and staff captain (deputy master) before sailing as a relief master on the QE2 in November 1987. He had been the permanent master of the QE2 since August 1989.

On August 6, the evening before the QE2 arrived at The Vineyard, the master attended a reception at 2000 for passengers in one of the ship's restaurants. He dined and visited with the passengers until about 2300, after which time he went to the bridge and wrote his night orders. At 2400, the master went to the Grand Lounge to watch the evening show but soon decided to retire to his cabin for the night. He awoke at 0700, after approximately 6 to 6 1/2 hours of sleep, which he described to investigators as "plenty." In the afternoon, between bridge and desk activities, he rested for about 1 hour.

First Officer.--The 8-12 first officer aboard the QE2 went to sea in 1974 as a cadet while studying at the College of Nautical Studies, Warsash, Southampton, England. Upon graduation, he sailed for 17 years aboard Shell tankers. He also sailed bulk carriers, liquified natural gas tankers, and cross channel ferries. He joined Cunard in May 1992 as a second officer on board the QE2. He was promoted to first officer in July 1992. He held a master's Certificate of Competency for Foreign-going Steamships from the Department of Transport, U.K., issued in October 1985, and a dangerous cargo endorsement for liquified gas issued in November 1986.

The first officer stated that because he worked the 8-12 watch, he normally received 6 hours of sleep during the night before the morning watch and usually had a short nap in the afternoon.

Second Officer.--The 8-12 second officer aboard the QE2 joined Cunard in April 1991. Prior to employment with Cunard, he had served on tankers, freighters, and ammunition ships for the Royal Fleet Auxiliary Service since 1974. He held a Class 2 Certificate of Competency, issued by the Department of Transport, U.K., in April 1982.

Helmsman.--The helmsman on watch aboard the QE2 graduated from Cebu Central College, the Philippines, in 1980, with a nautical degree. He sailed for 7 years as a seaman on tugboats, passenger ships, and general cargo ships. He held a third mate's license issued by the Republic of the Philippines in February 1992 and received a certificate of qualification as an efficient deckhand from the U.K. Department of Trade in March 1992. He was at the helm when the QE2 sailed from The Vineyard. He spoke and understood English and had no difficulty understanding the pilot's orders.

Quartermaster.--The quartermaster on the 8-12 watch aboard the QE2 graduated from the Philippine Maritime Academy in 1979. He started sailing aboard Greek cargo vessels in 1983 and joined Cunard in 1989 as a quartermaster. He was issued a third mate's license by the Republic of the Philippines in October 1986 and an able seaman's (AB's) certificate from the

U.K. Department of Transport Marine Office in October 1991. The quartermaster was stationed at a small log desk at the forward end of the wheelhouse. His duties included keeping the Arrival and Departure Log.

Vessel Information

The keel for the trans-Atlantic passenger liner QE2 was laid on July 4, 1965, at the Upper Clyde Ship Builders, Glasgow, Scotland. The vessel was launched September 20, 1967, and following outfitting, embarked on its maiden voyage on May 2, 1969. The QE2's home port is Southampton, England, and Cunard Lines, Ltd., operates the vessel under the U.K. flag (official number 336703). The principal characteristics of the QE2 are as follows:

Length overall:	963 feet 1 inch (293.53 meters)
Beam:	105 feet 3.5 inches (32.09 meters)
Depth:	56 feet 0.1 inches (17.07 meters)
Draft (maximum):	32 feet 7.5 inches (9.945 meters)
Gross tonnage:	69,053
Net tonnage:	36,038
Deadweight tonnage:	15,521

The QE2 was built of all-welded-steel construction in accordance with the rules of Lloyd's Register of Shipping, receiving that classification society's highest rating for hull and machinery. The ship also met the national requirements of the British Merchant Shipping Act and the United Kingdom Department of Transport, the regulations of the International Convention for the Safety of Life at Sea 1960 (SOLAS '60), and the International Convention on Load Lines, 1966. Following completion of major modifications in 1987, the QE2 met the standards of SOLAS '74 and the International Convention for the Prevention of Pollution from Ships by Oil, 1973, as modified by the Protocol of 1978. In addition, the U.S. Coast Guard issued the vessel a letter of compliance following a control verification examination for foreign-flag vessels carrying U.S. passengers out of U.S. ports.

The QE2 has accommodations for 1,900 passengers and 1,015 crewmembers, a total of 2,915 persons. The vessel is divided horizontally into 14 decks, 10 of which are passenger decks. The navigation bridge, with the enclosed wheelhouse, is at the forward end of the signal deck, the uppermost deck on the vessel. Posted in the wheelhouse at the time of the accident was a maneuvering information fact sheet that included a maneuvering diagram and data for turning and for time and distance to stop; the fact sheet did not contain information on the ship's squat characteristics. (Hydrodynamic factors and vessel squat are discussed in the Tests and Research section of this report.) The central control station is located in the forward section of the wheelhouse; the control consoles contain various ship and machinery condition indicators, alarms, and other instrumentation, including controls for the vessel's speed and course.

The navigation equipment in the wheelhouse includes two radars, speed logs, electronic navigation units (including Global Positioning System (GPS), Satellite, Omega, and Loran C), compasses (both gyro and magnetic), and a steering control system. One echo sounder was installed in the wheelhouse and was inoperative at the time of the accident. Inside the wheelhouse and directly aft of the ship's control consoles and helm steering stand is a chart table, which was used by the second officer to plot the vessel's positions. The chartroom, located aft of the wheelhouse, contains a chart desk; positioned over the chart desk were the two operational echo sounders that record the soundings. Also in the chartroom are gyrocompass adjustment controls, a course recorder, and other equipment used by the navigator, including nautical charts and publications. The QE2's chart portfolio has about 1,500 charts covering most of the world's oceans and ports, most of which were issued by the British Admiralty Hydrographic Department; the chart portfolio also includes some U.S. charts issued by the National Oceanic and Atmospheric Administration.

Nine diesel-driven generator units, each with a rated output of 10.5 Megawatts at 10,000 volts AC, provide the vessel with 130,000 horsepower for propulsion. The generated electric power drives two electric propulsion motors, one for each propeller shaft. The vessel is equipped with a controllable-pitch propeller on each shaft. Operating a minimum of four of the nine diesel generators provides the QE2 with sufficient electrical power for all ship's services, in addition to the electrical power required for main propulsion. The electric propulsion motors can propel the ship at a full sea speed of 32 knots and a cruising speed of 28.5 knots.

The QE2's main propulsion and other machinery are installed on the lowest deck in the ship, the tanktop, also known as the inner bottom. In addition to machinery support, the tanktop provides the ship with an inner watertight barrier. If the exterior bottom hull is penetrated, the watertight inner bottom will prevent sea water from flooding the ship's interior. The inner-bottom plating also forms the top of the QE2's 36 double-bottom tanks, which are used for stowage of fuel oil, fresh water, boiler feed water, and sea water ballast. The double-bottom tanks extend across the hull from port to starboard for nearly the full length of the ship. (Double-bottom tanks are discussed in more detail in the Wreckage section.)

Wreckage

After the disembarkation of passengers following the grounding, the QE2 moved into drydock at General Ship Repair in Boston. While the ship was in drydock, Safety Board investigators conducted a damage survey on August 14, 1992, to ascertain the condition and extent of damage to the underwater hull plating, the internal structural steel in the double-bottom and deep tanks,[14] the tanktops of the double bottom, and the deep tanks. (See figure 4 for a typical double-bottom tank arrangement.)

[14]A tank in the bottom of a cargo hold used for dry or liquid cargo.

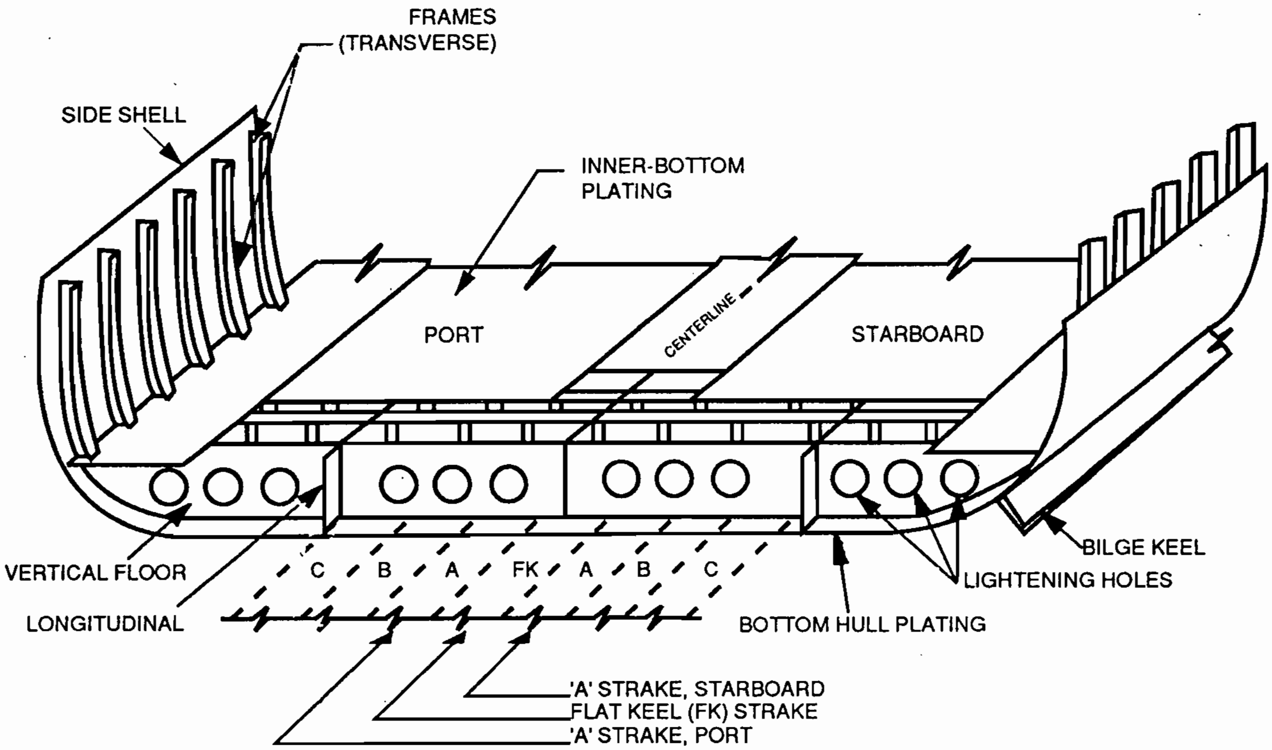

Figure 4.--Typical double-bottom arrangement.

Overall, the damage consisted of indents (dented plating pushed upward into the double-bottom space), gouges, and associated fractures in the bottom-hull plating. The damaged area extended from the bulbous bow aft to the forward diesel generator engineroom, a length of about 400 feet. The width of the damage area was 81 feet, which extended from the bilge keel on the port side to the "D" strake[15] longitudinal row of shell plating on the starboard side. The indents, gouges, and fractures were located in and to both sides of the centerline flat-keel plate. Twenty inner-bottom tanks and two void spaces sustained damage of varying degrees in the grounding. Most of the damaged tanks were water ballast tanks, except double-bottom fuel oil tanks Nos. 8, 9, and 10; of the three double-bottom tanks, only No. 10, an empty fuel oil tank, released oil residue at the time of the accident.

Starboard Hull Plating.--The forwardmost hull grounding damage consisted of a 6-inch-deep indent and heavy gouging in the starboard bottom-hull plating at the bulbous bow, about 18 inches off centerline. The most severe bottom-hull plating indents and gouging were found in the flat-keel and adjacent starboard "A" strake plating. This damage consisted of a nearly

[15]Strakes run fore and aft and are sequenced alphabetically port and starboard from the keel up; the individual plates in each strake are numbered fore and aft.

continuous series of indents about 190 feet long, 24 to 42 inches off centerline, that gradually became wider and deeper, varying from 18 to 60 inches wide and 1.5 to 14 inches deep.

The three largest bottom-hull fractures were in the area of the most severe indents, which occurred in a nearly continuous 100-foot-long line down the starboard side of the flat-keel plate and "A" strake. The first fracture was 10 feet long and was in double-bottom ballast tank No. 1. The second fracture was 70 feet long and extended through double-bottom ballast tank No. 5, double-bottom fuel oil tank No. 10, and double-bottom fresh water tank No. 15. The third fracture was 18 feet long and was in double-bottom fresh water tank No. 15. The path of the major indents and associated fractures crossed the flat-keel plating from the starboard to the port side of the centerline below the forward generator room.

Port Hull Plating.--Three adjacent areas of severe indents and gouges were found on the port bottom-hull plating. The first was 93 feet long and about 9 feet off centerline, the second was 96 feet long and about 12 feet off centerline, and the third was 105 feet long and about 15 feet off centerline. All three indents were in the bottom plating of Nos. 1, 2, 3, and 4 water ballast deep tanks, just aft of the forepeak.

Further aft were three other indents and gouges. The first was 78 feet long and about 14 feet off centerline, the second was 240 feet long and about 22 feet off centerline, and the third was 75 feet long and about 31 feet off centerline. These indents and gouges transited the No. 4 water ballast deep tank, Nos. 2, 5, and 6 water ballast double-bottom tanks, No. 8 fuel oil double-bottom tank, and No. 14 fresh water double-bottom tank. A 32-foot section of the port bilge keel was also severely damaged in the grounding.

Tank Internals.--Inside the double-bottom tanks, transverse floors and longitudinals were deformed (folded over) in the damaged area. In addition to the forepeak tank and dry tank "B," deep tanks Nos. 1, 2, 3, 4, and 5 and double-bottom tanks Nos. 1 and 3 sustained internal structural damage in the grounding. Significant internal structural steel damage was also observed in port-side double-bottom tanks Nos. 2, 4, 6, 8, and 14; starboard double-bottom tanks Nos. 7 and 9; and center double-bottom tanks Nos. 5, 10, and 15.

The inner-bottom tanktop plating over the double-bottom tanks was raised (bulged) upward into the ship in only one location in the inner-bottom plating (tanktop) of the No. 3 cargo hold. No penetration or indication of sea water leakage through inner-bottom tanktop plating was noted. The empty double-bottom tanks that were open to the sea had flooded because of fractures sustained in the grounding.

Waterway Information

Vineyard Sound lies in a northeast to southwest direction. The Sound is bounded by Nantucket Sound on the northeast, the island of Martha's Vineyard (The Vineyard) on the southeast, Rhode Island Sound to the southwest, the Elizabeth Islands to the northwest, and the southwestern part of Cape Cod to the north. The Elizabeth Islands separate Buzzards Bay from

Vineyard Sound. (Refer to figures 2 and 3 earlier in this report for a depiction of this area, including buoy locations and depths.)

The navigable portion of Vineyard Sound is marked with navigational aids for day and night navigation. Buoys 26 and 28 mark the north side of the Vineyard Sound waterway, and buoy "NA" marks the center of the waterway and can be passed on either side. (See figure 3.) Between 0009 and 0318 on August 9, the Coast Guard checked the position of navigational aids in the area of the grounding and found them to be correctly positioned and displaying the correct light characteristics according to the navigation charts and the Coast Guard light list for the area.

The NOAA chart in use at the time of the accident (No. 13218, issue date January 11, 1992) indicates that the waterway is about 0.7 of a mile wide, with depths from 35 feet up to 100 feet at mean lower low water (MLLW)[16] and with Federal anchorage areas outside the deep part of the Sound. From buoy 26 at the upper end of Vineyard Sound to the center section, between buoys 28 and "NA," outside the south side of the channel, are rocky shoal areas less than 30 feet deep. About 1/2 mile northeast of the "NA" buoy north of the center of the channel are 35- and 39-foot depths, and at the "NA" buoy, the NOAA chart indicates a 36-foot depth. After passing the "NA" buoy, depths can exceed 60 feet, except in the area close to Gay Head and Cuttyhunk Island. About 2.5 miles south of Cuttyhunk Island on the southwestern end of Vineyard Sound is a rocky area with a 39-foot depth within the 60-foot water-depth-contour curve. The rocks impacted by the QE2 are between 450 and 825 feet east of the 39-foot sounding and the rocky or shoal area shown on the NOAA and BA charts. About 1 1/2 miles south-southwest of the southwestern end of Cuttyhunk Island is a 29-foot sounding within a 30-foot water-depth contour extending from the Sow and Pigs Reef, which is also about 1 1/2 miles north of the above referenced 39-foot sounding. (See the Tests and Research section of this report for a discussion of the NOAA and Cunard Lines, Ltd., surveys.)

NOAA's Coastal and Estuarine Oceanography Branch advised that the Gay Head tidal station best predicts the water level at the accident site, which is about 5.5 miles to the west-northwest of Gay Head. According to the NOAA 1992 Tide Tables for the East Coast of North and South America, the high tide predicted for August 7 at Gay Head, The Vineyard, was 3.2 feet above MLLW at 1559 and the low tide predicted for that location was 0.7 feet above MLLW at 2355.

Using the published tide table predictions, the Coastal and Estuarine Oceanography Branch calculated the predicted tide at (+)1.08 feet above MLLW just before the grounding at 2154 and (+)1.04 above MLLW immediately after the grounding at 2200 on August 7, 1992. The actual tidal data were computed using a tide gauge at the Sakonnet Yacht Club, Sakonnet, Rhode Island, about 12 miles northwest of the grounding site. The actual tide at the time of grounding (2158) was (+)0.77 feet above MLLW.

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[16]MLLW is the chart datum (reference point) for charted depths used in this area of the coast and is the average of the lower of two daily low tides. At most states of the tide, the mariner has at least the water depth as marked on the navigation charts. Tide tables use the same reference as the navigation charts.

According to the pilot, none of the other vessels that had previously passed through Vineyard Sound had a draft as deep as the QE2's 32-foot draft. The pilot also stated that on average, three to four 20- to 26-foot draft vessels transit Vineyard Sound each year. Numerous research vessels with drafts of 15 to 19 feet visit Woods Hole Oceanographic Institute. Other traffic in the sound consists of small passenger vessels and commercial fishing vessels with drafts of less than 15 feet and during the late spring, summer, and early fall, numerous recreational vessels such as power boats and sailboats.

Ocean and coastal vessels traveling north or south of Cape Cod that are less than 825 feet long, with a distance from the waterline to the top of the highest point of the vessel of less than 135 feet (air draft) and with a draft of less than 32 feet, generally transit Buzzards Bay and the Cape Cod Canal. The Cape Cod Canal shortens the trip by 50 to 150 miles by providing an inside passage that avoids Nantucket Shoals.

The master stated that the QE2 was last in Vineyard Sound and Oak Bluffs anchorage about 5 years before; however, this was his first trip to The Vineyard. In the fall of 1991, the QE2 anchored off Newport, Rhode Island, but departed the area soon after because weather conditions made it unsafe to ferry passengers ashore for sightseeing.

Meteorological Information

The weather near Cuttyhunk Island was clear at the time of the accident with a visibility of 10 to 15 miles. Winds were light, about 4 to 8 knots out of the east-northeast to southeast, and the seas were calm with no swells. The air temperature in Vineyard Sound was about 62 °F.

Toxicological Information

When asked about Cunard's drug and alcohol testing program, the Staff Vice President of Legal Affairs for Cunard Lines, Ltd., stated in an affidavit that "under English law, there is no rule or regulation requiring drug or alcohol testing of crewmembers."

However, Cunard policy makes it clear that if an incident occurs in U.S. waters, the master and crew are to cooperate with U.S. Coast Guard authorities when postaccident toxicological testing is requested. In a memorandum to the masters of its passenger ship fleet dated February 1992, the company states, "In the event of an incident in U.S. waters, the Coast Guard has powers to board and test crewmembers involved for the presence of drugs or alcohol, and, if proven, to detain such crewmembers."

Northeast Marine Pilots Association, Inc., maintained a corporate membership in the Newport Alliance for Business Health (NABH) consortium to manage random, postaccident, and for-cause drug testing in accordance with Federal drug testing regulations. The pilot, who was a member of the Northeast Marine Pilots Association, paid an annual fee for NABH membership.

The Coast Guard boarding officer from the MSD Cape Cod testified that about 1100 on August 8, while talking with the pilot about the accident, the pilot informed him that a nurse from the NABH would be coming out to the ship to administer a drug test to the pilot. The Coast Guard boarding officer advised his commanding officer at the Marine Safety Office (COMSO) in Providence and was instructed to ask the nurse from NABH to also obtain toxicological samples from the bridge crew on watch at the time of the grounding.

The nurse, who had been directed by NABH to test only the pilot, arrived with three urine specimen collection jars. Only the pilot, the master, and the first officer of the watch were tested. Urine samples were collected from these individuals approximately 16 hours after the accident at about 1420 on August 8. SmithKline Beecham Clinical Laboratories in Pennsylvania, the laboratory used by NABH, performed drug screens only (no alcohol testing) on the urine samples provided by the pilot, the master, and the first officer.

After the COMSO was informed of the circumstances of the toxicological testing, the boarding officer went to a meeting with the damage survey diver and representatives from Cunard to determine what the next step would be regarding the vessel. At that point, the master requested the Coast Guard to allow the QE2 to move closer to Newport to disembark the remaining passengers. The Coast Guard agreed to this, and because all bridge crewmembers were subsequently engaged in ferrying operations to transfer passengers ashore, the remaining three watchstanders were not tested for drugs or alcohol until later.

About 0800 on August 9, after a conversation between the Coast Guard boarding officer on the QE2 and the COMSO, it was decided that because the crew's activities had tapered off, toxicological sampling could be performed on the three remaining members of the bridge watch. However, the boarding officer, the master, and the senior physician on the QE2 decided that taking the samples could wait until the end of the crewmembers' 0800-1200 watch. About 1330, approximately 39 hours after the grounding, the second officer on watch, the helmsman, and the quartermaster went to the medical office, where a nurse drew two vials of blood from each crewmember. The blood vials were sealed in two containers and refrigerated. One container was designated for the Coast Guard's use, and the other container remained in the custody of Cunard for testing. No further instructions concerning the samples were given to the ship's medical personnel by the Coast Guard representatives.

The QE2's physician was not informed about what to do with the samples until Safety Board investigators arrived. Safety Board investigators also requested that the Coast Guard release the one set of samples to the Safety Board for independent toxicological testing. These samples were retrieved from the medical office aboard the QE2 and sent immediately to the Center for Human Toxicology (CHT) in Salt Lake City, Utah. Tests performed for the Safety Board by CHT reported low levels of caffeine in the samples but were negative for other drugs. No alcohol testing was performed because of the 39-hour delay in sample collection. Results of tests for drugs and alcohol performed for Cunard by METPATH/New England on the remaining bridge crew were negative for drugs and for alcohol.

Survival Factors

The Safety Board sent a questionnaire concerning the accident to 529 of the 1,824 passengers who were on the QE2 when it grounded. The observations of the 240 passengers responding to the Safety Board's survey are summarized below:

- The majority of the respondents, 80 percent, indicated that the grounding occurred between 2130 and 2200 hours. Most of the respondents said they were having dinner in the dining room when they felt the impact.

- Almost 65 percent of the respondents felt a slight to moderate change in the ship's motion; one-third thought that the impact was severe.

- Almost all of the respondents were initially informed of the accident by the master; a small number of the respondents (1 percent) reported that they initially received information about the grounding by watching CNN news on television in their cabins. One hearing-impaired passenger responding to the survey complained that at the time of the grounding she knew something was wrong, but she could not hear the public address system. When she turned on her television to seek information, she found that it was not equipped with closed caption.

- Almost all of the respondents indicated that immediately after the grounding, an individual who identified himself as the "Officer of the Bridge," announced over the public address system, "Ladies and Gentlemen, we seem to have struck an unidentified underwater object. There is no apparent damage to the vessel and no cause for concern; the ship is perfectly safe."

- All of the respondents reported that they were later advised by the master that they were in no danger and would disembark the vessel the following day.

- Although almost all of the passengers responding to the Safety Board's survey thought that the disembarkation was handled safely, 5 percent of the respondents commented that they believed the nighttime disembarkation was unsafe and that the transfer should have been delayed until the following morning.

- None of the respondents were aware of any injuries occurring during the grounding and subsequent disembarkation.

- About 20 percent of the respondents said that it was their first experience traveling by sea, 40 percent said they rarely traveled by sea, and 40 percent said they frequently traveled by sea.

- Ninety-five percent of the respondents indicated that they participated in the lifeboat drill and lecture at the beginning of the cruise as they left New York. However, of the approximately 20 passengers who boarded the vessel at Halifax, Nova Scotia, on the return leg of the voyage to New York, several said that they did not participate in any emergency drills or safety lectures after boarding the vessel.[17]

- Eighty-seven percent of the respondents remembered observing illustrations and instructions on safety and emergencies posted in areas such as passageways, stairwells, and bathrooms. These passengers also remembered stewards pointing out the locations of life jackets, booklets explaining the meaning of ship's alarm bells, and the public address system when they arrived in their cabins.

Tests and Research

Course Recorder and Trackline Study.--The QE2 was equipped with a course recorder and a recording echo sounder. The recordings from both were used to reconstruct the QE2's trackline through Vineyard Sound to the point of grounding--from 2054 to 2158. The reconstruction showed that the headings to the "NA" buoy ranged between 235° and 240°, then changed to a maximum of 255°, followed by a change of 242° to the point of grounding.

The course recorder graph showing vessel headings with respect to time was photographically enlarged to improve readability, and the enlarged photograph was then used for all data assessment.

Preliminary examination of the vessel's heading data yielded a trackline that was inconsistent with the QE2's required general southwesterly course through the sound. The Safety Board determined that adding 24° to the recorded heading values yielded a trackline consistent with known data on the QE2's course through the sound.

Further, the QE2's heading data with respect to recorded time contained a probable grounding signature (a disturbance in the heading trace) at 0206 Universal Time (UT). According to the vessel's log, however, the grounding occurred at 2158, or 0158 UT. Assuming the vessel's log entry to be the authoritative time of grounding, a time correction of

[17]No international requirement currently exists for passengers boarding vessels at intermediate parts, such as Halifax on this trip, to receive safety briefings or participate in emergency drills.

(-)8.0 minutes was applied to all the course recorder graph's times to make them consistent with the time of vessel positions.

The adjusted course recorder headings and times were integrated into a trackline using average speeds for the QE2 derived from position fixes and corresponding times from the vessel's navigation chart, assuming negligible effects of current and wind. The trackline was then visually adjusted as a whole to make the best fit with position fixes taken from the vessel's navigation charts, the course alterations at significant points in the waterway, and the location of the grounding. Sounding data from the echo sounder were correlated to the trackline and the trackline further adjusted to best fit the sounding data and depth contour data from NOAA charts.

The average speed of the QE2 for 22 minutes before the grounding (2136 to 2158) was calculated by the Safety Board at 24.6 knots.

When questioned about the course recorder's malfunction, the ship's navigator stated that the course recorder was probably checked while the vessel was anchored at The Vineyard. He stated that the discrepancies found in the headings and times were probably due to "slippage" while the vessel was swinging at anchorage. He also stated that the course recorder needed adjustment from time to time.

Bottom Topography From the 1992 NOAA Survey.--The detailed bottom topography of the grounding area was established using testimony by the Commanding Officer (CO) of the NOAA survey vessel RUDE, the echo sounder trace of the QE2, and underwater video by the RUDE's divers. The NOAA vessel RUDE had been in Rhode Island Sound and Buzzards Bay conducting hydrographic investigations[18] when it was diverted to survey the area of the QE2 grounding. From August 10 through 17, 1992, the RUDE surveyed the grounding site.[19] The vessel used side-scan sonar to locate bottom objects within 100 meters of either side of the vessel's track (in effect covering a 200-meter path) and dual-frequency electronic depth sounders to determine depths. Position accuracy was determined by a differential Global Positioning System (DGPS) in conjunction with NOAA shore-based microwave transmitters that provided location accuracies of 5-10 meters. When a depth less than the surrounding area was found, the RUDE's two divers were sent down with a pneumatic depth gauge to measure the depth of the object(s) and look around the area as much as possible. The pneumatic device and the electronic depth sounder

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[18]Hydrographic investigations are specific project surveys to investigate reported underwater wrecks, obstructions, and other submerged features to verify their existence and location. This information is subsequently used to update navigation charts.

[19]In a letter dated December 11, 1992, NOAA stated it had "decided to terminate survey operations when the impact site was located because of (1) the U.S. Coast Guard's and National Transportation Safety Board's desire for testimony regarding the finding [of the RR I and II], (2) the need to process and evaluate the data set before resuming the survey in the area, and (3) the decision to resume survey operations in Buzzards Bay thereby continuing the orderly progression of work. We estimate that follow-up work in this area will occur during 1993."

readings were compared, usually resulting in only minute differences. The shallower depth was used for survey/charting purposes.

The CO of the RUDE testified that he used the QE2's initially reported grounding position as the starting point of the search and made about 170 tracks or sounding lines, some as close as 5 meters apart, to determine the location of the rocks or boulders that the QE2 may have contacted. He stated that he made sure that he had enough depth information before he sent the divers down to further identify boulders in the area of the grounding.

He further testified that the diver's videotape showed that the first rock that the divers found, about 1,450 feet northeast of the QE2's initially reported grounded position at a depth of about 34 feet, was intact and did not appear to have been moved by vessel impact. However, this rock or boulder, which NOAA named Red Rock I (RR I), did have what appeared to be bottom paint and metal shavings on it. In addition, the divers found that the top of the boulder had been scraped clean of kelp. RR I measures about 12 feet by 12 feet by 7 feet high.

The RUDE proceeded along the 240° reported trackline of the QE2, when another spot of about 34-foot depth was found about 525 feet from RR I. Divers again went down and found another boulder or rock that NOAA named Red Rock II (RR II), which appeared to have been heavily impacted. This boulder is about 8 feet by 10 feet by 6 feet high and surrounded by other boulders of similar size, forming a generally rocky area. The top of RR II appeared to have been broken off by a major impact, leaving a slight "V" shape at the top of the rock containing metal scrapings and paint marks. In the same area, the diver's video showed a third rock that had kelp scraped off a portion of it and paint deposited at its edges. The divers proceeded for 70 meters beyond RR II along the reported trackline of the ship and found the bottom to be strewn with boulders that also showed evidence of contact with a vessel. The NOAA divers recovered paint chips and metal shavings from RR I and RR II, and Safety Board investigators also obtained paint chips and metal shavings from the hull of the QE2 while it was in drydock in Boston, Massachusetts. The samples were examined in the Safety Board materials laboratory.

The RUDE's CO described the area of the grounding as having a considerably heavier concentration of rocks or boulders than the surrounding area, where the water is 50 to 60 feet deep, with a sandy bottom and only an occasional boulder in all directions. In the vicinity of RR II are "some more tumbled boulders and just a generally disturbed bottom," according to the RUDE's CO. The 39-foot depth shown on the navigation charts was verified by the RUDE as being about 400 feet to the west of RR II and about 660 feet northeast of the QE2's initially reported grounded position. The positions of the rocks relative to the 39-foot depth and grounding location are shown in figure 5 on the following page.

Survey data obtained by the RUDE indicate that the water depths at MLLW are 34.2 feet at RR I and 33.6 feet at RR II. Adding NOAA's calculated tidal effect of (+)0.8 feet to the MLLW sounding indicates that a depth of 35.0 feet at RR I and 34.4 feet at RR II existed at the time of the grounding.

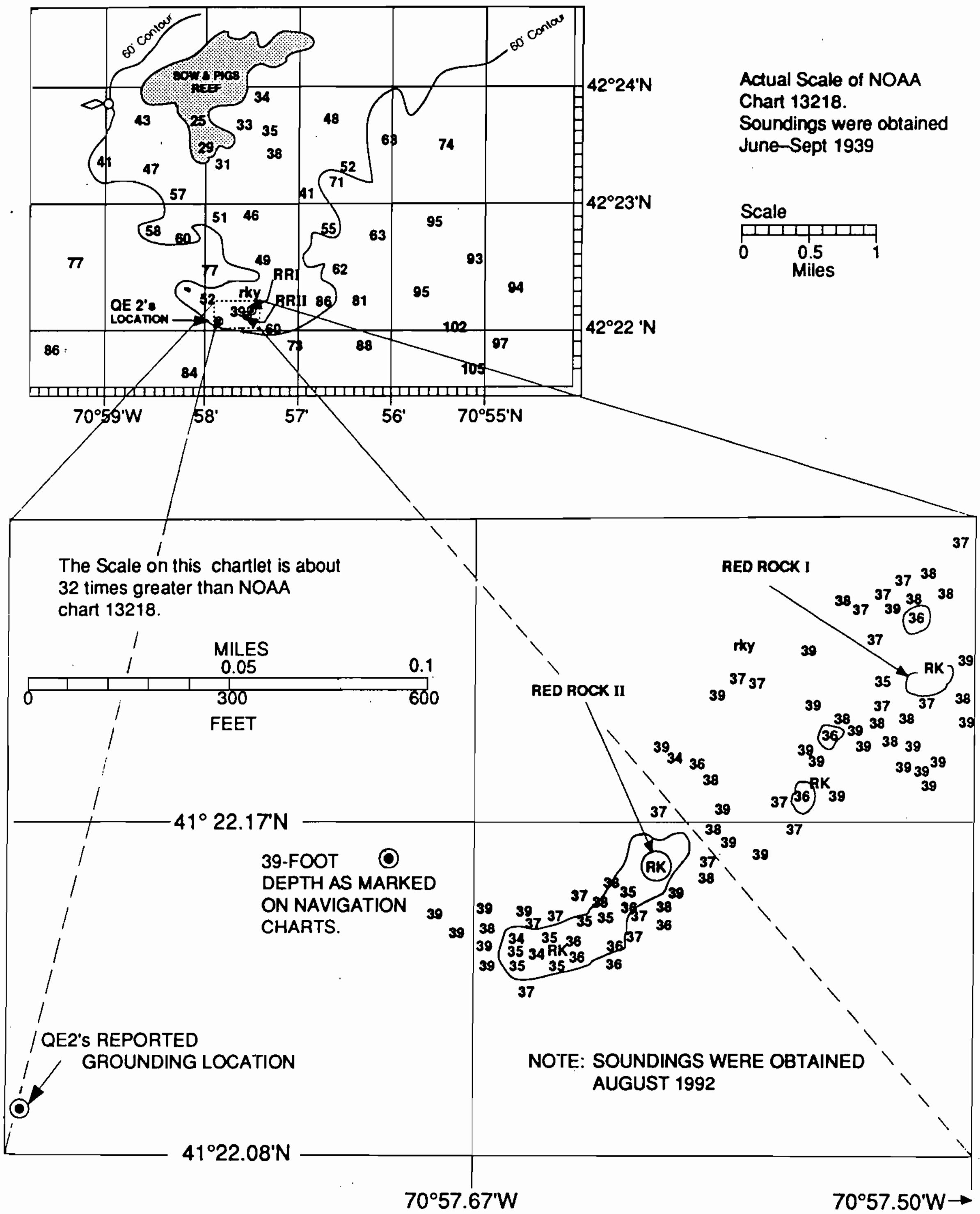

Figure 5.--Chart and survey data.

Cunard Lines, Ltd., Survey.--On behalf of Cunard Lines, American Underwater Search and Survey, Ltd., (AUSS) conducted an independent oceanographic (tide and current) and bottom survey from September 9 through November 14, 1992. The AUSS stated in its report[20] that the tide at the time of grounding was (+)0.6 feet and concluded, "In general, the charts show the presence of a shoal less than 40 feet deep near the impact rocks. Approximately 16 large boulders of 6 to 12 foot diameter are located near this shoal with depths of less than 35 feet." The survey also states that four rocks were found in addition to RR I and II with "...bottom paint and metal shavings [from the QE2]."

In its report, the AUSS described how it estimated the vertical and horizontal movements of the rocks struck by the QE2. The AUSS estimated the vertical movements of the rocks by tape-measuring the vertical distance between the sea bottom and the disturbed marine growth on the rock surfaces; however, the vertical movements could not be reliably established by this method for impacts 3 through 6. The vertical movements were taken into account in establishing the available water depths above the rocks before the impact. The prevailing water depths as reported by the AUSS before and after the impact, as corrected for tide, are presented in table 1, along with the estimated movements of the rocks.

Table 1.--AUSS estimated movement of rocks.

Impact number	Water depth (before impact--ft.)	Water depth (after impact--ft.)	Movement (horizontal--ft.)	Movement (vertical--in.)
1 (RR I)	33.6	34.6	9	12 down
2	31.9	31.2	2	9 up
3	31.8	31.8	1	Unable to determine
4	32.0	32.0	7	Unable to determine
5 (RR II)	31.6	31.6	11	Unable to determine
6	30.6	30.6	2	Unable to determine

Note: The impact number does not indicate the order of impact for impacts 2 through 6, nor could it be determined.

[20]*Survey of the Area Impacted by the Grounding of the QUEEN ELIZABETH II [2] on August 7, 1992*, American Underwater Search and Survey, Ltd., Cataumet, Massachusetts, December 15, 1992.

Results of the 1993 NOAA Survey.--In April 1993, the RUDE returned to the grounding site to resurvey the depths of the six rocks that, according to the Cunard/AUSS survey, had been impacted. Preliminary results indicated that impact sites 2, 4, 5 (RR II), and 6 were 35.1, 35.7, 35.1, and 36.1 feet deep, respectively, at MLLW; impact sites 1 and 3 had not yet been resurveyed. RUDE divers located impact site 6 about 31 meters west-northwest of the position reported by the AUSS.

Comparison of the 1992 NOAA Survey With the Cunard/AUSS Survey.--Impact numbers 1 and 5 were identified by the NOAA survey as RR I and II. NOAA reported that RR I was at a depth of 35.0 feet and RR II was at a depth of 34.4 feet before the grounding, assuming a tide of (+)0.8 feet. By comparison, the AUSS survey reported the depths before the impact of RR I (impact 1) and RR II (impact 5) as 33.6 and 31.6 feet, respectively, using the AUSS's calculated tide of (+)0.6 feet. In other words, the NOAA survey depths are 1.4 and 2.8 feet greater than those reported by AUSS for RR I and II. The difference in depths reported for RR I can be attributed to NOAA not considering RR I to have moved vertically due to the impact (NOAA divers were not looking for vertical movements of the rocks nor did they notice that any movement had occurred), whereas the AUSS estimated that 1 foot of downward movement had been caused by the impact. As noted in table 1, the AUSS was unable to determine the vertical movement for RR II (impact 5).

Paint Chip and Metal Shaving Comparisons.--The paint chips received from the NOAA divers were examined in cross section with an optical microscope and a scanning electron microscope (SEM). Energy dispersive x-ray (EDX) spectra of each discernible layer were acquired during the SEM examination. EDX spectra identified the major chemical elements in each of the layers; for example, the metallic gray layers on all samples consisted mainly of aluminum and chlorine. The elemental makeup of the layers was consistent for all the samples. The color and thicknesses of the individual layers in the paint chips also appeared to match, indicating that the bottom samples were from the QE2.

The metallic shavings received from the NOAA divers were subjected to EDX analysis. Both samples (from the QE2's hull and impacted rocks) were consistent with low alloy steel containing only manganese as a detectable alloying element and appeared to match.

Hydrodynamic Factors and Vessel Squat.--When a vessel moves through shallow water, it experiences a complex hydrodynamic phenomenon known as squat. Squat is the combination of (a) sinkage of the hull and (b) a change in the elevation of the bow with respect to the stern, known as trim. As a vessel's speed increases, the water level around the hull is lowered;[21]

[21]The water flow under a vessel's hull is severely restricted in shallow water due to the proximity of the vessel's bottom to the sea floor of the waterway. As the water is forced under the hull, there is an increase in the velocity and kinetic energy (energy associated with motion) of the water. To compensate for the increase in kinetic energy, the potential energy (energy of a system derived from elevation rather than motion) must reduce, because the total energy of a system must remain constant. The reduction in potential energy is achieved through the lowering of the water level around the hull.

consequently, the vessel sinks deeper with the lowered water level, reducing its underkeel clearance, but its draft (the distance from the keel to the vessel's waterline) remains the same. A further reduction in underkeel clearance is caused by a change in trim. The amount of change in trim depends on whether the stern is supported by a wave crest or dips into the trough of the wave created by the ship. In shallow water, trim changes are more pronounced than in deep water. The combination of sinkage and trim considerably increases the risk of a ship touching the bottom of a shallow waterway, particularly when a ship moves at high speeds.

Approach to the Determination of Squat.--The squat of a vessel increases approximately as the square of its speed, and the QE2 had increased its speed from about 18 to 24.5 knots after it had entered Vineyard Sound. Because the combination of high vessel speed and shallow water depth is likely to cause unusually large squat effects, the squat of the QE2 was closely investigated.

The Safety Board examined the probable extent of squat using two independent approaches: a direct approach based on the height of observed damage marks on the QE2's hull and a theoretical approach based on calculations using simplified formulas. The two approaches and the results obtained are described below.

Direct Approach.--Photographs of damage to the ship's hull taken while the ship was in drydock indicate that the hull was damaged at least 2 1/2 feet above the vessel's baseline near the bow thruster openings. Paint chips and metal filings found on RR I and II and the damage suffered by those rocks indicate that the damage at the bow was most likely caused by RR I or RR II. Using this information along with the water depths above RR I and II as reported by the NOAA survey, the Safety Board estimated the squat to be in the range of 4.6 to 5.2 feet.

Theoretical Approach.--In view of the uncertainties and conflicts between the survey data from the AUSS and NOAA, the Safety Board also used a theoretical approach to estimate squat. In this approach, the Safety Board calculated squat using formulas obtained from a number of references (see appendix C). These calculations revealed that a large squat, reducing underkeel clearance up to 8 feet, was probable for the QE2 at speeds of about 24 knots in 40 feet of water. The QE2 was operating at depths ranging from 39 to 100 feet between the anchorage and the "NA" buoy.

Squat is a complex hydrodynamic phenomenon and particularly at high ship speeds cannot usually be accurately predicted by simple formulas. Nonetheless, approximate calculations using these formulas indicated the important role that squat may have played in this accident and the need for a more thorough calculation of squat using a computer. Consequently, the Safety Board and Coast Guard jointly funded a computer prediction for the squat of the QE2 at the David Taylor Research Center (DTRC). The results are discussed below under Computer Calculations.

Computer Calculations.--The computer calculations carried out by the DTRC show that the QE2 could have experienced squats, by the bow, of 8 and 15 feet at speeds of 20 and 22 knots, respectively, in water 50 feet deep. In water 40 feet deep, DTRC calculated a squat, by the bow, of 8 feet at a speed of 18 knots. The DTRC results show that the QE2 experienced squat by the bow throughout the entire range of speeds considered--from 12 to 24 knots. The sloping bottom that exists in the area where the QE2 ran aground was not directly modeled in the calculations; instead, squat was calculated in water of depths of 40, 45, 50, and 60 feet to estimate the effects of the sloping bottom on squat.

Estimate of Squat by Cunard's Representatives.--Cunard's representatives used the AUSS survey and information on the hull damage to estimate the probable squat experienced by the QE2. Cunard's analysis showed that the most likely squat was between 2 to 3 1/2 feet, probably closer to 2 feet. Cunard envisioned that had the damage to the port-side bilge keel resulted from impact with RR I, the squat would have been 3 1/2 feet. In an alternate scenario, Cunard estimated that RR I may have penetrated the keel area by 8 inches, and based on the ship's draft and the depth of the rock, the squat would have been about 2 feet.

Model Test by Cunard.--Cunard also had BMT Fluid Mechanics, Ltd., England, conduct squat measurements on a model of the QE2. The test results showed that up to a speed of about 14 knots, the vessel squatted down by the bow, and at higher speeds the bow began to rise rapidly while the stern sank. At a speed of 16 knots, the stern grounded in a water depth of 41 feet. At a speed of 24 knots, the bow would have been too high in the water to be damaged by the rocks.

Effect of a Sloping Waterway Bottom.--The echo-sounder trace of the QE2 indicated that the bottom of the waterway steadily sloped up, reducing underkeel clearance from about 50 feet until the point of grounding, as the vessel traveled a distance of about 15,000 feet in roughly 6 minutes. When the effect of a similarly sloped bottom on ship squat had been modeled[22] for a similar grounding, the model showed that abrupt variations in the sea-bottom profile, such as rocky ledges, could cause sudden, transient increases in the squat of a vessel and result in groundings.

Information Available on Ship Squat.--Information on squat characteristics was not provided aboard the QE2; however, information on maneuverability characteristics was provided in accordance with the Coast Guard regulations at 33 CFR 164.35(g). The presentation of shipboard information on squat as guidance to masters and pilots is very closely related to the shipboard presentation of maneuverability information. The work done by the International Maritime Organization (IMO) and by the U.S. Coast Guard to develop and present this information is summarized below.

Since 1968, the IMO has worked to establish recommended standards for the maneuverability of ships and standards for the shipboard display of maneuvering and squat information. After exhaustive technical analysis and discussions by various member

[22]A.M. Ferguson, D.B. Seren, and R.C. McGregor, *Experimental Investigation of a Grounding on a Shoaling Sandbank*, The Royal Institution of Naval Architects, 1982.

governments of the IMO, Resolution A.601(15), "Provision and Display of Maneuvering Information Aboard Ships" (hereafter referred to as "the Resolution"), was adopted by the IMO on November 19, 1987. In addition to the maneuverability information of a vessel, the Resolution recommends that the wheelhouse poster include an estimate of squat experienced by a vessel at various speeds. Further, the Resolution recommends that a maneuvering booklet be provided aboard each vessel that includes estimates of squat versus speed for various water depths and vessel drafts in open, shallow waters, as well as in confined navigational channels. The IMO has urged all member governments to encourage ship owners to provide the information on board all ships of at least 100 meters (about 328 feet) in length and for all new chemical and gas carriers regardless of size. However, an IMO Resolution is a recommendation only, unlike the requirements contained in the IMO Safety of Life at Sea (SOLAS) Convention, which are mandatory. In general, the IMO's long-term goal is to incorporate Resolutions into the SOLAS Convention after sufficient experience has been gained through the practical usage of Resolutions. Although the Resolution was adopted in 1987, it has not been incorporated into the SOLAS Convention, and the Safety Board is not aware of any plans by the IMO to do so in the near future.

In January 1990, the Coast Guard published Navigation and Vessel Inspection Circular (NVIC) 7-89, entitled "Maneuvering Information," to call attention to IMO Resolution A.601(15), which provides guidance to ship owners and operators regarding a standard format for presenting maneuvering and squat information to personnel operating ships. Coast Guard NVICs provide guidance to industry and, unlike regulations, are not binding.

Meanwhile, the Coast Guard had already published regulations, effective November 28, 1984, at 33 CFR 164.35(g) requiring all vessels, domestic or foreign, measuring over 1,600 gross tons and operating in U.S. waters, to post certain maneuvering information in the wheelhouse. However, these regulations do not require that squat information be provided aboard vessels and do not incorporate or refer to the Resolution, since the IMO adopted the Resolution after the Coast Guard regulations were published. Consequently, squat information generally is not provided aboard vessels despite the recommendations contained in the IMO Resolution. Because of this, information on squat characteristics, which are unique to each vessel, was not available aboard the QE2 for its operating personnel and pilot.

The authority for the Coast Guard regulations referred to above was granted by the Port and Waterways Safety Act (PWSA) of 1972 (U.S. Public Law 12-21 et seq.), which was enacted following the major pollution and environmental damage caused by tankship groundings in the late 1960s. The regulations were published to implement the intent of the PWSA--to promote navigational and vessel safety and to protect the marine environment as "matters of major national importance."

Information on the squat behavior of ships at high speeds is not readily available for use by mariners; it is primarily available to hydrodynamic researchers. General criteria have been developed by harbor and dredging authorities for determining the required depths of dredged channels for safe navigation.[23] An allowance for squat is a key component in the criteria for determining safe underkeel clearances. Operating instructions issued in 1966 by the Engineer in Charge of the Cape Cod Canal, U.S. Army Corps of Engineers, to traffic controllers in the canal specify an allowance of 1 1/2 to 2 feet for squat. However, these criteria are based on slow speeds of about 5 to 12 knots and, in general, are not applicable to vessels moving at higher speeds. The criteria also do not take into account the differences in squat behavior between various types of hull forms.

Master's and Pilot's Knowledge of Ship Squat.--The master and the pilot were generally aware of the reduction in underkeel clearance (squat) experienced by vessels in shallow water. Both testified that they thought the squat of the QE2 was 1 1/2 to 2 feet while leaving Vineyard Sound. The knowledge of a master or pilot regarding squat is usually derived from the practical experience of operating vessels at slow speeds in shallow waters. However, estimates for squat obtained from the sources described earlier indicate that the QE2 most likely experienced a squat of about 4.6 to 8 feet at the high speed of 24 knots.

Earlier Accidents Caused by Ship Squat.--The Safety Board is aware of a number of squat-related accidents that resulted in pollution and significant property damage. The Safety Board determined that "the excessive speed of the [U.K. tanker] ALVENUS[24] caused the ship to sink deeper in the water, trim forward, and ground" in the entrance to the Calcasieu ship channel near Cameron, Louisiana, in 1984. The grounding caused major structural damage to the vessel and spilled 10,000 tons (about 3,000,000 gallons) of crude oil. About 3,000 tons of oil washed ashore onto the Texas shoreline; it cost an estimated $20 million to remove the oil and repair waterfront property. The Safety Board estimated that the underkeel clearance of the ALVENUS had been reduced about 4 feet at the bow as the vessel moved at a speed of 10 knots.

In a grounding similar to that of the ALVENUS and also caused by squat, the bulk carrier MV WELLPARK[25] grounded on a shoaling sandbank while proceeding at 8 to 9 knots in the La Plata River, Argentina, on August 14, 1977. The ship suffered a sudden, transient increase in squat and trimmed by the bow as it approached the sloping sandbank.

In an accident that occurred in 1980, the Safety Board determined that the piloted Bermudian bulk carrier FORT CALGARY[26] in the Houston Ship Channel was operating near full sea speed. This intensified the effects of squat, contributing to the loss of control and

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[23] *Criteria for the Depths of Dredged Navigational Channels*, Marine Board, National Research Council, 1983.

[24] *Marine Accident/Incident Summary Report--ALVENUS, July 30, 1984* (NTSB/MAR-85/02/SUM).

[25] A.M. Ferguson, D.B. Seren, and R.C. McGregor, *Experimental Investigation of a Grounding on a Shoaling Sandbank*, The Royal Institution of Naval Architects, 1982.

[26] Marine Accident Report--*Collision of the U.S. Towboat BRAZOS with Bermudian Bulk Carrier FORT CALGARY, Houston Ship Channel, August 7, 1980* (NTSB/MAR-81/01).

causing the vessel to experience a sheer and collide with the U.S. towboat BRAZOS and its tow. Butadiene gas escaped from one of the towed barges and ignited and set fire to the BRAZOS, injuring all five crewmembers. The total damage was estimated at $860,000. In another analysis of this accident,[27] the author stated that the excessive speed of the FORT CALGARY increased the squat, causing the vessel to strike the bottom of the channel and lose control.

Other Information

Bridge Resource Management.--Since 1989, the Safety Board has promoted the concept of bridge resource management (BRM), which is an outgrowth of the concept of cockpit resource management (CRM). CRM was developed by the commercial aviation community during the late 1970s and early 1980s in response to the increasing number of accidents caused by the failure of crewmembers to coordinate critical information.

Major air carriers and researchers developed CRM training to modify the way flightcrews approached their work and functioned on the flight deck. The term "cockpit resource management" refers to the emphasis on teaching flightcrew members how to use teamwork to optimize the available cockpit resources, such as hardware, software, and personnel, to foster effective decisionmaking during critical periods of the flight. The key to successful CRM is identifying and making the flightcrew aware of communication barriers: namely, the existing flightcrew culture about behavior in the cockpit, flightcrew members' attitudes about their respective responsibilities, and personality types that conflict with the team approach to problem solving.

Since its conception, CRM training has been adopted by many major U.S. commercial airlines and the military and has also been credited with saving lives and aircraft.[28]

The problems with crew coordination and communication in the cockpit also exist on a ship's bridge. The Safety Board has investigated a number of marine accidents that occurred because of the failure of members of a bridge watch to communicate and coordinate efforts, to recognize potential problems during voyages, and to cooperatively solve imminent problems.[29]

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[27]E.T. Gates, *Maritime Accidents--What Went Wrong?* Gulf Publishing Company, 1989.

[28]Aviation Accident Reports--*Aloha Airlines, Flight 243, Boeing 737-200, N73711, Near Maui, Hawaii, April 28, 1988 (NTSB/AAR-89/03); United Airlines Flight 232 McDonnell Douglas DC-10-10 Sioux Gateway Airport, Sioux City, Iowa, July 19, 1989* (NTSB/AAR-90/06).

[29]Marine Accident Reports--*Grounding of the U.S. Tank Ship STAR CONNECTICUT, Pacific Ocean, near Barbers Point, Hawaii, November 6, 1990* (NTSB/MAR-92/01); *Collision between the Greek Tankship SHINOUSSA and the U.S. Towboat CHANDY N and Tow near Red Fish Island, Galveston Bay, Texas, July 28, 1990* (NTSB/MAR-91/03); *Grounding of the Panamanian Passenger Vessel BERMUDA STAR in Buzzards Bay, Massachusetts, on June 10, 1990* (NTSB marine accident brief DCA90MM043, adopted February 12, 1993); *Ramming of the Spanish Bulk Carrier URDULIZ by the USS DWIGHT D. EISENHOWER (CVN 69), Hampton Roads, Virginia, August 29, 1988* (NTSB/MAR-90/01).

Investigations of many of these accidents by the U.S. Coast Guard, the National Transportation Safety Board, and other organizations have determined that the cause of many rammings, groundings, and collisions could be attributed to a core of problems deriving from the failure of the bridge team to

- properly plan, execute, and monitor their vessel's navigation;
- establish clear lines of communication between members of the bridge team;[30]
- effectively utilize all resources available to them (i.e., information, personnel, and equipment);
- properly prioritize tasks and responsibilities; and
- effectively respond to unexpected situations.

Marine pilots are hired to provide the master with information on local port conditions and for their knowledge of shiphandling, communications with local authorities, and mooring or berthing. In performing their duties, they routinely encounter expected and unexpected obstacles that can affect their ability to effectively integrate themselves into the bridge team. Some of the more common obstacles marine pilots encounter include the following:

- The majority of the vessels visiting U.S. ports are foreign-flag and are operated by crews of varying skills and abilities.
- The pilot and members of the bridge team often do not share the same primary language.
- A ship's pilot has little or no time to evaluate the knowledge, training, and experience of a vessel's bridge team.
- The pilot may lack familiarity with the vessel and its maneuvering characteristics.

These obstacles detract from the development of an effective master/pilot relationship, discourage the formation of a proper passage plan, and do not promote the efficient use of the resources available on the bridge.

Navigational Publications.--The nine volumes of the *U.S. Coast Pilot* are published by the Coast and Geodetic Survey of the National Ocean Service, an office within NOAA. These nine

[30]The bridge team normally includes the vessel's master, watch officers, helmsman, lookout, and pilot.

volumes cover the waters of the United States and its possessions and contain supplemental information of importance to navigators that cannot be shown on nautical charts and is not readily available elsewhere. The publication contains information on port facilities, pilotage service, restricted areas, winds and currents, and more details on canals and channels. The U.S. Coast Pilot volume[31] dealing with Vineyard Sound states the following regarding navigation charts:

> It cannot be too strongly emphasized that even charts based on modern surveys may not show all sea-bed obstructions or the shoalest depths, and actual tide levels may be appreciably lower than those predicted....Other appreciable corrections, which must be applied to many ships, are for...squat. These corrections depend on the depth of the water below the keel, the hull form and speed of the ship....The value of a nautical chart depends upon the accuracy of the surveys on which it is based....The chart represents general conditions at the time of surveys or reports and does not necessarily portray present conditions....In coral regions and where rocks and boulders abound, it is always possible that surveys may have failed to find every obstruction....The date of a chart is of vital importance to the navigator.

U.S. charts are revised periodically to incorporate the results of changes in navigational aids, new bottom surveys (partial or full), new obstructions, or the removal of obstructions to navigation; however, the date of the most recent survey of bottom soundings for any chart or part of a chart is not indicated on the chart. In addition, neither charts nor the Coast Pilot explain the survey type and survey coverage used.

One source of navigational information on board the QE2 was the *British Pilot Book*,[32] which contains the following information for Nantucket and Vineyard Sounds:

> Great caution is necessary in the navigation of Nantucket and Vineyard Sounds, owing to the numerous shoals, strong tidal streams, thick fog at certain seasons, and to the large number of vessels which are often encountered in the narrow parts of the channels....Most of the shoals are steep-to and the depths are very irregular, so soundings alone cannot be depended upon for warning of too close an approach to danger.

Chart and Survey Information.--Prior to this accident, the last three surveys of the area were conducted from August through November 1887, June through September 1939, and August through September 1966. During the 1939 survey, the 39-foot sounding was discovered

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[31]*United States Coast Pilot, Volume 2–Atlantic Coast: Cape Cod to Sandy Hook,* Coast and Geodetic Survey, National Ocean Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 26th edition, 1992, chapter 1, pp. 1 and 14.

[32]*British Pilot Book–East Coast of the United States Pilot*, Crown Copyright Stationary Publication NP-68, volume I, 7th edition, May 23, 1975, and supplement no. 10-1991, November 30, 1991.

about 2.5 miles south of Cuttyhunk Island. The hydrographer also determined then that the seabed was rocky, which was indicated on the navigation charts of the area by the term "rky." The 1939 survey recommended additional field work in the area of the 39-foot sounding, but there is no evidence that it was accomplished. A NOAA letter dated March 8, 1993, provided the following information from the 1931 hydrographic manual:

> Development [of soundings]- Extent of development will vary from a maximum on shoals in important locations and in channels and anchorages having depths near the draft of vessels to be accommodated to a minimum...in clear areas of much greater depth than is required for navigation.
>
> The immediate area of the 39-foot sounding, just south of Cuttyhunk Island in Vineyard Sound, was not in a channel or other important area. The important areas on this chart were those areas affecting shipping farther to the west from Buzzards Bay down into Rhode Island Sound....In any event, the determination as to what is an "important area" is certainly judgmental and firmly within the discretion of the hydrographer.

Approximately 60 percent of the U.S. inshore surveys used to develop U.S. charts were acquired by the lead-line sounding technique. This was the sounding method used before 1930. Soundings in 1939 were taken by a nonrecording electronic echo sounder with a required sounding-line-track spacing of 400 meters (about 1,300 feet) in water of a maximum depth of 6 to 10 fathoms (36 to 60 feet). Sounding positions for that survey were determined by using three-point sextant fixes. The actual track spacing was slightly wider in some areas than the 400-meter maximum. The depth was displayed on a dial and recorded manually on a form; there was no graphic record of bottom soundings. The area on the bottom covered by the echo sounder was 0.4 times the depth of the water. At depths between 40 and 50 feet, an area with a diameter of 16 to 20 feet was encompassed by the echo sounder's signal. The NOAA depth accuracy requirements in effect during the 1939 survey were as follows:

> Comparative soundings [wire soundings and echo soundings] for fathometer verification shall be taken not less than twice daily in depths not exceeding 50 fathoms [300 feet]. When the weekly average of the differences between fathometer soundings and vertical casts [wire soundings] is less than 1.5 percent, the fathometer shall be regarded as correct.

In 1966, when the latest survey was taken, the depth accuracy requirements were more stringent:

> ...measure depths less than 11 fathoms (66 feet) accurately within one half foot, and greater depths within one percent, unless specifically authorized by the Director [Coast and Geodetic Survey]. In rapidly changing depths and over irregular bottoms the requirements may be lowered to one foot for depths less than 11 fathoms.

Current NOAA depth accuracy requirements are found in the International Hydrographic Organization standards:

> The total error in measuring depths should, with a probability of at least 90 percent, not exceed: (a) 0.3 meters [about 0.984 feet] from 0 to 30 meters [about 98.4 feet] and (b) 1 percent of depths greater than 30 meters.

The 1966 survey overlapped part of the 1939 survey but did not include the rocky area near the 39-foot depth south of Cuttyhunk Island. Position control was accomplished using a medium frequency radio navigation system known as Hi-Fix. Electronic soundings were automatically and continuously recorded along the track of the sounding vessel, but features could be missed between sounding lines.

As stated by NOAA in a March 19, 1993, letter on this subject: "All Hydrographic Manuals from 1935 to 1984 prescribe general guidelines on spacing but further clarify that maximum spacing of lines for various zones or depths of the project is ordinarily prescribed in the project instructions." Proper spacing of sounding lines depends on the purpose of the survey, depth of the water, character of the submarine relief, scale of survey, and importance of the area. In general, the manuals show a 200-meter-sounding-line spacing in coastal areas of 20-fathom water depth or less. The hydrographer on the vessel can change line spacing for critical areas as needed for a complete hydrographic survey. Project line-spacing instructions cannot be increased or decreased over large areas without the approval of the Director, National Ocean Service.

The British Admiralty (BA) charts 2456 and 2890 are printed to a scale of 1:100,000 and developed from NOAA data; soundings printed on the BA charts are from smaller scale NOAA charts. The QE2's BA charts had been corrected in accordance with the latest BA Notice to Mariners, but the NOAA charts had not been corrected because the QE2 does not receive the *U.S. Notice to Mariners* for U.S. charts. The navigator and the master on the QE2 stated that the BA charts were normally used for navigation and the NOAA charts were normally used for reference because of their larger scales (1:20,000, 1:40,000 and 1:80,000).

ANALYSIS

General

The Safety Board eliminated the following factors as causal to the accident: weather, vessel traffic, mechanical condition of the QE2, bridge watch crew qualifications, and bridge watch crew impairment.

The weather at the time of the accident was clear, with visibility at 10 to 15 miles, and the waterway was calm with light winds. After the QE2 passed traffic in the area of Woods Hole, it encountered no other traffic during the voyage out of Vineyard Sound. Except for the course recorder, all propulsion, steering, and navigation equipment was functioning properly both before and after the grounding.

The Safety Board examined the pilot's, the master's, and the bridge watch crew's training, experience, and certifications for inadequacies and found all training, experience, and certifications to be in accordance with current Federal or foreign requirements. The master of the QE2, the pilot, and the bridge watch were found to be fit for duty and free of physical or medical problems that would have hindered the performance of their respective duties. The master, the pilot, and the bridge watch all testified that work/rest routines followed during the days preceding the accident were normal. Specifically, the master, the first officer, and the pilot reported that the amount of rest received 24 hours prior to the accident was normal and adequate, and the Safety Board found no evidence of impairment from lack of sleep. In addition, the initial toxicological samples collected from the master, the pilot, and the first officer, and the samples collected later from the second officer, the helmsman, and the quartermaster, all tested negative for drugs. However, none of the toxicological samples were taken from the pilot and deck watch officers of the QE2 in a timely manner. The master, pilot, and first officer provided urine samples about 16 hours after the grounding. The second officer, helmsman, and quartermaster provided blood samples about 39 hours after the grounding. Four hours maximum has been recommended by the Safety Board as a guideline for completing sampling following an accident.

The grounding occurred in an area of Vineyard Sound where the water depth is indicated as 39 feet on NOAA and British Admiralty charts. The QE2 had a maximum calculated draft of 32 feet 4 inches when it departed the anchorage at Oak Bluffs. Vineyard Sound is an area where few deep-draft vessels similar to the QE2 transit; the QE2's voyage 5 years before was the last time a ship with a draft greater than 28 feet entered Vineyard Sound. The NOAA and Cunard surveys conducted after the grounding showed that several rocks in the area were at depths ranging from 30.6 feet to 35.0 feet at the time of the grounding. The surveys and paint chip samples taken from two rocks, RR I and RR II, show that the QE2 struck RR I at a depth of 33.6 to 35.0 feet and RR II at a depth of 31.6 to 34.4 feet. As a result of the grounding, 400 feet of the 963-foot-long ship were damaged, and seven of the vessel's double-bottom tanks were punctured. However, because of its double-bottom construction, the vessel was never in danger of sinking and was able to proceed to port for repair under its own power.

In analyzing this accident, the Safety Board considered several safety issues that may have contributed to the grounding of the QE2. The master/pilot relationship, including the master's and pilot's presailing conference, their manner of communication, and their interaction with each other and with the bridge watch during the trip out of Vineyard Sound, were examined.

The choice of tracklines, including the courses and speed selected, the effect of decisions made by the pilot and the master about the ship's course, and the master's and pilot's assumptions about the outbound track were also analyzed. In addition, the Safety Board examined whether the hydrodynamic phenomenon of squat, which resulted in reduced underkeel clearance, contributed to the grounding and the severity of damage and whether the master and the pilot had knowledge of the extent of squat at high speeds.

Other safety issues analyzed included the adequacy of navigation charts and information, the adequacy of Coast Guard guidelines and support to foreign vessel owners and masters for conducting toxicological testing following accidents in U.S. waters, and the adequacy of shipboard evacuation procedures for disabled passengers.

The Accident

After the QE2 departed the anchorage at Oak Bluffs and the pilot was given the conn, the master assumed that the outbound passage would continue along the same trackline but in the opposite direction as the inbound track because the pilot never mentioned that he intended to use a different route outbound. The pilot testified that "the courses were fairly self-explanatory. We would primarily follow the...inbound passage." The configuration of the waterway between the anchorage and the "NA" buoy leaves no option of what course to steer. The ship's navigator had laid out his outbound trackline on the local charts as directed by the master, taking care to avoid shoal areas. However, no consultation ever took place between the navigator and the pilot regarding the route for the outbound voyage.

The pilot testified that he was not guided by the actual trackline plotted by the ship's navigator but instead opted to pilot the vessel using his own points of reference (buoys and landmarks) and courses. When the QE2 reached the "NA" buoy, the pilot ordered a course change to 250°, which was different from the trackline that the ship's navigator had laid out.

The pilot testified that the 250° course would have taken the vessel to a point 2 miles south of Cuttyhunk Island. He further stated that when arriving at that point, he planned to change course further to the west and proceed to the point where he intended to disembark. After the course change at the "NA" buoy, the second officer took a fix and immediately reported to the first officer that the projected heading would put the ship over shoal waters north of Brown's Ledge.

When the master became aware of this, he expressed his concern to the first officer, who informed the pilot that the master would rather pass further south of Sow and Pigs Reef. Accordingly, the pilot ordered a course change. Neither the master nor the watch officer knew that the pilot intended to make a second course change to proceed west to his intended disembarkation point, and he did not inform them of his plan. The pilot should have informed the master that he intended to pass north of Brown's Ledge in their earlier discussion on where the pilot planned to disembark. Had the QE2 master/pilot conference included the pilot's navigational intent, the master would have realized earlier that the pilot intended to take a route to reach his disembarkation point that differed from the navigator's original tracklines. The Safety Board believes that the pilot should have communicated his intentions to the master or the master should have asked the pilot his intentions before departing the anchorage so that both were in agreement on the route out of Vineyard Sound. The Safety Board concludes that had a thorough master/pilot conference been held, the master would have been aware of the pilot's intentions, an agreement on an appropriate route would have been reached, and the accident probably would not have occurred.

When the master informed the pilot of his preference to take the vessel further to the south, neither knew whether the QE2 would cross the 39-foot sounding area where it later grounded. Only after the second officer plotted the 2154 position on the chart and drew the 240° course trackline from that position did this information become available. However, even if the second officer had informed the master or the pilot of the situation once he became aware of it, little or no time would have been available to evaluate another course before the 2158 grounding. Moreover, the second officer, relying on the accuracy of the navigation chart, testified that because he knew the draft of the vessel, he was not concerned about passing over the 39-foot sounding.

The pilot had the choice of using his predetermined route west of the "NA" buoy to pass 2 miles south of Cuttyhunk Island and north of the 39-foot sounding/rky area, or of passing to the south of the 39-foot sounding/rky area, closely retracing the inbound trackline and thereby staying in deeper water. The pilot stated that he had previously used the route that passed north of Brown's Ledge to exit Vineyard Sound on vessels with drafts up to 28 feet. According to NOAA chart 13218, the minimum charted depth along his intended courses was 49 feet. Thus, if the pilot's intended route (passing 2 miles south of Cuttyhunk Island) had been followed, the grounding would probably have been avoided. However, because the QE2's master showed concern over the pilot's route, the pilot, in deferring to the master's preference, altered the course; soon afterwards, the ship grounded. Although the pilot was aware of the 39-foot sounding marked on the chart, both he and the master later testified that they envisioned no problem passing over the spot, even with the master's estimate of 2 feet of squat. However, the Safety Board believes that had the pilot or the master received specific and sufficient advance notice of the proximity of the 39-foot sounding to the vessel's new trackline (after the 2154 fix), they probably would have tried to avoid the area because the trackline laid down by the ship's navigator and the pilot's intended route both avoided the 39-foot sounding.

When the pilot executed the course change in accordance with the master's preference, he did not check whether the new course was clear of hazards. The Safety Board believes that a new trackline should have been established before the course was altered to comply with the master's request to avoid the shoal at Sow and Pigs Reef, so that the 39-foot sounding could also have been avoided. The Safety Board concludes that had the master and the pilot of the QE2 discussed the location of a new trackline before the pilot altered course to pass south of Brown's Ledge, they would have been alerted to the trackline's proximity to the 39-foot area and probably avoided the shoal.

If the entire route out of Vineyard Sound had been decided upon in a master/pilot conference, either the more southerly route laid out by the ship's navigator, where there was deeper water, or the pilot's intended route, which would have passed 2 miles south of Cuttyhunk Island, could have been selected; either route would have avoided the 39-foot sounding area entirely, and the grounding would not have occurred. With both options available, either the judgment of the pilot or that of the master would have prevailed after they had reached an agreement during their pre-sailing discussion. Neither trackline would have taken the ship directly across the 39-foot sounding into the area of the uncharted rocks.

The master's selection of 25 knots as the speed to exit Vineyard Sound was based on the ship's navigator's calculations of the speed necessary to make the scheduled arrival in New York the following morning. During testimony, the master pointed out that the vessel was routinely operated at even greater speeds. The Safety Board, however, disagrees with the master's choice of and the pilot's acquiescence in the 25-knot speed as the QE2 transited Vineyard Sound.

Despite the fact that the plotted tracklines out of the waterway were fairly straight (not short and numerous) and posed no maneuvering problems with the increased speed, more attention should have been given to Vineyard Sound's bottom clearances when determining the speed to navigate through it. The pilot stated he was using a minimum depth of 40 feet for selecting the trackline for the 32-foot draft vessel. However, the navigation charts of the area indicate great variations in depth over short distances, along with a rocky bottom; this information should have alerted the pilot and the master to move at slower speeds in order to gain a greater margin of safety for the underkeel clearance of the QE2. Regardless of the pilot's confidence in the accuracy of the navigation charts, the pilot should have endeavored to navigate the QE2 in the deeper water, which would have allowed for variances or differences in charted depths. Because even minor errors in estimating the vessel's position in a restricted waterway would have greater consequences than in open waters, moving at a slower speed would have provided more time to take corrective action in the event of a steering casualty or other mechanical failure.

When the Safety Board asked the pilot whether he would take every ship with a draft of 32 feet at 25 knots through Vineyard Sound the pilot replied: "No, I would not, simply because you wouldn't have that quality of people working for you. Or you might not even [have] that number of people on the bridge working for you." Regardless of the pilot's opinion of the crew's ability, the decision to accept the 25 knots of speed should be based on more than the crew's qualifications. The Safety Board concludes that the speed of 25 knots selected by the master and agreed to by the pilot was inappropriate for a vessel of this draft moving through an area with great variations in depth, rocky bottom, and marginal underkeel clearance.

Bridge Resource Management

Traditional Management of Bridge Navigation Activities.--According to the testimony of the officers on the QE2, the first officer and the second officer of the watch complied with standing orders of the master to monitor the navigation and keep the master informed. The second officer was monitoring the pilot's navigation using a radar to take fixes using predominant landmarks. When the vessel departed from the original trackline, he reported his observations to the first officer, who in turn alerted the master of the alternate course. The master then relayed his decision to return to the original trackline through the first officer for execution by the pilot. Although this method of information transfer from the second (navigation) officer allowed for strict control of the accuracy of the information and responsibility for the communication, it also required time for each participant in the chain of communication to respond individually. More important, the communication chain segregated the navigational activities of the ship's navigation officers from the pilot's navigational activities. Thus, no one on the bridge was aware of the immediate intentions of the pilot or had sufficient time to evaluate the implications of the pilot's abrupt altering of the ship's course back toward the original trackline to the south of Brown's Ledge.

This communication chain also separated the master from the direct observations of the second officer. The master stated that he was not aware the trackline would pass over the 39-foot sounding, and the second officer said he did not communicate that information to anyone before the grounding, apparently because of his own assessment of the course. The Safety Board did not determine whether the communication procedure was the reason that the second officer did not inform anyone of the pilot's new trackline over the 39-foot sounding. Had he communicated this information directly to the master, as well as to the pilot, the associated risk of striking bottom along the new course may have been identified.

Bridge Resource Management of Navigational Activities.--Bridge resource management (BRM) requires that all pertinent sources of information flowing on the bridge be shared among the bridge crewmembers so that critical decisions can be made by the master with the best information the bridge crew can collectively present. Clearly, bridge resource management includes navigation planning. When a pilot comes on board a vessel, the pilot's knowledge and expertise of the local waters should be integrated into the bridge team's flow of information.

One problem in effective bridge resource management is the substance and nature of the currently required master/pilot conference. Presently, the briefing only requires details of the vessel's status and its maneuvering characteristics at the beginning of a voyage. There are no requirements for detailed navigational planning or followup conversations during the voyage. Furthermore, the nature of the conference requires only the inclusion of the master and the pilot. Thus, even if they did choose to discuss their navigation plans, other members of the bridge team may be excluded from those discussions.

Bridge resource management provides a management model that addresses the operational problems stemming from inadequate communication between the pilot, master, and other members of a bridge watch collectively forming the bridge team. BRM applies to this accident in that all members of the QE2's bridge team should have been more communicative and aware of the vessel's status, performance, and general situation so that they could have contributed to operational decisionmaking. Also, BRM would have enabled the QE2's bridge team to react more effectively to emergency situations than the traditional bridge operation. The activities of the QE2's pilot and bridge team were examined within the context of bridge resource management and found lacking in several instances.

Bridge resource management provides an alternative structure for the management of shipboard operational activities. The Safety Board investigation determined that neither the pilot nor the master of the QE2 were aware of all the factors and conditions that significantly affected the vessel when the pilot decided to alter the course from the original trackline. This deficiency relates to the classic definition of situational awareness,[33] a basic requirement for effective bridge resource management. One major clue to the loss of situational awareness is a deviation from a planned or anticipated maneuver. The Safety Board believes that the pilot's decision to change course at the "NA" buoy should have alerted the master to his lack of full understanding of the pilot's intentions. The consequence of the course change was a decision to return to the base course without completely assessing the reasons for the course change or the implications of the proximity of the vessel to an area having reduced bottom clearances.

The Safety Board also believes that a critical need existed for improved communication between the pilot, the master, and the other crewmembers on the bridge. The master had apparently made incorrect assumptions about the pilot's intentions, and the pilot saw no need to inform the master about what he actually planned to do. The pilot expressed full confidence in the ability of the officers on the bridge to perform navigational tasks; he was aware that the second officer was monitoring the ship's progress and was reporting that information to the master. The pilot said that he had opted to pilot by his own methods rather than following the courses plotted by the navigator. The master stated that he assumed that the pilot was going to follow the reverse of the inbound course. Thus, the navigation of the vessel as understood by the pilot was not communicated to the master or the bridge watch.

Evidence from the investigation indicates that the master did not fully understand how the pilot had planned to get to his debarkation point or that the pilot planned a course change at the "NA" buoy. The Safety Board believes that had adequate communication been established between the master and pilot, the master would have told the pilot of his preference to remain on a course that passed Brown's Ledge to the south. Moreover, the pilot probably would have explained his intention to stay north of the shoals near Brown's Ledge, and he and the ship's officers would have discussed the implications for safety in returning or not returning to the base course. Had the pilot and the ship's officers discussed the ship's course either immediately

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[33]Douglas Schwartz, "CRM Training for FAR 91 and 135 Operators" in H.W. Orlady and H.C. Foushee, eds., *Cockpit Resource Management Training*, NASA Conference Publication 2455, May 1987, p. 171.

following the turn at the "NA" buoy or during a predeparture pilot/master conference, the factors increasing the risk of striking bottom would have become apparent.

The Safety Board is also concerned about the pilot's reluctance to integrate the trained bridge personnel directly into his voyage planning. He clearly had confidence in the ability of the bridge officers and assumed that they would detect any serious miscalculations. However, by failing to familiarize bridge personnel with his overall plan before its execution, the pilot prevented them from effectively monitoring or verifying his decisions. The advantages of integrating these bridge resources into his navigational procedures are apparent, and the pilot would probably have done so if he had been familiar with BRM concepts.

BRM concepts evolved from the research started in the early 1970s to uncover some of the more perplexing problems underlying pilot error accidents in aviation. It was found that, rather than individual piloting skills, other factors such as crew coordination, interpersonal communications, decisionmaking, and leadership were the underlying causal factors. In a paper on psychological issues in flight crew performance,[34] Dr. Robert L. Helmreich discussed the capabilities and limitations of training programs as ways to effect modification of crew behavior for alleviating error. He states that "changing attitudes about personal limitations may well result in much more adaptive behavioral strategies and coordinated behavior in critical situations where maximum effectiveness is a life or death issue." Bridge resource management training deals with changing the attitudes that people bring to the workplace and how to channel these basic human traits into a more cohesive and efficient work environment.

The Safety Board has addressed the need for the maritime industry to reassess the traditional philosophies concerning the proper conduct of navigation watches. In a recent report[35] of the grounding of a tanker near Honolulu, Hawaii, the Safety Board stated,

> The management of modern transportation systems has evolved over many years from the simpler hierarchical form of team management in which one or a few persons provide expertise and direction and the remainder of the team carry out orders, to one in which a team of highly trained people with varying degrees of experience manipulate and monitor complex operating systems. In the course of the Board's accident investigations, we have frequently identified operational breakdowns, coordination lapses, lack of communication, and poor task allocation which clearly reflect failures in the organization and use of available resources.

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[34]Robert L. Helmreich, "Theory Underlying CRM Training: Psychological Issues in Flight Crew Performance and Crew Coordination," *Cockpit Resource Management Training*, proceedings of a workshop sponsored by the National Aeronautics and Space Administration Ames Research Center, May 6-8, 1986, San Francisco, California.

[35]Marine Accident Report--*Grounding of the U.S. Tank Ship STAR CONNECTICUT, Pacific Ocean, near Barbers Point, Hawaii, November 6, 1990* (NTSB/MAR-92/01).

Research in system management has demonstrated that crew members needed to change the way that they approached their jobs; they needed to see themselves as team members with a goal for improved communication.

In that report, the Safety Board reiterated the following safety recommendation issued to the U.S. Coast Guard on March 14, 1991, as a result of the grounding of the WORLD PRODIGY:[36]

M-91-6

Require bridge resource management training for all deck watch officers of U.S. flag vessels of more than 1,600 gross tons.

On March 11, 1992, the Safety Board classified this recommendation "Open--Acceptable Response," following the Commandant of the Coast Guard's January 6, 1992, response:

I concur with the intent of this recommendation. I anticipate addressing this type of training in an Advance Notice of Proposed Rulemaking upon review of the studies mandated by the Oil Pollution Act of 1990, which are to determine whether existing laws and regulations are adequate to ensure the safe navigation of vessels transporting oil or hazardous substances in bulk.

The Board believes that the circumstances of this accident reinforce the need for this type of training for deck watch officers and eventually for all ship personnel, including Federal and State pilots. The Safety Board has been advised that the Coast Guard is aggressively seeking amendments to the Standards for Training, Certification, and Watchkeeping (STCW) at the International Maritime Organization that will comply with the intent of this recommendation. The revision of 46 CFR 10 has been deferred pending the amendment of the STCW, and it is expected that the STCW, to which the U.S. is signatory, will be incorporated into 46 CFR 10 upon completion. Amendment of the STCW is tentatively scheduled to take place in May 1995. Therefore, Safety Recommendation M-91-6 will remain classified "Open--Acceptable Action" and as a result of this investigation has been reiterated.

Two of the most recent accidents investigated by the Safety Board with BRM implications, including the failure to conduct a master/pilot conference, are discussed in the remainder of this section.[37]

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[36]Marine Accident Report--*Grounding of the Greek Tankship WORLD PRODIGY off the Coast of Rhode Island, June 23, 1989* (NTSB/MAR-91/01).

[37]Marine Accident Reports--*Collision between the Greek Tankship SHINOUSSA and the U.S. Towboat CHANDY N and Tow near Red Fish Island, Galveston Bay, Texas, July 28, 1990* (NTSB/MAR-91/03); *Grounding of the Panamanian Passenger Vessel BERMUDA STAR in Buzzards Bay, Massachusetts, on June 10, 1990* (NTSB accident brief DCA90MM043 adopted February 12, 1993).

About 1440 on July 28, 1990, the 601-foot-long Greek tankship SHINOUSSA collided with a three-tank barge tow pushed by the U.S. towboat CHANDY N near Red Fish Island, Houston Ship Channel, in Galveston Bay, Texas. The inbound CHANDY N had just been overtaken by the 820-foot-long Liberian tankship HELLESPONT FAITH and was meeting the outbound SHINOUSSA when the collision occurred. No one was injured, but the estimated damage to vessels and cargo was $1,784,105. The Coast Guard estimated oil-pollution cleanup at $2.1 million. The Safety Board determined the following:

> ...the probable cause of the collision between the SHINOUSSA and the CHANDY N tow was the SHINOUSSA pilot's use of excessive speed and the failure by the SHINOUSSA and the HELLESPONT FAITH pilots to adequately plan for the overtaking and meeting maneuvers....

The Safety Board concluded that both the pilot and navigation watches on the SHINOUSSA and HELLESPONT FAITH did not properly plan their meeting to prevent the three vessels from passing in close proximity and that the master and the pilot of the SHINOUSSA failed to hold a proper master/pilot conference.

Federal regulations (33 CFR 164.11(k)) require that the master ensure that when a pilot other than a member of the vessel's crew is employed, the pilot is informed of the draft, maneuvering characteristics, and any ship-handling peculiarities that may affect the vessel's safe navigation. However, this regulation fails to address discussing the navigation plan for maneuvering the vessel in pilotage waters.

Consequently, on October 21, 1991, as a result of its investigation of the accident, the Safety Board issued the following recommendation to the U.S. Coast Guard:

> <u>M-91-28</u>
>
> Amend 33 CFR 164.11(k) to require that masters and pilots discuss and agree beforehand to the essential features and relevant checkpoints of maneuvers they expect to undertake.

On May 31, 1992, the Coast Guard replied that it believes "no further regulations are necessary." Because the Coast Guard placed the recommendation on the agenda for consideration by the Navigation Safety Advisory Council, the Safety Board classified this recommendation as "Open--Acceptable Response" on August 31, 1992. However, due to the history of similar recommendations on this issue, the Safety Board has reclassified Safety Recommendation M-91-28 as "Open--Unacceptable Response" and reiterated it. (For additional information on the Safety Board's recommendations to the U.S. Coast Guard relating to master/pilot communications issues, see appendix D.)

In another accident the Safety Board investigated, the Panamanian passenger ship BERMUDA STAR[38] ran aground in Buzzards Bay, Massachusetts, on June 10, 1990. No one was injured in the accident, but the bottom of the hull was severely damaged, causing about $4 million in repairs.

The BERMUDA STAR is another example of poor master/pilot communication in which the lack of an agreement on a navigation plan and poor monitoring of the ship's progress in relation to that plan resulted in a grounding. Because both the BERMUDA STAR and QE2 reports were being written at the same time, the Board did not make any recommendations regarding BRM as a result of its investigation of the BERMUDA STAR. The Safety Board determined that the BERMUDA STAR grounded because the ship's navigation watch officer and the State pilot failed to take and plot frequent navigation fixes while the vessel was operating in restricted visibility close to a rocky shoal. The Board further determined that the master's failure to oversee the navigation of his vessel contributed to the cause of the grounding. The vessel's master, who was present on the navigation bridge at the time of the grounding, made no effort to get involved with the navigation of his vessel. According to the pilot, the master was preoccupied with a personal computer that he had recently purchased rather than attending to the navigation of his vessel while the pilot was on board. Moreover, the pilot and the watch officer seemed to have been conducting navigational duties independent of one another and even though the ship was in heavy fog, they did not confer on the navigation of the vessel or coordinate their work.

The Department of Trade of the United Kingdom, addressed the issue of pilot navigation briefings and the absence of a formal navigational routine that would enable mistakes to be detected before an accident occurred, in August 1978, when it issued Merchant Shipping Notice No. M.854 to ship owners, masters, and deck officers in the British merchant navy and skippers and second hands[39] of fishing vessels. Notice M.854 recommends that the "...intentions of a pilot are fully understood and acceptable to the ship's navigational staff" and also recommends that "...the pilot should be clearly consulted on the passage plan to be followed."

The notice is intended to address entire voyage planning, which at times may involve a pilot. However, the planning model stages described in M.854 could easily be adapted for shorter passage planning, during which pilots are hired and could well be considered in the master/pilot conference. However, Merchant Shipping Notices are guidelines to vessel navigation safety.

Conclusions from the SHINOUSSA, BERMUDA STAR, and other accidents investigated by the Safety Board show that training is needed to broaden the scope and depth of communication among the bridge team and between pilots and bridge watch officers to improve

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[38]Marine Accident Brief--*Grounding of the Panamanian Passenger Vessel BERMUDA STAR in Buzzards Bay, Massachusetts, June 10, 1990* (NTSB DCA90MM043, adopted February 12, 1993).

[39]Second person in the chain of command aboard British fishing vessels.

the crew's collective operational performance. The Board believes that the IMO and the Coast Guard should develop standards and curricula for bridge resource management training and that such training should be required for masters, deck officers, and pilots. The Safety Board concludes that the use of effective bridge resource management techniques by navigation watches will greatly increase the safety of navigation and believes that pilots and ship's officers should undergo such training. Further, the Board believes that the maritime industry should draw from the cockpit resource management training developed by commercial air carriers when developing bridge resource management training curricula.

Determination of Squat and Its Role in This Accident

As a result of its investigation of the phenomenon of squat and analysis of the damage to the QE2, the Safety Board determined that squat was a factor in this accident. The surveyed depths of the rocks as reported by NOAA were compared with those reported by AUSS/Cunard Lines, and these depths were used in estimating the squat of the QE2. The Safety Board also found through its independent estimates of squat using hydrodynamic theory, NOAA topographic survey data, and photographic observations of hull damage that a dramatic decrease in the QE2's underkeel clearance (squat) resulted at high speeds; this finding is further supported by independent analyses conducted at the David Taylor Research Center. The Safety Board also found that squat information is not usually provided aboard ships and that mariners' knowledge of squat is limited and should be expanded; ways of effectively implementing an existing IMO Resolution recommending that squat and maneuvering information be provided aboard ships are discussed.

Differences Between the 1992 NOAA Survey and the AUSS Survey.--The AUSS survey reported that six rocks were impacted rather than two rocks, as reported by NOAA in its 1992 survey. Based on its survey of the bottom damage, the Safety Board believes that more than two rocks were struck by the QE2 in the area of the grounding.

When conducting the NOAA survey, divers surveyed the ocean bottom along a line representing the ship's trackline and found RR I and II to lie approximately on the trackline. If these were the only rocks impacted, then based on the dimensions and proximity of the rocks, the damage inflicted on the hull bottom would have been contained within paths separated by 20 feet when measured in the direction of the vessel's beam. However, damage survey and photographs show that the hull suffered damage along widely separated parallel lines, extending from forward on the bow to aft on the starboard side and from forward to aft out to the bilge keel on the port side. RR I and II are relatively narrow (about 8 feet) compared with the 105-foot beam of the ship and could not have caused the large extent of transverse damage that was observed. It should be noted that the NOAA diver's underwater survey was limited by restricted underwater visibility to a narrow corridor as wide as a third of the breadth of the vessel. The AUSS survey, on the other hand, was conducted over a longer time and after the preliminary work was accomplished by NOAA.

Because the 1992 NOAA survey did not report the depths of impacts (rocks) 2, 3, 4 and 6, no depth comparisons can be made with the AUSS survey. The survey depths presented by the AUSS include estimates for vertical movements of the rocks caused by the impact. However, these movements could be reliably estimated by the AUSS for only two of the six rocks impacted.

Comparison of the Safety Board's Squat Estimate With Cunard's Estimate.--The depths of the rocks, as reported by the NOAA and AUSS surveys, were used as baseline information by the Safety Board and Cunard to estimate the squat of the QE2. The Safety Board estimates the QE2's squat at between 4 1/2 to 8 feet, whereas Cunard estimates it at 2 to 3 1/2 feet. A major component of the difference in these squat estimates can be attributed to the differences in depths of the rocks (1.4 for RR I and 2.8 feet for RR II) reported by the NOAA and AUSS surveys. Using the AUSS survey data instead of NOAA's significantly reduces the squat estimates. Regarding the large differences between the surveyed depths of NOAA and the AUSS, NOAA explained in its letter of April 6, 1993, to the Safety Board that "the agreement between AUSS Impact Site One reduced depth and the NOAA Red Rock I least depth compares favorably. The AUSS resumed pneumogage observations approximately 1 1/2 months later, and the gage appears to have drifted significantly." NOAA noted that there appear "to be significant differences in the procedures and requirements used by each Agency to check the instrument [pneumogage] and verify the results." Further, NOAA stated that "it appears that the AUSS pneumogage was not calibrated in a certified laboratory prior to sounding acquisition."

The Board believes that NOAA's information is more reliable because it is based on a detailed resurvey, the results of which were generally consistent with those obtained in NOAA's 1992 survey. Also, the equipment calibration procedures reported by NOAA are much more thorough than the procedures stated in the AUSS's report.[40]

In determining the ship's squat, Cunard assumed that the highest damage inflicted by RR I occurred about 2 feet above the ship's keel. However, the evidence shows that the hull was also damaged 4 to 5 feet above the keel. If this higher damage was inflicted by RR I, then Cunard's squat estimate would increase from 3 1/2 feet based on the bilge keel damage to 5 1/2 to 6 1/2 feet based on the highest hull damage.

The Safety Board believes that numerous accident scenarios can be envisioned in view of the proximity and the multiple rocks involved, as well as the conflicting survey information. The Safety Board, therefore, has independently conducted theoretical calculations to correlate with the analyses from observations of hull damage. The theoretical methods used by the Safety Board are based on extensive research by hydrodynamicists and demonstrate good correlation with the Board's analysis of observed damage to the vessel's hull. The computer analysis of squat subsequently conducted by hydrodynamicists at the David Taylor Research Center also

[40] *Equipment, Procedures, and Calibration Used to Determine Bathymetry and Construct Bathymetric Charts of Vineyard Sound Near Cuttyhunk Island, Massachusetts*, American Underwater Search and Survey, Ltd., Cataumet, Massachusetts, March 1993.

correlated with the Board's earlier estimates. Cunard's opinion of the model test conducted by BMT Fluid Mechanics, Ltd., was that it "had little evidentiary value" because the test results were "wholly inconsistent with the actual damage to the QE2." Because the Safety Board has obtained consistent estimates of squat using independent analytical methods, it considers its conclusions reliable.

Role of Squat in This Accident.--The Safety Board believes that the severity of the damage inflicted on the hull was due to the large squat most likely experienced by the QE2 while it was proceeding at about 25 knots. The NOAA and Cunard/AUSS surveys agree that, among the rocks struck, RR II was most severely impacted. It is therefore very likely that it was the impact of the hull with RR II that caused the greatest damage to the hull. Based on NOAA's reported depth of RR II, the QE2 would not have struck RR II in the absence of squat. Based on the AUSS's reported depth of RR II, the QE2 may have struck the rock, but the impact would have been much less severe in the absence of squat. In addition, had no squat occurred, the QE2 would have avoided collision with RR I altogether, regardless of whether the NOAA or AUSS reported depths were valid.

Based on the depths of rocks reported by the AUSS for impacts 2, 3, 4, and 6, the QE2 still may have grounded on these rocks even if there had been no squat. However, these rocks were not as severely impacted as was RR II and probably did not inflict much damage to the hull. On the other hand, based on the depths for impacts 2, 3, 4, and 6 obtained by NOAA's resurvey in April 1993, this accident would not have taken place if a complete absence of squat is assumed. However, this accident demonstrates that squat did occur, and the Safety Board believes that the extent of squat directly affected the severity of the grounding damage.

Squat significantly increases the risk of grounding and hull damage in shallow water, especially at high speeds. Hull damage exposes a vessel, along with its crew and passengers, to the dangers of flooding and sinking, or capsizing. IMO regulations require that all passenger vessels be constructed with a double bottom and be built to stability standards that allow the vessels to safely survive a significant amount of hull damage. These design features enabled the QE2 to safely withstand the damage it suffered and permitted all passengers to be safely transferred from the vessel. If the vessel's double bottom had been penetrated, the consequences may have been more severe.

Effect of the Master's and Pilot's Choice of Ship Speed on Squat.--The master and pilot jointly selected the speed of about 25 knots to meet the QE2's operating schedule. As mentioned earlier, at a speed of 24 knots, a large squat of 4.5 to 8 feet was estimated.

Table 2 illustrates the speed sensitive nature of squat, as calculated for a water depth of 40 feet:

Table 2.--Effect of speed on squat.

Speed (knots)	Squat (feet)	Decrease in squat
24	8	baseline
18	4.5	-44%
15	3.1	-61%
10	1.4	-83%

Although the pilot and master of the QE2 were generally aware of the phenomenon of squat, they testified that they had expected no more than 2 feet of squat, whereas the actual squat of the QE2 was probably 4.5 to 8 feet. Most mariners would probably agree with the master and pilot of the QE2 that a 2-foot allowance for squat was typical because most mariners' experience with squat is based on operating vessels in restricted waters, where vessels usually proceed at speeds of 10 to 12 knots or less.

Mariners' inadequate appreciation of ship squat at high vessel speeds can be attributed to a variety of factors. Squat cannot be adequately measured by a shipboard mariner using draft gauges or other commonly used shipboard equipment, because the draft remains largely unchanged while the clearance under the keel decreases. Squat is not visible to the mariner as it occurs and must usually be deduced through postaccident analysis, as in this grounding. Also, squat effects diminish as the vessel's speed is reduced and disappear without a trace immediately after a vessel is stopped.

The Safety Board found that the literature (see appendix C) on ship squat commonly available to the marine industry primarily addresses vessels operating in shallow waterways, canals, and river approaches to ports. In such areas, squat is normally not a severe problem because vessel traffic, speed limits, the often meandering nature of navigational waterways, and other factors automatically restrict ships to slow speeds. Consequently squat, as experienced by many mariners, is limited to 2 feet or less for speeds of up to 12 knots. Also, in some waterways, ships are frequently operated at slow speeds with the keel touching the sandy or muddy bottom of the waterway. Such situations are normally not dangerous if ship speeds are slow, the waterway's bottom is soft, and the master and the pilot are well aware of the area's navigational limitations. The operating conditions of the QE2 were entirely different: they involved high speeds, a rocky sea floor, and a route seldom traversed by deep-draft vessels.

Information regarding the unusually large squats experienced by vessels at high speeds does not receive widespread distribution outside the community of hydrodynamic researchers. However, as the grounding of the QE2 demonstrates, ships with a high service speed occasionally operate at high speeds in waters that are not considered shallow in the conventional sense and that do not have speed restrictions. Nonetheless, squat effect can make these waters effectively too shallow when a vessel proceeds at high speeds, as shown by this accident. The lack of information about squat, especially at high speeds, can therefore be dangerous.

The Safety Board believes that had the master and the pilot been provided with information by the vessel operators about the large squat likely in shallow waters, they may have chosen a route through deeper water or proceeded at a slower speed, thereby avoiding this accident. The master and the pilot could have benefitted immensely from the knowledge that their rule-of-thumb squat allowance of 2 feet could be exceeded by more than 300 percent during the QE2's transit through Vineyard Sound. Such information would have provided them with the necessary knowledge for making safe decisions during the master/pilot conference. The Safety Board concludes that the lack of information available on the QE2 about its squat characteristics caused the master and pilot to overestimate the vessel's underkeel clearance.

The world fleet has a large number of fast ships, such as container ships and passenger ships, that typically have service speeds ranging between 15 and 27 knots. Unlike the fixed-route transatlantic passenger liners of the past, modern cruise vessels change their area of operations from one part of the world to another depending on passenger traffic and economic considerations. Therefore, modern cruise vessels will at least occasionally encounter routes that are relatively new to the mariner or that never have been traversed by deep-draft vessels. Similar circumstances may arise, as well, for container and other cargo vessels. Because modern passenger ships carry 1,000 to 2,600 or more passengers and up to 1,000 crewmembers, an accident has the potential for causing high loss of life and/or injuries. For container and other cargo vessels, an accident poses a danger to the crew and could cause environmental damage through the spillage of fuel oil, cargo oil, or hazardous materials. These vessels remain potentially exposed to the same risks as the QE2 until information on their squat characteristics is supplied to the masters and pilots of these vessels.

Provision and Display of Squat Information on Board Ships.--Since 1968, the international maritime community has expended considerable resources and effort at IMO to address the problems created by vessels with poor maneuvering characteristics and the consequent dangers posed to life, property, and the marine environment. This sustained effort culminated in the development of IMO Resolution A.601(15), "Provision and Display of Maneuvering Information on Board Ships" (the Resolution). The Safety Board considers the development of the

Resolution to be a noteworthy achievement in the ongoing effort to educate operators of all types of vessels regarding the maneuvering and squat characteristics of their vessels. The urgent need for such information to help prevent accidents has been highlighted again in the squat-related grounding of the QE2, as well as in accidents involving comparatively slower vessels such as the ALVENUS, MV WELLPARK, and the FORT CALGARY, to cite just a few examples.

IMO resolutions are recommendations that are intended to be widely used throughout the maritime community to gain experience in their practical application. Despite the fact that the Resolution A.601(15) was adopted by international consensus in 1987 to further the IMO's declared objectives of improving the safety of ships and waterways, the Safety Board is concerned that the Resolution is not being implemented. Therefore, the maritime community has not gained the necessary experience in the practical application of the Resolution, a situation that appears likely to continue in the foreseeable future. The Safety Board believes that the Resolution has not been effective because it remains only a recommendation and is not enforceable by national regulations or through the SOLAS Convention. The grounding of the QE2 should heighten the awareness of the maritime community and its safety regulators concerning the relevance of Resolution A.601(15) and the importance of implementing it.

The Safety Board believes that implementation of the Resolution will not overly burden the marine industry. The Resolution calls for squat only to be estimated; this can be accomplished by using the empirical formulas and experimental data developed by researchers over the past 20 to 30 years. Most of this information, such as the resources listed in appendix C, is readily available in the public domain and can be easily utilized by naval architects. Most of the other information required by the IMO Resolution pertains to ship maneuvering characteristics that are routinely obtained during shipyard delivery trials conducted for new or modified vessels. The safety benefits of implementing the Resolution would far outweigh the minimal effort involved in adding the squat information to the maneuverability information already available.

The Safety Board commends the Coast Guard for requiring, since 1984, the display of certain maneuvering information on the navigating bridges of vessels operating in U.S. waters. This regulation (33 CFR 164.35(g)) applies to all ships over 1,600 gross tons, both foreign and domestic, that trade in U.S. waters. The Safety Board notes that although the Coast Guard requires much of the maneuverability information identified in the Resolution, squat information is not required. However, these Coast Guard regulations took effect before the adoption of the Resolution, which for the first time made the international maritime community aware of the importance of presenting squat information.

Although the Coast Guard published Navigation and Vessel Inspection Circular (NVIC) 7-89 to encourage ship operators to implement the IMO Resolution, the experience of the Safety Board shows that there has been little response to the NVIC by the maritime industry or followup by the Coast Guard, as exemplified by this accident. Despite the good intentions embodied in the NVIC, it has failed to help avoid squat-related accidents. An objective of the Port and Waterways Safety Act of 1972 (PWSA) is to improve the navigational safety of vessels and waterways of the United States. The lack of ship squat information poses dangers to navigation similar to the lack of maneuverability information on ships. The Safety Board, therefore, believes that to truly fulfill the intent of the PWSA, the Coast Guard should require that squat information be provided aboard ships, as a complement to the existing regulations requiring maneuvering information.

The Safety Board believes that shipboard information on squat characteristics should be required by Coast Guard regulation at least for deep-draft, high-speed vessels. Because the marine community's knowledge regarding squat is largely limited to slow-speed vessel operation (under about 12 knots), squat information should be developed and disseminated covering the higher speeds at which many vessels operate and at which squat behavior becomes most severe. Recognizing that the development of regulations concerning squat may take time, the Safety Board believes that, in the interim, the Coast Guard should widely publicize the fact that at high speeds squat can significantly exceed the commonly used figure of 2 feet and could expose vessels to the risk of grounding.

Navigational Information

Charts provide the mariner with much information, including data about objects above and below the water and, in particular, the depth of the water. To help determine the value of this information, the mariner needs to know the date of the most recent depth survey from which the plotted data were derived. If the mariner has further questions about the surveys, more detailed information should be available in the *U.S. Coast Pilot* volume for the area. The *Coast Pilot* also advises the mariner that the date of a chart is of vital importance. However, the issue date on a chart does not provide enough information about the surveys upon which a chart is developed nor does it mean that all information has been updated or that the previously charted data has been verified. The *Coast Pilot* further warns that uncharted rocks will always be a problem, no matter how current or accurate a chart may be.

The methods used in 1939 to take soundings in the Vineyard Sound area were state of the art at the time. The sea bottom area radius encompassed by the echo sounder was 0.4 times the depth of the water and at depths between 40 to 50 feet would encompass an area 16 to 20 feet in diameter. However, given a distance between the sounding lines of about 400 meters (about 1,300 feet), a considerable area remained unsurveyed or only minimal information was available about the bottom between the survey lines. Because mariners accept the sounding data on charts as essentially correct, a brief explanation should appear on the chart and a more complete explanation be provided in the *Coast Pilot* indicating the thoroughness of the survey that produced the soundings. Even so, charts should always be used with caution because they are a navigational aid, not a guarantee of safety. Charts are no more accurate than the survey techniques on which they are based, and except in waters well traversed by vessels of similar size, few surveys have been so thorough as to make certain that all dangers have been discovered. The survey should be described to provide the mariner with sufficient information to determine how to navigate in an area of limited or questionable depth.

The QE2's navigator planned the trackline of the QE2, with the master's approval, south of the shoal near Brown's Ledge and south of the 39-foot sounding. The navigator also put marks on the shoal that included the 39-foot sounding to call attention to it and warn users of the chart to be aware of it. The pilot planned his track north of Brown's Ledge, which was south of the Sow and Pigs Reef and north of the 39-foot sounding, about midway between the two shoal areas. Although the charts in use at the time of the accident did not have the accurate sounding information available today, they served their purpose in warning mariners of the rocky shoal, a concern shown by the master's and navigator's planned trackline and also by the pilot's route out of Vineyard Sound. The Safety Board concludes that although NOAA's navigation charts and *U.S. Coast Pilot* volumes lack the necessary depth survey information for mariners to effectively evaluate the safety of waterways, the charts did provide sufficient information for the master and pilot of the QE2 to plan a course that would have avoided the 39-foot sounding and rocky area.

British Admiralty (BA) and some U.S. Defense Mapping Agency charts show the dates of surveys within a small diagram on the chart when such information is available. On November 22, 1992, NOAA revised its *Nautical Chart Manual*[41] to require that "source diagrams" be added to all nautical charts with a scale of 1:500,000 or larger. The source diagrams will include information on survey dates similar to that found on BA charts and provide other details of the surveys from which the chart was developed. Because NOAA's frequency of issue of new charts varies from 6 months to 12 years, this process will take several years to complete.

Each *U.S. Coast Pilot* volume lists the charts that are available and indicates the charts that should be used for a particular area or port. However, the *Coast Pilot* does not provide data concerning bottom surveys, such as when they were accomplished, by what method the soundings were taken, or what the frequency of sounding line spacing was. This information would be helpful to a mariner in voyage planning by providing information on the degree of data quality, thus allowing navigators to use their own judgment regarding the accuracy of the data for a particular route. Although surveys taken before 1930, which used lead lines, may be as accurate as recent surveys of specific points, they are generally not as thorough because of the sounding line spacing and the chance that the lead-line sounding may have missed rocks or other obstructions. More modern methods of taking bottom surveys, such as side-scan sonar, were not used until the mid-1980s.

Unlike charts, *U.S. Coast Pilot* volumes are not limited by space in printing navigational information. Therefore, additional information that cannot be presented in a chart without obscuring necessary navigational information should be included in the applicable *Coast Pilot* volume to provide thorough and complete data to the navigator. The Safety Board also supports the use of source diagrams for navigation charts.

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[41]*Nautical Chart Manual*, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 7th edition, 1992.

The QE2's navigator testified that the *British Pilot Book*, which contains information similar to the *U.S. Coast Pilot*, recommended that deep-draft vessels pass southeast of the "NA" buoy when entering (or leaving) Vineyard Sound. The *U.S. Coast Pilot* volume covering Vineyard Sound and Buzzards Bay, however, does not give a similar recommendation concerning entry to or exiting from Vineyard Sound for deep-draft vessels. The *Coast Pilot* does give specific information on the eastern approach from Nantucket Sound, Wood's Hole, Oak Bluffs, Vineyard Haven, and other channel approaches in the area. The Safety Board believes that similar information on the western approach for deep-draft vessels entering Vineyard Sound should be included in volume 2, chapter 5, of the *U.S. Coast Pilot*.

Toxicological Testing

Delays in the collection of toxicological samples were significant. The Coast Guard boarding officer from the Marine Safety Detachment (MSD), Cape Cod, did not begin to arrange for the collection of toxicological samples from the bridge watch until approximately 13 hours after the grounding, when the pilot mentioned to him that someone from the NABH would be coming out to the ship to collect samples from the pilot. At that point, the boarding officer contacted MSO Providence for advice on collecting samples from the master and bridge watch of the QE2.

Sample collection should take place as soon after the accident as practical because of the perishability of the evidence used to determine the role of alcohol or drugs in the accident. Such a requirement is also important because it could help deter crewmembers' drug abuse and discourage tactics that may delay sample collection. Nonetheless, the logistics of an accident, especially in the marine environment, can delay timely collection, and in those circumstances, samples should be collected as soon as practical and the reason for the delay documented. However, it should also be noted that no penalties are imposed against foreign vessels whose crews refuse to test for alcohol or drugs after an accident.

Because only urine was collected from the master, pilot, and first officer, and because of the delay in obtaining samples, the possibility of detecting alcohol in the crewmembers involved in this accident was diminished. A timely blood sample is preferred for determining the blood alcohol concentration, but a timely breath sample would have been an acceptable alternative because the concentration of alcohol from deep-lung air is proportional to the concentration of alcohol in blood.[42]

The Safety Board was able to determine from toxicological testing that drugs played no role in this accident. However, the Safety Board could not determine whether alcohol was a factor because the master, first officer, and pilot were not urine-tested or breath-analyzed for alcohol. The only information available to the Safety Board on the possible use of alcohol by the master,

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[42]C.M. Dubowsky, "Absorption, Distribution and Elimination of Alcohol: Highway Safety Aspects," *Journal of Studies on Alcohol*, supplement No. 10, July 1985, pp. 98-108.

pilot, or first officer was the Coast Guard boarding officer's observation that neither the pilot nor the QE2 bridge team, including the master, exhibited behavior indicating alcohol intoxication.

The Safety Board has investigated several other marine accidents where delays in the collection of toxicological samples have been excessive.

For example, following the grounding of the U.S. tankship EXXON VALDEZ,[43] delays in obtaining toxicological samples were significant. The vessel traffic center watchstander on duty at the time of the grounding was tested about 14 hours after the accident. The master, third mate, lookout, and helmsman were not tested until 11 or 12 hours after the accident, even though toxicology kits had been available on the EXXON VALDEZ.

The Safety Board's investigation of that accident showed the Coast Guard was not prepared to assist with toxicological sampling. The Safety Board found that the Exxon Company knew of the testing requirement and had placed toxicological sampling kits on board the EXXON VALDEZ for that purpose, and the Coast Guard was aware that toxicological samples had to be collected but lacked field or operational guidelines to accomplish this.

After the capsizing and sinking of the SEA KING,[44] a U.S. fishing vessel, the Coast Guard was unable to obtain a toxicological sample from the operator of the vessel. The owner failed to direct the operator to submit to a toxicological test under the authority of 33 CFR 95, and the Coast Guard could not penalize the operator because commercial fishermen may operate unlicensed and Federal regulations do not address penalties for unlicensed or undocumented U.S. crewmembers who refuse to test. Because of the lack of information available, the Safety Board could not determine whether drugs or alcohol were factors in the accident.

The report concluded that the Coast Guard had not provided guidance to its personnel for informing the owner of the vessel of the responsibility to toxicologically test crewmembers and for assisting the owner in toxicological sampling, as necessary.

The Safety Board has recommended 4 hours as the maximum time allowed to obtain toxicological samples. In this accident, the delays of 16 and 39 hours before toxicological samples were taken constituted untimely sampling and shows that insufficient priority was given to this area of accident investigation.

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[43]Marine Accident Report--*Grounding of the U.S. Tankship EXXON VALDEZ on Bligh Reef, Prince William Sound Near Valdez, Alaska, March 24, 1989* (NTSB/MAR-90/04).

[44]Marine Accident Report--*Capsizing and Sinking of the U.S. Fishing Vessel SEA KING, Near Astoria, Oregon, January 11, 1991* (NTSB/MAR-92/05).

The Safety Board has made a number of recommendations to the U.S. Department of Transportation and the U.S. Coast Guard regarding the importance of timeliness in the collection of postaccident toxicological samples.

On December 5, 1989, as the result of a Safety Board special review of its investigation of transportation accidents, the Safety Board recommended to the U.S. Department of Transportation (DOT) that the regulations for all modes [of transportation] should

> <u>I-89-6</u>
>
> Adopt uniform regulations on postaccident and postincident testing of private sector employees for alcohol and drugs in all transportation modes. Use the Federal Railroad Administration's (FRA) current regulation as a model regulation for all transportation modes except for the permissible blood alcohol level of less than 0.04 percent. Using the FRA regulation as a model for other transportation modes refers only to the collection of blood and urine and the screening and confirmation of positives in blood. As a minimum, the drugs identified in FRA screen should be used in the other modes. Reference to the FRA model does not refer to the administration or implementation of the regulation. The Safety Board recognizes that the implementation of the regulation may be different in the various transportation modes. The regulations for all modes should provide for the collection of blood and urine within 4 hours following a qualifying incident or accident. When collection within 4 hours is not accomplished, blood and urine specimens should be collected as soon as possible and an explanation for such a delay shall be submitted in writing to the administrator.

On August 3, 1990, the DOT replied,

> I am responding to your letter that transmitted nine National Transportation Safety Board (NTSB) recommendations (I-89-004 through 012) concerning the Department's drug alcohol regulations, particularly with respect to post-accident testing. I share your concern about the problem of alcohol and drug use in the transportation industry. That concern prompted the comprehensive drug regulations that are now in effect, as well as the pending rulemaking concerning alcohol abuse, and drives my continued personal involvement in these issues.
>
> Your recommendations, and the issues they raise, are discussed in greater detail in the enclosure to this letter. The primary purpose of the Department's program is to prevent such abuse by deterring improper conduct by employees performing sensitive safety and security-related functions. While we recognize that results of Department of Transportation (DOT) mandated

testing may have relevance to accident investigations in some situations, the DOT program is not primarily intended as an accident investigation tool.

The overall thrust of your recommendations appears to be to ask the Department to create an additional program -- distinct in scope, purpose, methods, and procedures from the Department's existing drug and alcohol abuse prevention program -- to determine the role of substance abuse in the causation of transportation accidents. We do, however, understand your concern and are willing to discuss the need for such an additional program with the NTSB, as well as the implications in terms of resources, costs, benefits and the respective transportation safety roles of the Department and the NTSB.

On May 31, 1991, the Safety Board replied that based on the responses set forth in the letter of August 3, 1990, and on the Board's concern that there has not been any real progress on the development of the more comprehensive postaccident drug testing program requested by Safety Recommendation I-89-6, it has been classified as "Open--Unacceptable Response."

On December 15, 1992, the DOT issued a Notice of Proposed Rulemaking: "Limitation on Alcohol Use by Transportation Workers" and "Procedures for Transportation Workplace Drug and Alcohol Testing Programs." Concerning testing periods, the Board's comment was as follows:

The proposed postaccident testing rules are inconsistent among the modes of transportation. The Safety Board has recommended that specimen collection take place "within four hours following a qualifying incident or accident." We hope that specimen collection can be completed within 2 hours in all transportation modes as proposed by DOT. The Safety Board believes that all modes should require a notification to the modal Administrator when a postaccident test specimen is not collected within 2 hours of the accident. Notification requirements should not be further delegated by the Administrator and the notification should include reasons for the delay. Further, there should be no limit on the time for testing if 2 hours has elapsed. Testing should be completed as quickly as possible after the accident with the objective of obtaining specimens within either the 2 hours proposed or the 4 hours recommended by the Safety Board....

Marine postaccident drug testing problems have existed because operational safety issues are attended to first, as they should be. Nonetheless, boarding officers should have a plan for informing marine employers[45] of their responsibility to test crewmembers and for assisting marine employers in carrying out toxicological testing, if necessary. Although drug testing may

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[45]Title 33 CFR 95.010 and Title 46 CFR 4.03-45 defines marine employer as an owner, managing operator, charterer, agent, master, or person in charge of a vessel other than a recreational vessel.

not be of immediate concern, it should not be treated as an afterthought. Toxicological samples must be obtained in any and all cases in which crew performance may be questioned and must be collected as soon after the accident as is practical.

The Safety Board concludes that the Coast Guard boarding officer on the QE2 knew that toxicological testing was required, but lacked field or operational guidelines to inform the vessel owner of the responsibility to test crewmembers and to assist the marine employer, as necessary, in accomplishing toxicological sampling and testing.

Although drug testing regulations are described in titles 33 and 46 of the Code of Federal Regulations, the Coast Guard has limited guidelines for boarding officers outlining their specific duties for toxicological testing. Moreover, these guidelines (Commandant Instruction 16247.5 dated May 7, 1991) refer mainly to recreational boating. Therefore, problems still exist for "other than recreational vessels" because of the limited guidance on how to accomplish drug testing, which causes delays in the collection of toxicological samples. Coast Guard field investigators and the owner/operator of the vessel involved in an accident must decide whether testing is required under the regulations and if so, who must be tested and when sample collection will occur and by whom. The Safety Board believes that marine employers of vessels should be familiar with the Federal requirements for postaccident toxicological testing. The Safety Board also believes that Coast Guard boarding officers should inform marine employers of their responsibility to conduct toxicological testing and should provide assistance when necessary (such as providing sampling kits and making arrangements for testing with local laboratories).

Survival

Responses to the Safety Board's questionnaire on this accident indicated that the passengers were made aware of the circumstances surrounding the grounding in a timely manner and were informed quickly that they were in no danger and would not have to leave the vessel.

The next day (August 8) Cunard decided to transfer all passengers ashore in Newport after the extent of the bottom damage was known. The master, upon receiving reports that poor weather was predicted, decided to continue the disembarkation into the evening of August 8 and early morning hours of August 9. Eleven of the passengers responding to the Safety Board's questionnaire wrote that the nighttime disembarkation was dangerous and suggested that the transfer should have been delayed until daylight hours on August 9. However, the vast majority of the passengers reported that they had a safe disembarkation from the vessel, and the Safety Board found no evidence that the passengers transferred during the hours of darkness were at additional risk.

With respect to passenger safety briefings and drills, chapter III, regulation 18, section 3.2, of the International Convention for the Safety of Life at Sea (SOLAS) states in part:

On a ship engaged on an international voyage, musters of the passengers shall take place within 24 hours after their embarkation. Passengers shall be instructed in the use of lifejackets and the action to take in an emergency. If only a small number of passengers embark at a port after the muster has been held it shall be sufficient, instead of holding another muster, to draw the attention of those passengers to the emergency instructions [placards] required by regulations.

The passengers who boarded the QE2 at Halifax did not have the advantage of participating in a lifeboat drill that those passengers who boarded the vessel at the commencement of the cruise in New York had. The Halifax passengers' emergency briefing consisted of being made aware of the emergency instructions posted in their accommodations by their room stewards. Because an emergency can occur at any time after the voyage commences, passengers boarding a vessel at intermediate ports should also receive comprehensive safety and emergency instructions by qualified vessel personnel. This lack of instruction in emergency procedures could have serious consequences if an emergency evacuation were to occur, especially late at night. The Safety Board concludes that the passengers who boarded the QE2 at Halifax believed they were unprepared for a shipboard emergency because they had not been given a comprehensive briefing or an emergency drill.

On August 21, 1985, as a result of its investigation of the fire on the Bahamian passenger vessel SCANDINAVIAN SUN[46] at Miami, Florida, the Safety Board issued the following recommendation to the Coast Guard:

M-85-59

Propose to the International Maritime Organization an amendment to SOLAS '74 to require that passenger ships on short international voyages conduct drills or safety orientations for passengers at emergency muster stations immediately upon departure from port. Safety orientation briefings should include a demonstration on the donning of life preservers, evacuation or disembarkation routes, information concerning the function of automatic fire doors, and actions to take in the event of a fire or other emergency.

The Coast Guard asserted that regulation 18 of chapter III of the 1983 amendments to SOLAS '74 addresses the recommendation. The Safety Board replied that it continues to believe that supplying passengers with verbal and written instructions is a poor alternative to giving them demonstrations at muster stations and consequently classified Safety Recommendation M-85-59 as "Closed--Unacceptable Action" on July 10, 1992.

[46]Marine Accident Report--*Fire Aboard the Bahamian Passenger Vessel SCANDINAVIAN SUN, Port of Miami, Miami, Florida, August 20, 1984* (NTSB/MAR-85/08).

The Safety Board believes that passengers who boarded the QE2 at Halifax should have been instructed by a crewmember in the use of life jackets and on the actions to take in an emergency rather than merely having had their attention directed to emergency instructions. The Safety Board also believes that the SOLAS regulations should be changed to require that passengers boarding a cruise after the first port of departure be given a comprehensive safety briefing by qualified crewmembers soon after boarding.

Although the difficulties experienced by disabled passengers were not a major problem in this accident, they illustrate the need for additional precautions to prepare disabled passengers for emergencies. For instance, one hearing-impaired passenger responding to the Safety Board's survey complained that she could not hear the public address system. When she attempted to gain information from the television in her room, she found that it was not equipped with closed caption. However, according to Cunard, the QE2 could have provided closed-caption programming through the ship's television system.

Hearing-impaired passengers should not be excluded from obtaining vital safety or emergency information. More than 28 million Americans have a hearing loss and 80 percent of those affected have permanent, irreversible hearing damage. In addition, more than one-third of the U.S. population has a significant hearing impairment by age 65, according to statistics compiled by the National Institute on Deafness and Other Communication Disorders. The population of older, potentially hearing-impaired passengers could be sizable. A statistician from the Cruise Line International Association stated that over a 5-year period, on average, 36 percent of the passengers traveling on cruise vessels were at least 60 years old.

The Safety Board believes that hearing-impaired and other disabled passengers should have a means of obtaining emergency information to prevent the possibility of not being notified of a vessel emergency such as fire, sinking, or evacuation. In light of the potential problems revealed by this investigation, the Safety Board concludes that disabled passengers who travel by ship require additional safety precautions to advise and prepare them to act in an emergency.

On September 6, 1991, the Department of Transportation (DOT) published final rules implementing the transportation provisions of the Americans with Disabilities Act of 1990 (the Act). The Act requires accessibility to transportation facilities and makes it unlawful to discriminate against individuals with disabilities in public accommodations, transportation, and telecommunications. The regulations did not contain any rules for vessels but reserved 49 CFR 37.109, "Ferries and Other Passenger Vessels" for future rulemaking. At this time, the DOT has indicated that it does not have sufficient information to develop accessibility regulations for disabled passengers and has contracted with a consultant to study the implementation of the Act as it pertains to passenger vessels.

The Safety Board believes that in addition to evaluating accessibility requirements, the DOT and IMO should study safety issues involving the disabled aboard passenger vessels.

CONCLUSIONS

Findings

1. The grounding would probably not have occurred if a thorough master/pilot conference had been held, which would have made the master aware of the pilot's intentions, and if an agreement on an appropriate route to the pilot's disembarkation point had been reached.

2. If the master and pilot had discussed and determined the location of a new trackline before the pilot altered course to pass south of Brown's Ledge, they would have been alerted to the trackline's proximity to the 39-foot area and probably avoided the shoal.

3. The speed of 25 knots selected by the master and agreed to by the pilot left inadequate room for a margin of error.

4. The use of effective bridge resource management techniques by officers in charge of navigation watches increases the safety of navigation.

5. Adequate squat information was not available to the crew.

6. Although NOAA's navigation charts and *U.S. Coast Pilot* volumes lack the detailed depth survey information necessary (survey dates, sounding method, and sounding line track spacing) for mariners to effectively evaluate the safety of waterways, the charts did provide sufficient depth information for the master and pilot of the QE2 to plan a course that avoided the 39-foot sounding and rocky area.

7. The marine employer failed to obtain timely toxicological samples from the bridge watch.

8. The Coast Guard boarding officer on the QE2 knew that toxicological testing was required but lacked field or operational guidelines to inform the marine employer of the responsibility to test crewmembers and to assist the marine employer, as necessary, in accomplishing timely toxicological sampling and testing.

9. The passengers who boarded the QE2 at Halifax should have been given a comprehensive briefing or an emergency drill.

10. Disabled passengers who travel by ship may require additional safety precautions to advise and prepare them to act in an emergency.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the grounding of the QUEEN ELIZABETH 2 was the failure by the pilot, master, and watch officers to discuss and agree on a navigation plan for departing Vineyard Sound and to maintain situational awareness after an unplanned course change. Contributing to the accident was the lack of adequate information aboard the QUEEN ELIZABETH 2 about how speed and water depth affected the ship's underkeel clearance.

RECOMMENDATIONS

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

--to the U.S. Coast Guard:

> Establish standards and curricula for bridge resource management training for Federal pilots licensed by the U.S. Coast Guard. (Class II, Priority Action) (M-93-17)
>
> Propose to the International Maritime Organization that standards and curricula be developed for bridge resource management training for the masters, deck officers, and pilots of ocean-going ships. (Class II, Priority Action) (M-93-18)
>
> Propose to the International Maritime Organization that the masters, deck officers, and pilots of ocean-going ships be required to successfully complete initial and recurrent training in bridge resource management. (Class II, Priority Action) (M-93-19)
>
> Require that all applicants for an original or the renewal of a Federal pilot and deck officer license for vessels of more than 1,600 gross tons successfully complete a course in bridge resource management. (Class II, Priority Action) (M-93-20)
>
> Propose that the International Maritime Organization incorporate IMO Resolution A.601(15), "Provision and Display of Maneuvering Information on Board Ships," into the SOLAS Convention. (Class II, Priority Action) (M-93-21)
>
> Amend the Navigation Safety Regulations (33 CFR 164.35(g)) to require that squat characteristics be included with the maneuvering information on vessels, as recommended by IMO Resolution

A.601(15), for deep-draft, high-speed vessels over 1,600 gross tons. (Class II, Priority Action) (M-93-22)

Widely publicize the particulars of this accident concerning the large squat for ships operating at high speeds in shallow waters. (Class II, Priority Action) (M-93-23)

Provide guidelines to boarding officers investigating marine accidents about informing marine employers of their responsibility to conduct toxicological testing and on providing assistance when necessary (such as providing sampling kits and making arrangements for testing with local approved laboratories). (Class II, Priority Action) (M-93-24)

Propose to the International Maritime Organization a requirement that all passengers boarding vessels at intermediate ports during a voyage receive comprehensive safety and emergency instructions by qualified crewmembers soon after boarding. (Class II, Priority Action) (M-93-25)

Propose to the International Maritime Organization that appropriate safety standards be developed to ensure the safety of disabled people aboard passenger vessels during an emergency. (Class II, Priority Action) (M-93-26)

--to the Department of Transportation:

When implementing the accessibility requirements for ferries and other vessels in the Americans with Disabilities Act (49 CFR 37.109), include requirements to advise and evacuate disabled passengers in an emergency. (Class II, Priority Action) (M-93-27)

--to the National Oceanic and Atmospheric Administration:

Include information on U.S. coastal charts and in *U.S. Coast Pilot* volumes concerning depth survey dates and brief descriptions of survey methodology, including such items as survey trackline separation, sounding method, and sounding accuracy for pilotage waters. (Class II, Priority Action) (M-93-28)

Include a description of the western approach to Vineyard Sound for deep-draft vessels in volume 2, chapter 5, of the *U.S. Coast Pilot*. (Class II, Priority Action) (M-93-29)

--to Cunard Lines, Ltd.:

Require that after a pilot boards one of your vessels, your masters conduct a conference that includes a discussion between the pilot and other relevant deck officers of the proposed route, including courses, speeds, squat, unique maneuvers, and danger areas. (Class II, Priority Action) (M-93-30)

Implement IMO Resolution A.601(15), "Provision and Display of Maneuvering Information Aboard Ships," paying particular attention to the provision of squat information for the QUEEN ELIZABETH 2 and other deep-draft, high-speed vessels in your fleet. (Class II, Priority Action) (M-93-31)

Require that all passengers boarding vessels at intermediate ports during a voyage receive comprehensive safety and emergency instructions by qualified crewmembers soon after boarding. (Class II, Priority Action) (M-93-32)

Provide a suitable means for communicating or relaying passenger advisories, instructions, and emergency alerts to disabled passengers. (Class II, Priority Action) (M-93-33)

--to State pilot commissions:

Require that State pilots, upon boarding a vessel, conduct a conference with the master and other relevant deck officers that includes a discussion of the pilot's proposed route, including courses, speeds, squat, and unique maneuvers that may be encountered. (Class II, Priority Action) (M-93-34)

As a further result of its investigation, the National Transportation Safety Board reiterated the following safety recommendations to the U.S. Coast Guard:

<u>M-91-6</u>

Require bridge resource management training for all deck watch officers of U.S. flag vessels of more than 1,600 gross tons.

<u>M-91-28</u>

Amend 33 CFR 164.11(k) to require that masters and pilots discuss and agree beforehand to the essential features and relevant checkpoints of maneuvers they expect to undertake.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

CARL W. VOGT
Chairman

SUSAN M. COUGHLIN
Vice Chairman

JOHN K. LAUBER
Member

CHRISTOPHER A. HART
Member

JOHN A. HAMMERSCHMIDT
Member

May 25, 1993

APPENDIXES

APPENDIX A

INVESTIGATION

Investigation

The National Transportation Safety Board was notified of this accident by the U.S. Coast Guard on Saturday morning, August 8, 1992. Five investigators from the Safety Board's Washington, D.C., headquarters were dispatched immediately to Woods Hole, Massachusetts, to commence the accident investigation.

This accident was investigated jointly by the Safety Board and the Coast Guard under the authority of section 304(a)(1)(E) of the Independent Safety Board Act of 1974 and in accordance with 49 CFR 850 (Coast Guard-NTSB Marine Casualty Investigations). The Coast Guard invited the United Kingdom to participate as recommended by the International Maritime Organization (IMO) Resolution A.637 (Co-Operation in Maritime Casualty Investigations). Two United Kingdom representatives arrived on scene but declined to participate, stating that their country's law required secrecy during an investigation.

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

The following parties participated in the investigation: Cunard Lines, Ltd., the owner of the QUEEN ELIZABETH 2, the master of the QUEEN ELIZABETH 2, and the pilot of QUEEN ELIZABETH 2.

Hearing/Deposition

There was no separate Safety Board public hearing conducted during the investigation; the joint Coast Guard/NTSB investigation board took sworn testimony at the Coast Guard Support Center, Boston, Massachusetts, from August 12 to August 15 and on August 17 and August 26, 1992.

APPENDIX B

CREW INFORMATION

Robin Allen Woodall

Captain Robin A. Woodall, 59, master of the QUEEN ELIZABETH 2, joined the Cunard Steamship Company as an apprentice in 1950. He served 4 years as an apprentice and then obtained his second mate's certificate. Though he had a second mate's certificate, Captain Woodall went to sea as a fourth officer and in 3 years had received his first officer's certificate. He returned to sea as a third officer on cargo ships and freighters and during the following 3 years, advanced to the position of second officer. In 1960, Captain Woodall was issued a master's certificate by the Department of Transport, United Kingdom (U.K.), and joined the Cunard passenger ship division as a junior third officer. Over the years, he has served in all mate's positions for Cunard Lines before his appointment as master of the QUEEN ELIZABETH 2 in August 1989.

John Francis Hadley

The pilot on board the QUEEN ELIZABETH 2, John F. Hadley, 50, graduated from the U.S. Merchant Marine Academy, Kings Point, New York, in 1965 and after graduation worked on commercial vessels. From 1970 until about 1973, he upgraded his licenses and obtained various pilotage endorsements for New England waters. Pilot Hadley received 14 months' training as a Panama Canal pilot on various types of vessels up to a 25-foot draft. While piloting in Panama, he was involved in two minor casualties. He returned to Providence, Rhode Island, where he joined the Northeast Marine Pilots Association in 1976. Pilot Hadley was issued his first master's license by the U.S. Coast Guard in December 1973 for steam or motor vessels of any gross tons, oceans, and also received a Pilot's Commission from the State of Massachusetts in November 1989.

Christopher Michael Wells

Christopher M. Wells, 36, a first officer and a senior watch officer aboard the QUEEN ELIZABETH 2, went to sea in 1974 as a cadet while at the College of Nautical Studies, Warsash, Southampton, England. Upon graduation, he sailed for 17 years aboard Shell tankers in the United Kingdom. While employed by Shell, first officer Wells sailed bulk carriers, liquid natural gas carriers, and cross channel ferries. He joined Cunard in May 1992 as a second officer on board the QUEEN ELIZABETH 2 and was promoted to first officer in July 1992. The Department of Transport, U.K., issued first officer Wells a master's certificate in October 1985 and a dangerous cargo endorsement for liquified gas in November 1986.

John James McKie

John J. McKie, 37, a second officer on aboard the QUEEN ELIZABETH 2, sailed 17 years on oilers, freighters, and ammunition ships for the Royal Fleet Auxiliary Service before joining Cunard in April 1991. Mr. McKie holds a Class 2 Certificate of Competency, which was issued by the Department of Transport, U.K., in April 1982.

Roberto Rosas

Roberto Rosas, 33, the helmsman and a quartermaster on the 8-12 watch aboard the QUEEN ELIZABETH 2, graduated in 1980 from Cebu Central College, the Philippines, with a nautical degree. He joined Cunard in 1989 and has served aboard the QUEEN ELIZABETH 2 since April 1992. Prior to joining Cunard, he sailed for 7 years as a seaman on tugboats, passenger ships, and general cargo ships. Quartermaster Rosas held a third mate's license issued by the Republic of the Philippines in February 1992. In March 1992, he received a certificate of qualification as an efficient deckhand from the U.K. Department of Trade.

Jardgie Arlos

Jardgie Arlos, 36, a quartermaster on the 8-12 watch aboard the QUEEN ELIZABETH 2, graduated from the Philippine Maritime Academy in 1979. He started sailing aboard Greek cargo vessels in 1983 and joined Cunard Lines in 1989 as a quartermaster; in October 1991, he was assigned to the QUEEN ELIZABETH 2. Quartermaster Arlos held a third mate's license issued by the Republic of the Philippines in October 1986 and an able seaman's (AB's) certificate from the U.K. Department of Transport Marine Office in October 1991.

APPENDIX C

LITERATURE CONCERNING SQUAT

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APPENDIX D

MASTER/PILOT COMMUNICATION ISSUES

The master/pilot conference and related issues have long been of concern to the Safety Board. Recommendations from four accidents investigated by the Safety Board in which the failure to have a master/pilot conference either caused or contributed to the accident are discussed below. This discussion also summarizes the U.S. Coast Guard's responses to the safety recommendations resulting from these investigations.

Safety Recommendation M-74-15

As a result of the investigation of the ramming of the Sidney Lanier Bridge at Brunswick, Georgia, by the AFRICAN NEPTUNE on November 7, 1972, the Safety Board recommended that the Coast Guard "require that every master of an oceangoing vessel inform himself of the pilot's plan to maneuver the ship in or out of a harbor and that the master determine, with the pilot's assistance, the critical aspects of the maneuver, including the pilot's plan for emergencies. The master should then be required to instruct his crew to insure that high-risk tasks receive priority."

The Coast Guard responded on July 8, 1975, and in three subsequent responses that this requirement would be incorporated into a Notice of Proposed Rulemaking (NPRM) that it was preparing. However, on April 14, 1981, after the recommendation had been reiterated following another accident, the Coast Guard stated that it disagreed with this recommendation.

Safety Recommendation M-77-33

As a result of the investigation of the collision between the EDGAR M. QUEENY and CORINTHOS at Marcus Hook, Pennsylvania, on January 31, 1975, the Safety Board recommended that the Coast Guard "Amend 33 CFR 164.11(k) to require that the masters and pilots discuss beforehand and agree to the essential features and relevant checkpoints of maneuvers to be undertaken."

The Coast Guard responded on April 13, 1978, that it was preparing an NPRM that would propose a requirement for a master/pilot conference prior to any substantial maneuvering of vessels but that the requirement for an agreement to essential features and relevant checkpoints before undertaking maneuvers would not be included in the NPRM. The Coast Guard further stated that such an agreement impinges upon the traditional master/pilot relationship and that the primary responsibility of the master for the safety of the vessel should be maintained.

Safety Recommendations
M-74-15 and M-77-33 (Reiterated)

As a result of the investigation of the collision of the Greek bulk carrier IRENE S. LEMOS and the Panamanian bulk carrier MARITIME JUSTICE in the lower Mississippi River on November 9, 1978, the Safety Board reiterated Safety Recommendations M-74-15 and M-77-33 to the Coast Guard.

The Coast Guard responded on April 14, 1981, that it disagreed with Safety Recommendation M-74-15 and stood by its previous position on Safety Recommendation M-77-33, stating that although the master and pilot should share pertinent information about the vessel and the waterway, further regulation in that area is unwarranted. Therefore, on July 10, 1981, the Safety Board classified Safety Recommendations M-74-15 and M-77-33 "Closed--Unacceptable Action."

Safety Recommendation M-88-20

As a result of the investigation of the ramming of the Sidney Lanier Bridge by the Polish bulk carrier ZIEMIA BIALOSTOCKA, at Brunswick, Georgia, on May 3, 1987, the Safety Board recommended that the Coast Guard "amend 33 CFR 164.11(k) to require that masters and pilots discuss and agree beforehand to the essential features and relevant checkpoints of maneuvers to be undertaken."

The Coast Guard responded on October 27, 1988, that it concurred with this recommendation in that it considers the sharing of information between the master and pilot to be a part of prudent seamanship. However, the Coast Guard also said it believed that the recommendation was a restatement of Safety Recommendation M-77-33 and that it still considered the language of 33 CFR 164.11(k) sufficient to achieve such communication. Because the Coast Guard stated that it planned no further action on Safety Recommendation M-88-20, on February 28, 1989, the Safety Board classified Safety Recommendation M-88-20 as "Closed--Unacceptable Action."