

SESSION TWO: LESSONS LEARNED: FINDINGS FROM RECENT INVESTIGATIONS OF A COMMERCIAL FISHING VESSEL MISHAP



Boats in eastern Russia (Photo courtesy of Alan Sorum)

THE *ARCTIC ROSE*: FORENSIC ANALYSIS OF A CASUALTY

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The purpose of this paper is to explain the findings of the Marine Board of Investigation in its search for the proximate cause of the sinking of the fishing vessel *Arctic Rose* and to provide details and discuss the forensic analysis techniques employed. Errors discovered during the investigation in the SafetyNET system are identified. Finally, key recommendations made to Commandant as a result of the investigation's findings are discussed.

Methodology: The use of modern technology and a novel dynamic stability model developed by Coast Guard naval architects are discussed to demonstrate the characteristics of the *Arctic Rose* at the time of the casualty. This stability concept allowed the Coast Guard to narrow the scope of its investigation and focus its energies on improving commercial fishing vessel safety.

Results: Through detailed analyses of all facts and testimony, the Coast Guard was able to determine the proximate cause of the sinking of the *Arctic Rose* and the events leading up to its demise.

Conclusions and Recommendations: Several safety recommendations for the commercial fishing vessel industry are evaluated with a focus on stability-related issues and standardization of stability operating tables.

The *Arctic Rose* was a 92-foot fishing vessel, western-rigged with the pilot-house forward and trawl deck aft with a large A-frame gantry at the stern. The ship operated primarily in the Gulf of Alaska and the Bering Sea as a head-and-gut processor, that is, the catch was deheaded and gutted in preparation for freezing and packaging in the processing space.

On April 2, 2001, the *Arctic Rose* encountered tragedy on the high seas, sinking between 2200 April 1 and 0335 April 2 (all times are Alaska Standard Time). The Seventeenth Coast Guard District Command Center received a 406 EPIRB (electronic position-indicating radio beacon) alert at 0335, issued an Urgent Marine Information Broadcast (UMIB), and sent an INMARSAT C message to all stations to alert other vessels. A search-and-rescue case was initiated, and Coast Guard aircraft were sent to the position of the EPIRB. At 0840, a Coast Guard C-130 arrived on the scene and located the vessel's EBIRB at 58°56.9'N/175°56.3'W. A large debris field and oil sheen were found in the vicinity. A nearby fishing vessel eventually responded to the UMIB and joined the search-and-rescue efforts. Shortly after arriving on-scene, the *Alaskan Rose* recovered the body of David Rundall from the water. A subsequent search by Coast Guard aircraft, two cutters, and two samaritan fishing vessels in the immediate area failed to recover additional personnel. Fourteen persons are missing at sea and are presumed dead. There were no survivors.

The Coast Guard's Marine Safety Office in Anchorage, Alaska, immediately began investigating the casualty. The Commandant of the Coast Guard recognized the significance of the casualty and convened a Marine Board of Investigation, the Coast Guard's highest level of investigatory body. Once the Marine Board members were selected, each member began researching the vessel's history and investigating all leads. The Marine Board faced a daunting task of trying to re-create and reconstruct the *Arctic Rose* at the time of her sinking. This case presented the investigators with several roadblocks. First, the investigators had no witnesses or survivors of the sinking. Second, the *Arctic Rose* was a one-of-a-kind vessel, built by backyard boat builders without plans. Finally, shifts in the commercial fishing industry in the Seattle, Washington, region displaced many of the vendors and technicians who had provided services to Arctic Sole Seafoods during refurbishment of the *Arctic Rose*.

The investigation was jointly conducted by investigators from the Coast Guard and the National Transportation Safety Board in various locales in

Alaska, Washington, and other western states. The investigators interviewed over a hundred witnesses in preparation for the hearing to gather facts concerning the *Arctic Rose* and its operation. The hearings for the Marine Board were held in two locations (Anchorage and Seattle) to accommodate witness travel and reduce costs. The Board received testimony from 55 witnesses addressing diverse topics as vessel stability, vessel operations, manning, industry practices, weather conditions, communications, and the Coast Guard's response to the accident.

The Marine Board launched an expedition to locate the wreck of the *Arctic Rose* in order to conduct an underwater survey of the vessel as it searched for more possible clues and answers to the mystery. The Board felt it was important to find the wreck of the *Arctic Rose* and conduct a survey of the vessel in search of clues to help identify the proximate cause of the casualty. The Board chairman petitioned Coast Guard Headquarters in Washington, DC, for permission and funding to carry out an expedition to locate and conduct underwater surveys of the vessel through the use of a remote operated vehicle (ROV). Coast Guard Headquarters granted the Marine Board's request, and two expeditions were ultimately organized to locate, survey, and videotape the condition the wreck of the *Arctic Rose*. Various contractors were organized to provide a suitable vessel to use as a platform for the ROVs and their support teams. The Marine Board was fortunate to locate a vessel, the M/V *Ocean Explorer*, already outfitted with a sonar array under charter to National Marine Fisheries Service and ready for deployment. The use of ROVs to locate and survey the wreck of the *Arctic Rose* was a critical tool for the Board. Two pieces of equipment were used during the first expedition, a Klein 5000 sonar array and a Phantom submersible.

The Klein 5000 is an extremely sensitive side-scanning sonar with the ability to detect minute objects or details on the sea floor. The Klein 5000 system consists of a towfish, tow cable, transceiver/processor unit, and a personal computer for system control and data viewing. The stainless steel towfish incorporates two multi-channel acoustic arrays and a pressure bottle, which houses all the electronics and sensors necessary for sonar recording, altitude sensing, system control, and telemetry. The sonar and sensor data are transmitted up the tow cable via a high-speed digital telemetry link, requiring only a single co-axial or fiber-optic cable. The surface-mounted transceiver/processor unit receives the data, performs all necessary digital processing functions on these data, and relays control commands to the towfish. It requires a team of two for its operation, one technician to fly the "fish" underwater

and the other to monitor the sonar picture. The Klein 5000 system and her crew proved to be critical in locating the *Arctic Rose*. The equipment for the sonar array was located in a small space just forward of the engine room of the M/V *Ocean Explorer*. This space became the operations center for the search.

The voyage from Unalaska, Alaska, to the search area took approximately 2 days. During that time, the expedition team readied their equipment and developed a comprehensive search plan. The Marine Board provided known locations of the composite EPIRB hit, debris field, oil slick, and liferaft to the sonar team, who used the information to build a search grid and search pattern. The team integrated technology of a Triton Elics International Isis Sonar digital acquisition system with a side-scan sonar Klein 5000 towfish. Data from the Klein 5000 was transmitted up 300 meters of tow cable.

Once on-scene, the M/V *Ocean Explorer* conducted a pass on the initial trackline using its bottom-scanning sonar to check for any possible snags that might entangle or damage the Klein 5000. During the third sonar pass, a large target was found. Subsequent passes revealed a silhouette that matched the profile of the *Arctic Rose*. Using these techniques, the team located the wreckage and identified the *Arctic Rose* soon after the start of the search. The *Arctic Rose* lies at a depth of 428 feet 200 miles northwest of St. Paul Island in the Bering Sea. Several additional passes were made, producing high-resolution images of the wreck and scanning for any debris that might have entrapped the ROV.

The following morning, the ROV Phantom HD2 was readied, lowered into the water, and operationally tested. The ROV motored along the bottom with its video camera sending pictures to the surface (these images were recorded for the Marine Board). A hull came into view, and the ROV went alongside the hull, rising as it traveled. Finally, letters came into view, confirming that the *Arctic Rose* was located. The ROV was at the port bow of the vessel and proceeded toward the pilothouse. The video showed that the vessel was resting upright on the sea floor with a slight starboard list. The ROV attempted to power toward the stern of the vessel, but became hopelessly tangled in loose net-mending twine and was lost when the umbilical parted in a last-ditch attempt to free it. The Marine Board received approximately 14 minutes of usable video.

The Klein 5000 was placed back into service, and the *Ocean Explorer* made

several close passes of the wreck, hoping to obtain any additional clues about the sinking of the vessel. The expedition reluctantly returned to Unalaska, knowing its mission was unfinished.

The Marine Board received permission from Coast Guard Headquarters to prepare a second expedition to survey the wreck of the *Arctic Rose*. On August 20, this second expedition departed Unalaska aboard the M/V *Ocean Explorer* with a larger, more-powerful ROV to return to the *Arctic Rose* and complete its mission. The MAXRover was equipped with stronger thrusters and a robotic arm that could be used to cut the ROV free from debris.

The team arrived on-scene several days later, but was forced to loiter due to rough sea conditions. Finally the weather calmed to within the minimum weather window for safe ROV operations. The ROV was lowered over the side and operationally tested. The MAXRover descended to the wreck. The video camera was activated and filmed the wreckage for clues. The MAXRover completed five dives and surveys of the wreckage. The Marine Board was able to examine the entire starboard hull, stern/transom area, trawl deck along with all associated equipment, and the exterior of the processing space. The Marine Board was also able to view the aft port section of the hull, keel cooler, shaft, kort nozzle, and rudder. A great deal was learned about the vessel and its condition.

The use of the ROV and sonar equipment allowed the Marine Board to gain some first-hand knowledge of the condition of the *Arctic Rose*, which proved critical to the Board in reaching its conclusion as to the cause of the sinking.

The Marine Board discovered the following details concerning the vessel:

- ✦ No hull failure or excessive corrosion was seen.
- ✦ No damage or indication that the vessel had been rammed or had struck an object prior to the sinking was observed.
- ✦ No buckled decking or side shell insets were noted.
- ✦ The vessel's rudder was hard over to port.
- ✦ The vessel appeared to have struck the bottom stern first.
- ✦ The aft weathertight door to the processing space was open. A starboard guillotine closure for the by-catch overboard discharge chute was open.
- ✦ Heavy gear was strewn across the deck and resting over the starboard bulwarks of the vessel.

- ✦ The vessel's trawl doors were missing.
- ✦ The vessel's trawl net was on the net reels.
- ✦ The vessel's propeller and shaft were in place.

The discovery of these facts allowed the Marine Board to discount or eliminate many theories as to why the vessel sank, but raised a few questions, especially concerning the missing trawl doors. However, the facts provided more answers than questions and assisted the Marine Board in arriving at the most probable cause of the casualty.

SafetyNET

SafetyNET is an internationally adopted, semi-automated satellite service designed for the promulgation of maritime safety information to all types of vessels. SafetyNET broadcasts are made over the INMARSAT-C system of geostationary satellites and are free of charge. Virtually all navigable waters of the world are covered by INMARSAT satellites. It is a part of the global maritime distress and safety system (GMDSS). This system provides for automatic distress alerts in cases where a radio operator does not have time to send an SOS or Mayday call and, for the first time, requires ships to receive broadcasts of maritime safety information. If the INMARSAT-C satellite terminal is connected to a global positioning satellite or similar navigational receiver, or the ship's position has been recently updated manually, the vessel's position will be transmitted as part of the automatic distress alert. Specific radio carriage requirements depend on the ship's area of operation rather than its tonnage. The system also provides redundant means of distress alerts and emergency sources of power.

The designation of priorities in the SafetyNET system determines the order in which a message is broadcast. INMARSAT-C is a store-and-forward system where messages of higher priority are placed at the head of the queue for broadcast. The two highest priorities, distress and urgent, also set off the alarms of certain shipboard INMARSAT-C terminals, notifying the mariner that a high priority message had been received.

Most INMARSAT-C terminals will not receive a safety broadcast if it is transmitting a message or if it is tuned to an INMARSAT ocean region not used for safety broadcasts in the area traveled. Most SafetyNET messages are rebroadcast after 6 minutes to give a transmitting terminal time to receive missed messages. Lists of SafetyNET broadcast schedules and areas have

been published by the World Meteorological Organization to assist ship operators in tuning INMARSAT-C terminals to the proper INMARSAT ocean region.

The Seventeenth District Command Center in Juneau issued a SafetyNET broadcast at 0429 on April 2, relaying the *Arctic Rose* distress information with a service parameter of “navigational warning” and a priority parameter of “distress.” Because of the configuration of Telenor’s system prior to November 2001, the message defaulted to “safety priority” based on the service parameter. No documentation provided to the SafetyNET users at rescue coordination centers indicated that the priority of messages would be determined by the service parameter, and they were unaware of the system’s ability to default a message to a lower priority. Testimony provided to the Marine Board substantiated that Coast Guard users were unaware of the system’s default settings. Coast Guard personnel from TISCOM, Headquarters, and COMSAT held a series of meetings in which the software problem was identified and corrected. Telenor’s system was modified in November 2001 so that a message with any service parameter could be broadcast with any priority. Finally, the Coast Guard implemented training for all rescue coordination center personnel on the proper use and formatting of SafetyNET message configuration to avoid any unnecessary message delays in the future.

Stability

The Marine Board requested technical assistance from the Coast Guard’s Marine Safety Center (MSC) in conducting an independent stability analysis to determine the most likely cause of the loss of the *Arctic Rose*. The stability calculations were performed using Creative Systems’ General Hydrostatics (GHS) Version 7.50 software. MSC evaluated 19 different scenarios that could have led to the loss of the *Arctic Rose*. MSC used the best estimate of the loading condition of the vessel at the time of the casualty as the baseline for all stability calculations.

Based on these loading conditions, at the time of the casualty the *Arctic Rose* would have met the righting arm characteristic criteria and severe wind and roll criteria listed in Navigation and Vessel Inspection Circular (NVIC) 5-86. This assumes that the processing space had been maintained completely weathertight as required by the stability letter from Jensen Maritime Consultants’ (JMC) dated July 9, 1999.

Dr. Bruce Johnson, chair of the Society of Naval Architects and Marine Engineers Ad Hoc Panel on Fishing Vessel Operations and Safety, worked in concert with Lieutenant George Borlase of MSC to develop a progressive flooding analysis spreadsheet. This forensic analysis tool is based on quasi-static time steps through various progressive flooding scenarios into as many as six interior compartments where large free-surface effects would have negatively affected the vessel's stability.

The analysis established the three most likely causes of progressive flooding into the processing space: (1) from a wash-up hose left on or from the water supply to the plate freezers, (2) from the aft deck through the open aft door by boarding seas, and (3) through the open aft door if the vessel took a roll to starboard of only 23°. Regardless of how the water entered the processing space, subsequent stability would have been very reduced, and progressive flooding would have continued until the vessel sank. Had the processing space been maintained as weathertight as per the JMC stability booklet, the *Arctic Rose* would not have sunk.

The loss of the *Arctic Rose* was most likely caused by progressive flooding from the aft deck into the processing space through the door in the aft bulkhead of the processing space. Flooding probably continued rather rapidly forward through the open door in the forward bulkhead of the processing space. The water then flooded the galley and engine room through nonweathertight doors. Initial flooding of the lazarette/dry stores space or progressive flooding into the machinery space was not necessary for the vessel to lose all positive righting arm. In fact, progressive flooding of the processing space and fish hold alone would have caused the vessel to lose all positive righting arm due to the large free-surface effect. Flooding of these two spaces alone also suggests a much slower net flooding rate and therefore a much longer time to sink. The vessel would very likely have lost all positive stability between 90 seconds and 4 minutes after progressive flooding started and to have sunk in as little as 3 minutes once progressive flooding began.

The arrangement of the *Arctic Rose* increased the likelihood of progressive flooding from the processing space. The door from the processing space to the aft deck was far outboard on the starboard side, reducing the heel angle at which water could enter the processing space. In addition, the doors leading forward into the galley and the engine room were also on the starboard side of the vessel. A lolling angle to starboard caused by the inflow of water through the aft door and the free-surface effect inside the processing space

would have caused water to spill forward easily into the galley, down into the engine room, and eventually into the fish hold. The fish hold had a center-line hatch and would not flood significantly until enough water was in the processing space to spill into the fish hold. Also, it was very likely that none of the doors or hatches at the main deck were properly closed, which would have increased the likelihood of progressive flooding throughout the ship.

The *Arctic Rose* had a stability test conducted in 1991, after its conversion from the *Sea Power*, which generated a set of operating conditions for the vessel with the restriction that “These stability calculations assume the processing area is intact and watertight. If water accumulates in the processing area all fishing or processing operations must be halted until the water is cleared.” In 1999, after the *Arctic Rose* was purchased by Mr. David Olney, JMC was hired to generate a new stability booklet for the vessel. On March 31, 1999, a new inclining experiment was conducted to calculate the lightship displacement and centers of gravity for the vessel. Operating limits for the vessel were then created based on the stability criteria found in NVIC 5-86, entitled, “Voluntary Standards for U.S. Uninspected Commercial Fishing Vessels.” The stability booklet was signed on July 9, 1999, and contained restrictions on freeboard, tank usage, and the amount of cargo carried on deck and underdeck. The operating instruction’s second paragraph stated that, “This stability letter is void unless the processing space is kept weather-tight at all times.”

In Section IX, “Weather Tightness and Seaworthiness,” the operating instructions require that “All watertight doors shall be kept closed except when used for passage...Doors for the scrap chutes and the fish chutes in the factory bulkheads should be kept closed at all times except when necessary to conduct processing operations. All side fittings that open to the factory must be fitted with a watertight closure and check valve.”

A large number of weight additions, removals, and relocations were performed on the *Arctic Rose* between July 9, 1999, when the operating instructions were issued, and April 2, 2002. The stability calculations performed by JMC accounted for a 13,500-pound keel shoe (ballast bar) at the time of the inclining experiment. The owner later added approximately 20,000 pounds of a boiler shot-cement mixture (boiler shot is a term used to describe round steel pieces approximately 1-2 inches in diameter), which was poured into the shaft alley area of the fish hold of the vessel after the inclining. In addition, a plate freezer and new refrigeration equipment were added in the

processing space, a water maker was installed, and other equipment was added to the vessel. The owner did not track any of the weight additions, relocations, or removals for the vessel. Compounding this error, the owner did not contact a naval architect to evaluate the effect of the weight changes on the vessel's stability. Furthermore, the owner testified to his belief of meeting the operating chart through the addition of weight with the keel shoe and boiler shot-cement mixture. In fact, this was in error as these weights were accounted for in the JMC stability calculations.

The *Arctic Rose* was not in compliance with the operating instructions issued by JMC at the time of the casualty. The aft starboard door in the processing space was open and the guillotine closure for the starboard discharge chute was two-thirds open, preventing the processing space from being weather-tight. The fuel and water tanks were being used in the opposite order specified in the stability letter. A review of the *Arctic Rose* stability booklet and testimony provided to the Marine Board indicated the consumption order of the wing tanks had a negligible effect on the vessel's stability. The double-bottomed fuel tank was not kept pressed full at all times, but was instead being used as a day tank. Testimony provided to the Marine Board from a former chief engineer indicated the double-bottomed fuel-oil tank was used as a day tank and was refilled at the beginning of each day. There was between 9,500 and 12,000 gallons of fuel oil on board the vessel, and 53,000 pounds of product, stores, and ballast stored in the fish hold at the time of the casualty. According to the deck loading table from the JMC stability booklet, maximum deck load (which included both processing and cod end-loads) was 3,000 pounds. However, there was 10,000 pounds of deck load in the plate freezers at the time of the casualty. While independent calculations later found the vessel met the intact stability criteria, at the time of the accident, the master of the vessel had use only of the operating instructions to evaluate whether his vessel met the minimum stability criteria.

Recommendations

The Marine Board made over 20 safety recommendations to the Commandant. These recommendations were divided into several categories, including regulatory changes, policy, and training.

1. The Coast Guard should develop regulations in which all watertight and weathertight doors that are required to be closed by a vessel's stability booklet to be alarmed and equipped with a visual and audible system

in the pilothouse to indicate the position of the door(s). If the aft door to the processing space, which was required to be closed at all times by the *Arctic Rose's* stability booklet, had been equipped with such an alarm on the bridge, which would have sounded until the door was properly secured, the sinking of the *Arctic Rose* could have been prevented. There is a strong likelihood that future casualties of this nature could be prevented if this recommendation is implemented industry-wide.

2. In reviewing the overall SafetyNET system, the Marine Board found no requirements for the use of an INMARSAT-C system on fishing vessels. This reduces the effectiveness of an important link of the GMDSS. The Marine Board recommended requiring all fishing vessels operating beyond the boundary line to be GMDSS compliant. The Marine Board understands that "one size fits all" requirements may not be the right solution and further recommends that the Commandant evaluate the possibility of a regulation based on a regional approach and tied to vessel operations, number of persons on board, duration of voyage, and distance offshore. The Federal Communications Commission (FCC) and Coast Guard should partner during the development of these regulations. Finally, the FCC and Coast Guard should require each fishing vessel equipped with a GMDSS system to have a properly trained operator. There are two types of INMARSAT-C systems sold for use aboard ship: a GMDSS version and a non-GMDSS version, commonly referred to as the fisheries version. The two versions are very similar and provide many of the same features. However, with the non-GMDSS version, messages and safety broadcasts are often received and stored internally, without any notification to the operator that a message has been received. Although reception of SafetyNET traffic is automatic, the shipboard operator must set the proper parameters on the receiver at the start of the voyage. This includes the following steps:

- ✦ Select the appropriate broadcast channel. This can often be accomplished by logging on to the land earth station in the ocean region from which needed broadcasts are made.
- ✦ Select the NAVAREA identification code.
- ✦ If traveling near Australia, select the proper coastal area codes.
- ✦ Ensure that the INMARSAT-C station is connected to a working navigational receiver. If a connection cannot be made, the ship's position must be manually updated every 4 hours during the ship's voyage. Without these updates, countless unnecessary broadcast messages will be received.

3. The INMARSAT-C system aboard the *Arctic Rose* did not have an audible or visual alarm to notify the watchstander of an incoming urgent broadcast. The user would have had to go from the steering station to the INMARSAT-C unit and download messages. Each message would have to be viewed prior to deleting it from the queue. The system operator has to program the INMARSAT-C system to receive messages based on the location of the terminal to avoid overloading the system with messages from other broadcast stations. The *Alaskan Rose's* mate provided testimony to the Marine Board indicating the vessel did receive countless messages from Russia, but did not receive the distress message until several hours after it had been sent by the Coast Guard. This was due to the system not being properly configured. It is imperative to "program" the INMARSAT-C system properly to receive messages. Although reception of SafetyNET traffic is automatic, the shipboard operator must set up the receiver properly at the start of the voyage. The most critical step is to ensure that the INMARSAT-C station is connected to a working navigational receiver. If a connection cannot be made, the ship's position must be manually updated every 4 hours during the ship's voyage. Without these updates, countless unnecessary broadcast messages will be received.
4. The Marine Board received testimony from a naval architect and member of the Society of Naval Architects and Marine Engineers' (SNAME) Ad Hoc Panel on Fishing Vessel Operations and Safety Working Group B indicating that the average commercial fisherman is not familiar with stability information. Furthermore, stability information is provided in a myriad of forms as there is no set industry standard. This creates an environment where stability information is presented to the mariner in a format that can be difficult to read and/or interpret. As a result many fishermen determine the stability of their vessels by feel.
5. The information on the *Arctic Rose* is open to wide interpretation. A previous mate on the *Arctic Rose* reviewed the JMC stability booklet and stated, "I think if I had this information and I had seen this particular stability book, I would not have gone on the *Arctic Rose*."
6. The Coast Guard should encourage the use of color graphic displays within a stability booklet that are easily understood by mariners, such as the one under development by SNAME. The work group is promoting a format that presents stability information and operating guidelines in a color graphic that is easy to understand. This format provides the vessel's operator and crew with a quick visual reference to make an informed decision for safe operations without having to perform stability calcula-

tions. This format was presented to several witnesses during the Marine Board hearings and was well received by the fishermen, especially when placed side by side with other graphs, which were open to interpretation. The color graphic displays provide a quick visual reference and allowed each person shown the visuals to make a quick go/no-go decision.

7. The Coast Guard should encourage the development of fishing vessel construction standards that minimize the free flow of water through a vessel. In addition, the Coast Guard should remove all provisions that allow the use of above-main-deck spaces in the development of a fishing vessel's stability characteristics. This two-fold recommendation stems from the construction of the *Arctic Rose*. During its conversion from a shrimp/scallop trawler to a head-and-gut processing trawler, the fish processing space was added at the main deck level.
8. The Coast Guard and the commercial fishing industry should explore the development of a minimal safety indoctrination program for all first-time crew. Such training would include processors prior to getting underway. A means to document the training should also be found. This recommendation would expand existing regulations and provide all people working on vessels at sea with a basic training course so that all participants would have an overview of fishing vessel operations and the proper use of safety equipment aboard a vessel. Upon successful completion of the course, a participant would receive wallet-sized card that could be presented to vessel owners/operators when filling out a job application as proof of completion of the indoctrination course.

In closing, the purpose of the Marine Board and any Coast Guard investigation is not to place blame, but to determine the cause of the event and make appropriate safety recommendations to prevent future occurrences. The sinking of the *Arctic Rose* was a tragic accident and has affected countless lives forever. How the *Arctic Rose* sank will never truly be known. The use of modern technology and forensic naval architecture combined with superb investigative work aided the Marine Board in providing answers to many questions and reach sound conclusions.

