NATIONAL

TRANSPORTATION

SAFETY BOARD

WASHINGTON, D.C. 20594

MARINE ACCIDENT REPORT

SS EDMUND FITZGERALD

SINKING IN LAKE SUPERIOR

NOVEMBER 10, 1975
REPORT NUMBER: NTSB-MAR-78-3

UNITED STATES GOVERNMENT

Report No. NTSB-MAR-78-3

Title and Subtitle: Marine Accident Report SS EDMUND FITZGERALD Sinking in Lake Superior on

November 10, 1975

Report Date: May 4, 1978

National Transportation Safety Board
Bureau of Accident Investigation
Washington, D.C. 20594

Marine Accident Report November 10, 1975

NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594

***** The text and format of this report have been edited to allow for better presentation on the internet. The facts of the case and the findings remain unchanged.*****

Abstract

About 1915 EST., on November 10, 1975, the Great Lakes bulk cargo vessel SS EDMUND FITZGERALD, fully loaded with a cargo of taconite pellets, sank in eastern Lake Superior in position 46 59.91 N, 85 06.6'W, approximately 17 miles from the entrance to Whitefish Bay, Michigan. The ship was en route from Superior, WI, to Detroit, MI, and had been proceeding at a reduced speed in a severe storm. All the vessel's 29 officers and crewmembers are missing and presumed dead. No distress call was heard by vessels or shore stations.

The Safety Board considered many factors during the investigation including stability, hull strength, operating practices, adequacy of weathertight closures, hatch cover strength, possible grounding, vessel design, loading practices, and weather forecasting.

The National Transportation Safety Board determines that the probable cause of this accident was the sudden massive flooding of the cargo hold due to the collapse of one or more hatch covers. Before the hatch covers collapsed, flooding into the ballast tanks and tunnel through topside damage and flooding into the cargo hold through non-weathertight hatch covers caused a reduction of freeboard and a list. The hydrostatic and hydrodynamic forces imposed on the hatch covers by heavy boarding seas at this reduced freeboard and with the list caused the hatch covers to collapse.

Contributing to the accident was the lack of transverse weathertight bulkheads in the cargo hold and the reduction of freeboard authorized by the 1969, 1971, and 1973 amendments to the Great Lakes Load Line Regulations.

Key words

Great Lakes; bulk cargo vessel; flooding; foundering; sinking; load line; hatch covers; buoyancy; stability; Lake Superior; weathertight closures; hatch cover design; freeboard; seastate prediction; subdivision; bilge system.

NATIONAL TRANSPORTATION SAFETY BOARD

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MARINE ACCIDENT REPORT

Adopted: May 4, 1978

SS *EDMUND FITZGERALD*

SINKING IN LAKE SUPERIOR

NOVEMBER 10, 1975

INTRODUCTION

This casualty was investigated by a U.S. Coast Guard Marine Board of Investigation which convened at Cleveland, Ohio, on November 18, 1975. A representative of the National Transportation Safety Board observed part of the proceedings. The Safety Board has considered all facts pertinent to the Safety Board's statutory responsibility to determine the cause or probable cause of the casualty and to make recommendations.

The Safety Board's recommendations are made independently of any recommendations proposed by the Coast Guard. To assure public knowledge of all Safety Board recommendations, all such recommendations are published in the Federal Register. If the Coast Guard does not accept some of these Safety Board recommendations, the Coast Guard is required to set forth in detail the reasons for such refusal. This is one of the means by which the Safety Board exercises its responsibility of assessing the safety, operating, and regulatory practices of the U.S. Coast Guard.

SYNOPSIS

About 1915 EST on November 10, 1975, the Great Lakes bulk cargo vessel SS EDMUND FITZGERALD, fully loaded with a cargo of taconite pellets, sank in eastern Lake Superior in position 46 59.91 N, 85 06.61 W, approximately 17 miles from the entrance to Whitefish Bay, MI. The ship was en route from Superior, WI, to Detroit, MI, and had been proceeding at a reduced

speed in a severe storm. All the vessel's 29 officers and crewmembers are missing and presumed dead. No distress call was heard by vessels or shore stations.

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Contributing to the accident was the lack of transverse watertight bulkheads in the cargo hold and the reduction of freeboard authorized by the 1969, 1971, and 1973 amendments to the Great Lakes Load Line Regulations.

INVESTIGATION

The Accident

About 0830 (all times are Eastern Standard based on the 24-hour clock) on November 9, 1975, the SS EDMUND FITZGERALD began loading 26,116 long tons of taconite pellets at Burlington Northern Railroad Dock No. 1 in Superior, WI. This pier, known as a "chute pier," is equipped with built-in storage bins, known as "pockets," which are usually filled before a vessel arrives. Chutes are lowered from each "pocket" to direct the cargo into the hatches of the vessel. Most of the "pockets" are filled with 300 tons of taconite pellets; however, a few pockets are filled with 100 tons or 200 tons. These smaller amounts of cargo are used during the final phase of loading to trim the ship for departure.

Loading was completed about 1415 on November 9. The chief mate informed dock personnel that the vessel's final drafts were 27 feet 2 inches forward and 27 feet 6 inches aft. Drafts were taken after receipt of the taconite pellets and 50,013 gallons of No. 6 fuel oil, delivered by a barge which came alongside while the cargo was being loaded.

Neither shipboard nor dock personnel experienced difficulties while loading the cargo nor was any difficulty or damage reported by the crew of the FITZGERALD. Shore side personnel saw the ship's crew replacing the hatch covers after loading.

Upon departure at 1415, the FITZGERALD proceeded at full speed of 99 rpm, approximately 16.3 mph. About 1630, the SS ARTHUR M. ANDERSON departed Two Harbors, Minnesota, with a similar cargo en route to Gary, Indiana. Separated by 10 to 20 miles, the two vessels proceeded on similar courses across Lake Superior.

Because of predicted deteriorating weather, the receipt of storm warnings at 0200 on November 10, and discussions by radiotelephone, the FITZGERALD and ANDERSON departed the recommended shipping lanes along the southern shore of Lake Superior, and proceeded northeastward south of Isle Royal, then eastward along the northern shore, and then southeastward along the eastern shore. This departure from the recommended track allowed the two vessels to take advantage of the lee provided by the Canadian shore. This is a generally

accepted practice among Great Lakes mariners to avoid adverse sea conditions during fall and winter storms when the wind direction makes this lee available. During the first 10 to 11 hours of the voyage, the ANDERSON was ahead of the FITZGERALD; however, about 0300 on November 10, the faster FITZGERALD pulled slightly ahead.

The FITZGERALD made routine weather reports at 0100 and 0700 on November 10. In the normal morning report to the company office, the FITZGERALD said her estimated time of arrival at Sault Ste. Marie was indefinite because of bad weather.

As the FITZGERALD and the ANDERSON approached the eastern shore, the FITZGERALD proceeded farther east than the ANDERSON before changing to a southeasterly course toward Michipicoten Island. Since the FITZGERALD traveled a greater distance at a higher speed, the distance between the two vessels remained almost constant. About 1252, the ANDERSON was abeam Otter Island at a range of 10.8 miles, and the FITZGERALD was 8 miles ahead and slightly east of the ANDERSON's track. (See figure 1.) At that point, the FITZGERALD was about 17 miles north-northwest of Michipicoten Island.

At 1350, the ANDERSON changed course to 230 degrees T to allow more sea room west of Michipicoten Island because the wind was predicted to haul to the northwest. At this time, the FITZGERALD was 2 1/2 to 3 miles southwest of Michipicoten Island, and she advised the ANDERSON that she would "continue on" although she was "rolling some." The FITZGERALD continued southeastward toward Whitefish Point on a course of 1410 T while the ANDERSON proceeded southwestward to about 11 miles west of Michipicoten Island and changed course to 130 degrees T at 1445. At this time, the FITZGERALD was observed to be about 16 miles ahead, a position 9 miles south of Michipicoten Island. At 1520, the ANDERSON changed course to 125 degrees T at a position 7.7 miles southwest of Michipicoten Island. The FITZGERALD was 16 miles ahead and slightly to the right of the ANDERSON's trackline.

About 1530, the FITZGERALD, then in a position northeast of Caribou Island, called the ANDERSON and reported, "I have a fence rail down, have lost a couple of vents, and have a list." The FITZGERALD further advised that she would ''check-down'' to allow the ANDERSON to close the distance between the vessels. The ANDERSON asked the FITZGERALD if the pumps were going and the reply was, "Yes, both of them."

About 1610, the FITZGERALD advised the ANDERSON that both her radars were inoperative and asked that the ANDERSON keep track of the FITZGERALD and provide navigational assistance. At 1634, the ANDERSON changed course to 141 degrees T in a position 7.5 miles, 035 degrees T from the north end of Caribou Island and observed the FITZGERALD 14 to 15 miles ahead and slightly to the right of the ANDERSON's heading flasher. At 1728, the ANDERSON fixed her position 10.5 miles east of Caribou Light, determined that the FITZGERALD was 15 miles ahead and slightly left (east) of the ANDERSON's heading flasher, and advised the FITZGERALD that Whitefish Point was 35 miles from the FITZGERALD on a bearing of 144 degrees T. The FITZGERALD replied that she "wanted to be 2 1/2 miles off Whitefish Point," and appeared to be steering for that position.

About 1639, the Coast Guard station at Grand Marais, MI, advised the FITZGERALD, in response to her inquiry, that the radio beacon at Whitefish Point was not operating.

Between 1700 and 1730, a Great Lakes registered pilot on board the northbound Swedish vessel AVAFORS, in a position near Whitefish Point, answered a call from the FITZGERALD and said that Whitefish Point Light was operating but that the radio beacon was still off. During a radiotelephone conversation between the two vessels, the master of the FITZGERALD apparently spoke to personnel aboard the FITZGERALD while the radiotelephone remained on the transmit mode. The master was overheard saying, "Don't allow nobody on deck," followed by

some conversation concerning a vent, which was not understood aboard the AVAFORS. The master advised the AVAFORS that the FITZGERALD had a "bad list," had lost both radars, and was taking heavy seas over the deck in one of the worst seas he had ever encountered.

About 1820, the ANDERSON advised the FITZGERALD that the FITZGERALD was working to the left of the ANDERSON's heading of 1420 T and determined by radiotelephone that the FITZGERALD was steering 141 degrees T.

At 1900, the ANDERSON advised the FITZGERALD that she was 10 miles ahead and 1 to 1 1/2 miles to the left (east) of the ANDERSON's heading flasher. At 1910, the ANDERSON advised the FITZGERALD of northbound traffic 9 miles ahead of her. In response to a question about her problems, the FITZGERALD replied, "We are holding our own."

This was the last radiotelephone conversation with the FITZGERALD. When the ANDERSON's radarscope was checked about 1920, there was no radar contact with her. Visibility increased about this time and although lights on shore more than 20 miles away and lights of a northbound vessel 19 miles away could be seen, the FITZGERALD, which should have been approximately 10 miles away, was not visible.

Between 1920 and 2030, the ANDERSON tried calling the FITZGERALD on VHF-FM radiotelephone, but got no response. At 2032, the ANDERSON notified the Coast Guard that the FITZGERALD may have suffered a casualty.

Wreckage identified as that of the FITZGERALD was located in position 46 59.91 N', 85 06.6' W in 530 feet of water in eastern Lake Superior just north of the International Boundary in Canadian waters. This position correlates with the last position of the FITZGERALD as reported by the ANDERSON.

Crew Information

The crew of the FITZGERALD consisted of the following 29 persons: a master, 3 licensed deck officers, a chief engineer, 4 licensed engineering officers, and 20 unlicensed personnel. No survivors were found and no bodies were recovered.

The master and chief mate were experienced Great Lakes mariners, having been licensed since 1938 and 1941, respectively. Both men held valid licenses as Master and First Class Pilot for Great Lake vessels of any gross tonnage. The other mates held valid licenses as First Class Pilot for Great Lakes vessels of any gross tonnage which were first issued in 1969 and 1973, respectively. The engineering officers were similarly experienced.

The master had been employed by the vessel's operator since 1938, had been employed as master since 1951, and had served as master of the FITZGERALD since April 1972.

The chief mate had been employed by the vessel's operator since 1947 in various capacities, including relief master in 1966 and 1971,' and had served aboard the FITZGERALD as chief mate since April 1975.

Vessel Information

The FITZGERALD was one of a fleet of 14 to 18 vessels operated by the Columbia Transportation Division between 1972 and 1977. The Coast Guard casualty records for the company fleet did not reveal any heavy weather damage during this period.

The FITZGERALD was a conventional "straightdecker" Great Lakes bulk cargo vessel. (See figure 2.) It was 729 feet long, 75 feet in breadth, 39 feet in depth, 13,632 gross tons, and 8,686 net tons. It was propelled by a 7,500-hp, steam turbine and was built as Hull 301 at Great Lakes Engineering Works, River Rouge, Michigan, in 1958. The vessel was owned by Northeastern Mutual Life Insurance Company and operated by the Columbia Transportation Division of the Oglebay Norton Company.

The vessel had a 860,950-cubic-foot cargo hold divided by two nonwatertight transverse "screen" bulkheads. Outboard and below the cargo hold were eight ballast tanks divided at the centerline into port and starboard tanks. (See figure 2.) The forward deckhouse contained the pilot house and accommodations for the deck crew. The engine room was located aft, above which were the rest of the accommodations and the crew's messing facilities. Below the weather deck and above the ballast tanks were two tunnels, one port and one starboard, used for access between the accommodation areas during adverse weather. The sheer strake extended 15 3/8 inches above the weather deck at side and was connected to the stringer plate by a riveted gunwale bar.

There were 21 cargo hatch openings. Each opening measured 11 feet longitudinally and 48 feet transversely and had a 24-inch coaming above the weather deck. Each opening was made weathertight by a single-piece steel hatch cover. The hatch covers were made of 5/16-inch stiffened plate with a 9/16-inch rubber gasket around the underside of the plate's perimeter. Each hatch cover was secured by 68 manually operated "Kestner" clamps arranged on 2-foot centers. Each clamp had an adjustment bolt which determined the force applied by the individual clamp and therefore controlled the deflection of the hatch cover, the compression of the rubber gasket, and the weathertightness of the hatch opening. There were no written procedures concerning maintenance or adjustment of the hatch clamps or gaskets. An electrically operated hatch cover crane which ran on rails outboard of the cargo hatch openings was used for lifting the hatch covers.

Access to the cargo hold was provided through two 30-inch hatches through the weather deck located at the "screen" bulkheads fitted on 24-inch coamings, through doors from the tunnels, and through doors at the main deck level (i.e., the deck level below the weather deck) at the forward and after ends of the cargo hold.

Two 8-inch-diameter vent pipes which extended 18 inches above the weather deck were fitted for each ballast tank. The port and starboard access tunnels had similar vents extending 30 inches above the weather deck located forward and aft. In addition, each ballast tank was fitted with a remote water level indicator device, called a "King Gage," located in the lower engineroom near the ballast pumps. The only means of detecting water in the cargo hold or access tunnel was by visual inspection. Federal regulations do not require that Great Lakes vessels be equipped with instruments to indicate trim or list.

The bilge and ballast system consisted of a piping system connected through manifolds and valving to four 7,000 gallon-per-minute main pumps and two 2,000 gallon-per-minute auxiliary pumps. The ballast system could be used to de-water the cargo hold through two suctions located at the aftermost end of the No. 3 cargo hold, port and starboard. The tunnels could be drained by manually operated drains connected to the ballast tanks.

The following radiotelephone equipment was located in the pilothouse and chartroom: Two VHF-FM, 12-channel, 25-watt radiotelephones operated from vessel's power; one VHF-FM 12-channel, 25-watt radiotelephone operated from rechargeable batteries located in the pilothouse;

one AM, 8-channel, 100-watt radiotelephone operated from vessel's power; one AM, emergency, 50-watt radiotelephone including channel 51 (2182 kHz), operated from rechargeable batteries. The FITZGERALD also had a radio direction finder and two surface scan radar sets. No fathometer was required and none was installed.

After her delivery in 1958, the FITZGERALD operated essentially unchanged until 1969 when a diesel-powered bow thruster was installed. During the winter of 1971-1972, the main propulsion plant was converted from coal to oil and the coal bunkers were converted to fuel oil tanks. An automatic boiler combustion and feed-water control system was installed as part of this conversion.

Between 1958 and 1973, the FITZGERALD was permitted three reductions in the minimum freeboard required by 46 CFR Part 45. (Freeboard on the FITZGERALD was the distance from the maximum draft permitted to the weather deck at side.) A comparison of the requirements for Great Lakes cargo vessels and those for vessels operating on the oceans shows that for vessels of similar dimensions, the freeboard required for a Great Lakes Load Line and that required for ocean service would be approximately the same. However, the longitudinal strength required for a Great Lakes vessel is approximately one—half that required for a vessel in ocean service. The following table shows the freeboards assigned to the FITZGERALD:

Minimum Required Freeboard

Date	Midsummer	Summer	Intermediate	Winter
Originally assigned when vessel was built	11 feet-10 3/4 inches	12 feet-6 3/4 inches	13 feet-6 3/4 inches	14 feet- 9 1/4 inches
3 July 69	11 feet-4 1/2 inches	12 feet-1/2 inch	13 feet-3/4 inch	14 feet-3 1/2 inches
17 Sept 71	11 feet-4 1/2 inches	12 feet-1/2 inch	13 feet-3/4 inch	13 feet-2 inches
13 Sept 73	10 feet-5/12 inches	11 feet-2 inches	11 feet-2 inches	11 feet-6 inches

46 CFR 45.5 states that midsummer freeboard applies May 1 through September 15; summer freeboard applies April 16 through April 30 and September 16 through September 30; intermediate freeboard applies October 1 through October 31 and April 1 through April 15; and winter freeboard applies November 1 through March 31.

As part of the requirements for obtaining the freeboards assigned on September 13, 1973, all vents were to be at least 30 inches above the weather deck. However, under 46 CFR 45.133(b), the FITZGERALD was permitted to have ballast tank vents extending to only 18 inches above the weather deck because the 30-inch height interfered with handling cargo on the ship.

No major structural problems were detected during the operating years of the FITZGERALD. Some cracking was detected in the keelson connection to the

shell plating; however, during the winter layup of 1968-1969, this condition was corrected by redesign and repair. Only minor cracks were observed thereafter. Some minor fractures were detected in the hatch coamings and the gunwale bar which were caused by original construction faults and original design detail defects. These minor fractures were repaired and the design details were corrected during the winter layup of 1973-1974 and no subsequent fractures were found.

During its operating years, the FITZGERALD sustained damage from one grounding, one collision, and several instances of striking lock walls. In these instances, all the damaged structure was removed and replaced as original. The FITZGERALD was last dry docked in Cleveland, Ohio, in April 1974, when the accessible areas of the interior and exterior structure and hull plating were examined and all damage was satisfactorily repaired.

During the winter layup of 1974-1975 and while the Coast Guard was conducting the inspection for certification, the American Bureau of Shipping (AES) conducted an annual survey of the hull, machinery, and boilers; completed part of the continuous machinery survey; and conducted an annual load line inspection. These surveys were completed on April 9, 1975, with no outstanding requirements that affected the structural integrity of the hull.

The FITZGERALD was last inspected by the Coast Guard and the ABS on October 31, 1975. Four minor structural defects in way of the hatches were noted and the Coast Guard ordered these defects to be repaired before the 1976 shipping season. The structural defects consisted of: A 1-inch notch in the plate in way of hatch No. 13; a 1-inch gouge in the plate in way of hatch no. 15; a 10-inch crack in No. 16 hatch end girder; and a 1-inch crack at the intersection of No. 21 hatch coaming and hatch end girder. All four defects probably resulted from damage from off loading equipment and did not affect the strength of the hull girder.

Cargo Information

The FITZGERALD was carrying about 26,116 long tons of National Taconite Pellets. Taconite pellets are manufactured by a process known as "oxide pelletizing." This process begins with the mining of iron ore (magnetite), concentrated with the addition of bentonite, processed into balls of 3/8—inch to 5/8—inch diameter, and fired at temperatures of 2,2000 F to 2,4000 F, which changes its composition to relatively nonmagnetic hemotite. This process produces almost spherical pellets containing 67 percent iron, which are easily handled by belts and bulk cargo handling equipment. Taconite pellets weigh from 127 to 140 pounds per cubic foot, will absorb approximately 8 to 9 pounds (6 to 7 percent by weight) water per cubic foot, can contain up to 27.5 pounds of water in the interstitial void spaces in each cubic foot of pellets, and exhibit an angle of repose (the angle between the horizontal and the slope of a freestanding pile of the material) of approximately 260 either wet or dry.

Great Lakes bulk carriers are loaded to have as little trim, heel, and midship deflection as possible. Cargo is distributed so that the vessel does not hog; however, 1 inch of sag is considered acceptable. During loading, the crew monitors the forward, aft, and midship drafts,

and small amounts of cargo are added at selected locations to achieve the desired drafts when the loading is almost completed.

On the upbound voyage, en route to loading ports in the upper lakes, Great Lakes bulk carriers use water ballast to obtain the desired draft and trim to insure sufficient vertical clearance upon arrival at the loading berth. During loading operations, ballast water is pumped out at the same time cargo is loaded to maintain correct vertical clearances.

Meteorological Information

On November 8, 1975, a storm was generated over the Oklahoma Panhandle. By 0700 on November 9, the storm was centered over south-central Kansas and the National Weather Service (NWS) predicted that the storm would travel in a northeasterly direction and pass just south of Lake Superior by 1900 on November 10.

At 1300 on November 9, the storm was centered over the northeast corner of Kansas and the NWS predicted that the storm would shift to a more northerly direction, pass over Lake Superior east of Michipicoten Island, and by 1900 on November 10 be over James Bay, Canada.

At 1900 on November 9, the NWS issued gale warnings (expected winds from 34 to 47 knots) for all of Lake Superior. Winds in the eastern half of the lake were predicted to be "east to northeast, increasing to 25 to 37 knots during the night, and northeasterly by Monday afternoon (November 10), waves 5 to 10 feet." At 2239, on November 9, the forecast was revised to "easterly winds 32 to 42 knots, becoming southeasterly Monday morning, and west to southwest 35 to 45 knots Monday afternoon, rain and thunderstorms, waves 5 to 10 feet increasing to 8 to 15 feet Monday."

At 0100 on November 10, the storm was located over central Wisconsin, had a minimum barometic pressure of 29.24 inches of mercury and was moving at an average speed of 29 knots. At 0100 on November 10, the FITZGERALD was about 20 miles south of Isle Royal and reported winds from 030 T at 52 knots and waves of 10 feet.

At 0200 on November 10, NWS issued a storm warning (expected winds over 48 knots) predicting "northeast winds 35 to 50 knots, becoming northwesterly 28 to 38 knots, waves 8 to 15 feet."

At 0700 on November 10, the FITZGERALD was about 45 miles north of Copper Harbor, Michigan, and reported winds from 050 T at 35 knots and waves of 10 feet.

At 1034 on November 10, the NWS predicted "north to northwest winds 32 to 48 knots this afternoon becoming northwesterly 25 to 48 knots tonight and westerly 20 to 30 knots Tuesday, waves 8 to 16 feet decreasing Tuesday.''

At 1300 on November 10, the storm center had crossed Lake Superior to the west of Michipicoten Island and was over White River, Ontario. At 1300 on November 10, the ANDERSON was 20 miles northwest of Michipicoten Island and reported winds from 150 T at 20 knots, waves of 12 feet; the M/V SIMCOE was 15 miles to the southwest of the ANDERSON and reported winds from 270 T at 44 knots and waves of 7 feet. At the same time, Stannard Rock Weather Station reported winds from the west—northwest at 50 knots, gusting to 59 knots, and the Whitefish Point Station reported winds from the south—southwest at 19 knots, gusting to 34 knots.

At 1639, on November 10, the NWS predicted for Eastern Lake Superior: "Northwest winds 38 to 52 knots with gusts to 60 knots early tonight and northwesterly winds 25 to 35 knots diminishing Tuesday, waves 8 to 16 feet tonight, decreasing Tuesday."

At 1900, on November 10, as the storm center passed over the southern tip of James Bay, Canada, the ANDERSON reported winds from 3000 T at 50 knots, waves of 16 feet, and Stannard Rock reported wind west—northwest (292.50 T) at 40 knots, gusting to 65 knots. The highest winds recorded by Stannard Rock were west—northwest at 56 knots gusting to 66 knots at 1700 on November 10.

The log of the ANDERSON shows the following on November 10:

1. At 1350, just north of Michipicoten Island, the winds were northwest by west at 5 knots.

2. At 1445, west of Michipicoten Island, the winds were northwest at 42 knots.

3. At 1520, just south of Michipicoten Island, the winds were northwest at 43 knots.

4. At 1652, north east of Caribou Island, the winds were northwest at 52 knots.

The master of the ANDERSON testified that 10 or 12 miles north of Caribou Island, the seas were running 12 to 18 feet, and south of Caribou Island, the seas were running 18 to 25 feet. He further testified that he observed winds gusts of 70 or 75 knots.

A NWS meteorologist testified that before the FITZGERALD sank, the average sustained wind speed was 45 knots from the northwest for a period of 6 to 7 hours and that these conditions would produce waves with a significant height of 15 feet. He also testified that there are usually 4 or 5 intense storms on the Great Lakes during the fall to spring shipping seasons. A storm of the intensity of the one recorded on November 10 would not occur every year; however, more intense storms have been recorded on the Great Lakes.

Wreckage

Because of the weather conditions following the sinking of the FITZGERALD and because the wreckage was lying on the bottom of Lake Superior in 530 feet of water, a comprehensive examination of the damage to the FITZGERALD was not undertaken until May 1976. At that time, a task force was formed, including representatives from the Coast Guard Marine Board of Investigation, the National Transportation Safety Board, the U.S. Navy Supervisor of Salvage, the Naval Undersea Center, and Seaward, Inc. of Falls Church, Virginia, an engineering consultant firm under contract to the U.S. Navy Supervisor of Salvage to make a visual survey of the wreckage using the USN CURV III System under contract to the USCG. The CURV III is an unmanned, deep-diving vehicle controlled from the surface and capable of television and still photography. This vehicle made 12 dives with a total of 56 hours 5 minutes bottom time and recorded 43,255 feet of videotape and 985 still color photographs.

The results of the CURV III visual survey and three earlier side—scan sonar surveys were assembled and reviewed by Seaward, Inc., which prepared a sketch of the wreckage (see figure 3), and artists' conceptions of the wreckage from several viewpoints. (See figures 4 to 8.)

The wreckage lies approximately 17 miles northwest of Whitefish Point, Michigan. The wreckage consists of an upright bow section, an inverted stern section, and debris from a missing 200-foot midship portion. The bow section is 276 feet long, inclined 15 degrees to port from the upright,

extends from the stem to a location between hatches Nos. 8 and 9, and is buried in mud up to the 28-foot draft mark.

There was extensive damage to the forward deckhouse and there were several holes in the bow shell plating. The rest of the shell plating extending back to the rupture was intact. The No. 1 hatch cover was entirely inside the No. 1 hatch and showed indications of buckling from external loading. Sections of the coaming in way of the No. 1 hatch were fractured and buckled inward. The No. 2 hatch cover was missing and the coaming on the No. 2 hatch was fractured and buckled. Hatches Nos. 3 and 4 were covered with mud; however, one corner of hatch cover No. 3 could be seen in place. Hatch cover No. 5 was missing. A series of 16 consecutive hatch cover clamps were observed on the No. 5 hatch coaming. Of this series, the first and eighth were distorted or broken. All of the 14 other clamps were undamaged and in the open position. The No. 6 hatch was open and a hatch cover was standing on end vertically in the hatch. The hatch covers were missing from hatches Nos. 7 and 8 and both coamings were fractured and severely distorted. The bow section abruptly ended just aft of hatch No. 8 and the deck plating was ripped up from the separation to the forward end of hatch No. 7.

The stern section was upside down and inclined 10 degrees from the vertical away from the bow section. All bottom plating was intact from the stern to a location between hatches Nos. 17 and 18 where the vessel had separated. The rudder and propeller were undamaged with the rudder positioned no more than 10 degrees from centerline.

There was mud—covered wreckage extending out from the ruptured end of the stern section, but no identification of what part of the ship it came from can be determined. Three hatch coamings and a hatch cover were lying next to the stern section. One of the hatch coamings bore the numeral 11.

A few of the deck vents on the starboard side of the bow section could be seen above the mud. One vent near hatch No. 5 was torn away from the deck, leaving an opening in the deck at the base of the vent pipe. The vents on the port side of the bow section were covered with mud. Neither the spare propeller blade nor the hatch cover crane was visible and they have not been located.

Survival Aspects

The Coast Guard Certificate of Inspection issued on April 9, 1975, authorized the FITZGERALD to carry 49 persons, although it had only 29 crewmen aboard on November 10, 1975. The required lifesaving equipment, as stated on the certificate was: 1 lifeboat on port side for 50 persons; 1 lifeboat on starboard side for 50 persons; 2 inflatable liferafts for 25 persons each; 24 life rings; and 83 life preservers.

The two lifeboats and one 25-person liferaft were located aft and one 25-person liferaft was located forward. The inflatable rafts were installed in racks designed to allow the rafts to float free and automatically inflate.

Fire and boat drills conducted in good weather while the FITZGERALD was moored indicated that a conventional lifeboat could not be launched in less than 10 minutes. Testimony indicated that as much as 30 minutes would be required to launch a lifeboat in a seaway and that a lifeboat probably could not be launched successfully and boarded in the seaway experienced by the FITZGERALD at the time of her loss. Most witnesses felt that a Great Lakes vessel could be abandoned more successfully with an inflatable liferaft rather than with a lifeboat.

Coast Guard regulations require fire and boat drills to be conducted at least weekly. The logbooks of the FITZGERALD were lost with the vessel; however, records available from the offices of

Columbia Transportation Division indicate that 14 fire and boat drills were conducted between April 12 and October 31, 1975.

Based on the 49 persons permitted by the Certificate of Inspection, U.S. Coast Guard regulations require: 1 life preserver for each of the 49 persons, 25 as a required 50 percent excess, 2 in each lifeboat, 3 for the wheelhouse watch, and 2 in the engine room.

After an intensive search by U.S. Coast Guard and Canadian Coast Guard surface and air units, Michigan Air National Guard aircraft, and U.S. and Canadian merchant vessels between November 10 and 13, 1975, no survivors were found and no bodies were recovered. Ontario Canadian Provincial Police conducted numerous shoreline searches. The total lifesaving equipment recovered was: 1 lifeboat, one-half of another lifeboat, 2 inflatable liferafts, and 21 lifejackets or lifejacket pieces.

On November 10, the only Coast Guard surface search and rescue units available for open water deployment were the Buoy Tender WOODRUSH, located 300 miles from the accident at its home port in Duluth, Minnesota, and the Harbor Tug NAUGATUCK located at Sault Ste. Marie, MI. However, the NAUGATUCK is restricted from operating in open water when winds exceed 60 knots and, therefore, was directed not to proceed beyond the entrance to Whitefish Bay. All other Coast Guard surface units were either too far away or in a repair status.

Waterway Information

Only three navigational charts covering the area between Michipicoten Island and Whitefish Bay are available. These charts are:

a. Lake Survey Chart No. 9, "Lake Superior," which shows all of Lake Superior at a scale of 1:600,000 published by the U.S. National Oceanic and Atmospheric Administration (NOAA).

b. Canadian Chart 2310, "Lake Superior, Caribou Island to Michipicoten Island," which shows the area from slightly north of Michipicoten Island to slightly south of Caribou Island at a scale of 1:97,280 is published by the Canadian Hydrographic Service.

c. Lake Survey Chart No. 92, "Lake Superior, St. Mary's River to Au Sable Point," which shows the southeastern portion of Lake Superior from Sault Ste. Marie to just south of Caribou Island and west to Au Sable Point Light at a scale of 1:120,000 also is published by NOAA.

Great Lakes mariners normally use NOAA Lake Survey Chart No. 9 for navigation on Lake Superior. Larger scale charts are available for smaller areas, including harbors, where more detail is required. Lake Survey Chart No. 9 contains the following note: "Owing to the small scale, many aids to navigation, depths, contours, and topographical features have been omitted. For details, consult Coast and Harbor charts."

Lake Survey Chart No. 9 shows bottom contours of less than 3 fathoms and less than 5 fathoms around Caribou Island by blue shading in two tones. Two locations of charted depths of 6 fathoms are shown northeast and northwest of the shaded areas. The extent of shoaling with depths in excess of 5 fathoms but less than 10 fathoms is not shown and the mariner is not made aware of the extent of the shoal area north of Caribou Island known as North Bank, as identified on Canadian Chart 2310.

After this accident, the Coast Guard requested the Canadian Hydrographic Service to conduct a hydrographic survey of the area north of Caribou Island to confirm the charted soundings and to

update the charted data. Current charts are based on a survey conducted by the Canadian Hydrographic Service in 1916 and 1919.

The Canadian Hydrographic Service conducted a survey from May 19 to July 8, 1976, and from August 7 to September 30, 1976. The survey included the waters between Michipicoten Island and Caribou Island bounded by latitudes 47 l0' N and 47 04 5? N and longitudes 85 33 W and 86 11 W. Soundings were obtained by echo soundings and geographic positions were determined by use of a special three-station mini fix system.

The results of the survey were reduced to a datum of 182.99 meters (599.85 feet) above the International Great Lakes Datum. This base datum is within 0.53 foot of the datum used on current charts.

The hydrographic survey conducted by the Canadian Hydrographic Service of the area north of Caribou Island produced bottom contours very close to those shown on Canadian Chart 2310. In some locations on North Bank, some soundings were less than charted depths; however, in all instances these locations are within the 10-fathom curve as shown on Chart 2310. No soundings less than 10 fathoms were indicated either north or east of the charted 10-fathom curve.

Columbia Transportation Division, the operator of the FITZGERALD, conducted an independent hydrographic survey of the shoal area north of Caribou Island. Water depths were determined by sonic devices, lead line, and direct measurement by divers. The results of this survey show water depths that vary slightly from the Canadian survey. These differences can be attributed to the rocks and boulders on the bottom and the various tracklines on which soundings were recorded.

A former chief mate of the FITZGERALD testified that between September 13 and October 3, 1975, the FITZGERALD discharged at Toledo, Ohio. Because of the FITZGERALD's deep draft, she was not able to pull up to the dock and had to lay off some 12 feet each time. The ship seemed to plow its way toward the dock every trip, he said. Similar "groundings" of other Great Lakes bulk cargo vessels during discharge at various ports were observed by Coast Guard Marine Inspectors during the winter of 1976 and the spring of 1977 and by Safety Board personnel during the summer of 1977.

Tests and Research

The Safety Board analyzed the structure of the FITZGERALD's hatch covers to determine the forces necessary to cause their failure. The analysis assessed several possible failure modes and several possible draft conditions caused by flooding of either the cargo hold, the tunnel, or the ballast tanks. The results of the analysis indicated that boarding seas could have induced sufficient stresses to cause the catastrophic failure of one or more of the hatch covers when the FITZGERALD's freeboard was reduced by the flooding. The resulting catastrophic structural failure would have allowed rapid massive flooding of the cargo hold.

Other Information

Operating Instructions--Many Great Lakes bulk cargo vessel operators advised the Safety Board that they give their masters operating instructions concerning navigation in adverse weather and ice. These instructions are general and are usually verbal although some companies provide their masters with written policy. All the companies contacted stated that the final operational decisions concerning vessel navigation are made by the master whether to sail, delay sailing, divert to avoid adverse weather and sea conditions, anchor, or seek shelter. Each master is expected to

use his experience to evaluate the most current and accurate weather information in deciding the best course of action for the safety of his ship.

Great Lakes vessels covered by the 1973 Great Lakes Load Line Regulations (46 CFR 45.105) are required to have on board, in a form approved by the Commandant, USCG, sufficient information to enable the master to load and ballast the vessel so that unacceptable stresses in the vessel's structure are avoided. Testimony taken at the Coast Guard Marine Board of Investigation and subsequent inspections by the U.S. Coast Guard indicate:

1. The loading information provided Great Lakes vessels is not always used by the master.

2. The FITZGERALD's loading information provided no information on intermediate stresses during the loading sequence nor any information on any aspect of unloading.

3. The FITZGERALD's loading information was prepared for a two-belt loading system such as that used at Silver Bay, MN, the FITZGERALD's normal point of loading. It did not contain information directly applicable to a chute dock, such as the one at which the FITZGERALD loaded on November 9, 1975.

4. The FITZGERALD's loading information did not contain information on ballasting or deballasting in conjunction with loading and unloading.

Navigation Information--Navigation on Lake Superior normally is accomplished, as was the case aboard the ANDERSON, using Lake Survey Chart No. 9, described in waterway information.

An accurate record of the navigational tracklines of the FITZGERALD and the ANDERSON was not available. Information from which investigators determined a probable trackline for the FITZGERALD consisted of logs and charts from the ANDERSON, considerable testimony from the master and the mates of the ANDERSON, and weather messages filed by both the ANDERSON and the FITZGERALD. The ANDERSON was navigated by radar ranges and bearings and determined the positions of the FITZGERALD by radar observations. The crew of the ANDERSON did not plot the FITZGERALD's actual geographic position.

The radar presentation aboard the ANDERSON consisted of a relative bearing display on a plan position indicator (PPI) scope. The vessel's head was always toward the top of the scope and bearings were clockwise relative to the centerline of the ship. Range was determined from directly reading a dial indicating the distance from the center of the scope (the vessel's position) to a movable electronic indicator on the scope or by estimating a target's distance from fixed, electronically displayed range rings on the scope. On the 24—mile range display, these fixed range rings were shown at intervals of 4 miles.

Accurate bearings relative to ship's head could be read directly from the bearing ring surrounding the PPI scope. To obtain an accurate true bearing, the relative bearing had to be added to the ship's true heading at the time the bearing was taken. There is no testimony to indicate that the crew of the ANDERSON did this to obtain true bearings of the FITZGERALD or other targets they observed.

Testimony indicated that the ANDERSON's navigation was based primarily on bow and beam bearings, although range was sometimes determined. Further, the testimony did not always clearly state that both radar ranges and radar bearings were always obtained. The testimony indicated that at times the term ‘‘radar bearing" was used to indicate either range or bearing or both values. Beam bearings are relative to the ship's centerline and may be in error, depending upon the instantaneous heading of the vessel when the beam bearing is taken.

The ANDERSON plotted an intended course and did not start a new trackline plot in those positions where a fix did not fall on the intended trackline. At times, the ANDERSON determined her position and did not log or plot the data, steered courses other than those charted or logged, and changed course without simultaneously fixing her position. These procedures made reconstruction of a track difficult. Also, an analysis of the testimony and other data relating to the navigation of the ANDERSON and the FITZGERALD indicated that some of the information regarding the navigational plots was not consistent. In attempting to reconstruct the navigational tracks of the two vessels, greater credibility was given to positions based on radar information and routine log entries of navigational information from the ANDERSON than to visual estimates of the FITZGERALD's position given a month after the accident. (See figure 1.)

Testimony indicated that when the FITZGERALD and the ANDERSON were north of Michipicoten Island, they were on converging courses heading toward a point 2 1/2 to 3 miles west or southwest of West End Light. Information from other Great Lakes mariners indicated that 1410 T is a usual course from West End Light to Whitefish Bay and this trackline is well clear of any shoal areas.

ANALYSIS

The Sinking

An analysis of the wreckage itself did not give any conclusive evidence as to the cause of the sinking of the FITZGERALD. However, an analysis of the final events in conjunction with the wreckage indicated that the FITZGERALD experienced massive flooding of the cargo hold just before she sank.

When the master of the FITZGERALD first reported topside damage to the vessel at 1530 on November 10, he stated he had a fence rail down, had lost two vents, and had "both" pumps going. Flooding was occurring in one or more ballast tanks, the tunnel or a combination of ballast tanks and the tunnel. At the same time, because of the severe sea conditions, water was entering the vessel's cargo hold through nonweathertight hatch covers. Between 1530 and the sinking, the FITZGERALD's deck was awash with green water. Since the sheer strake extended 15 3/8 inches above the weather deck for the entire length of the vessel at side, water would have been trapped on deck. The combined effect of the water in the ballast tanks, the tunnel, the cargo hold, and on deck would have decreased the vessel's freeboard, permitted more water to enter the cargo hold, and increased any trim or list initiated by the ballast tank or tunnel flooding.

The Safety Board determined through its structural analysis of the hatch covers that the sea state, combined with the loss of freeboard and the trim caused by flooding, could have imposed sufficient hydrostatic loads to cause a hatch cover failure and collapse under static loading.

The Safety Board calculations assumed a wave height of 25 feet. This was based on the ANDERSON's observations of significant wave heights from 18 to 25 feet. A significant wave height of 25 feet means that the average height of the one-third highest waves is 25 feet. The Safety Board also calculated that, by 1915 on November 10, sufficient water had entered the hull of the FITZGERALD to reduce its freeboard to near zero at hatch No. 1. With zero freeboard, a wave of 25 feet in height would yield a static head of 12.5 feet. This static head was sufficient to cause hatch cover failure. 46 CFR 45.145 required that hatch covers be designed assuming a minimum 4-foot head of water.

The quartering seas would cause a piling" effect in the area behind the forward deckhouse and thus increase the static head. Any stresses caused by the dynamic forces of the boarding seas would have added to the static stresses and would have accelerated the hatch cover failure.

The hatch cover failure would have been severe enough to allow rapid massive flooding of the cargo hold. Since there were no watertight bulkheads within the cargo hold, the flooding water would have progressed throughout the hold within minutes, causing the vessel to sink bow first to the bottom of the lake. Upon impact with the bottom, the midship portion disintegrated and the stern section rolled over, coming to rest upside down.

The cargo hold was not fitted with a system of sounding tubes or other devices to detect the presence of flooding water. The only suctions for the bilge pumping system in the cargo hold were located aft in cargo hold No. 3 port and starboard. Testimony indicated that it is almost impossible to pump water from the cargo hold when there is bulk cargo aboard. The cargo tends to clog the strainer and prevent the flow of water into the bilge well where the pump takes suction. This inability to dewater the cargo hold indicates that the ballast pumps were taking suction on the ballast tanks where the system was normally effective for dewatering. There was no bilge suction for either tunnel; therefore, flooding was probably occurring in the ballast tanks or the tunnel which drains into the ballast tanks, or both.

Because of the large capacity of the FITZGERALD ballast pumps (four of 7,000-gpm capacity and two of 2,000-gpm capacity), the flooding must have been occurring through openings other than just the damaged ballast tank vents, or the tunnel must have been flooding at a rate greater than could be drained into the ballast tanks. Any flooding through the vent openings or tunnel drains into the ballast tanks would have been removed within a matter of minutes by the ballast pumps and the vessel’s list should have been eliminated.

The FITZGERALD did not explain what caused the damage to the fence rail and the vents. However, whatever caused this damage probably also caused some localized structural damage to the vessel’s hull plating. This damage to the hull plating would have permitted flooding into the tunnel and into the ballast tanks faster than the pumps could remove the water and thereby eliminate the list. The topside damage could have been caused by the vessel striking a floating object which was brought aboard by heavy seas or by some object on board, such as the hatch cover crane or spare propeller blade, breaking away in the heavy seas.

After the FITZGERALD’s master reported damage at 1530, the sea conditions became worse. Ten or 12 miles north of Caribou Island, the seas were 12 to 18 feet high, and below Caribou Island, the seas were 18 to 25 feet. Any structural damage to the shell plating would have propagated under the higher stress levels caused by these sea conditions and would have increased the rate of water flooding into the ballast tanks, or the tunnel, or both.

Visual inspections by Coast Guard Marine Inspections during the winter of 1976 and the spring of 1977 and by Safety Board personnel during the summer of 1977 indicate that hatch covers on Great Lakes vessels are not maintained weathertight.

A detailed analysis of the amount of water that could have entered the cargo holds through openings between the hatch covers and the hatch coamings of the FITZGERALD on November 10, 1975, was made by both the Coast Guard and the Safety Board. Both analyses show that the current hatch design used on Great Lakes vessels, such as the FITZGERALD, would have permitted significant amounts of water to enter the FITZGERALD’s cargo hold under the sea conditions encountered on November 10, 1975.

The effect of this flooding on both trim and list could have been determined by the use of trim and list indicating instruments. The instruments also could have provided an indication of the rate of

change of trim and list by comparing a series of readings at various times. The change of trim and list would have indicated if progress was being made by pumping or if conditions were getting worse.

Between 1700 and 1730, the master of the FITZGERALD told the AVAFORS that "I have a 'bad list,' I have lost both radars, and am taking heavy seas over the deck in one of the worst seas I have ever been in." In order for the FITZGERALD to have developed a "bad list" 2 hours after the list was first reported, the flooding rate into the ballast tanks must have exceeded the vessel's pumping capacity or flooding through the openings between the hatch covers and the hatch coamings must have contributed significantly to the list. Because of the severe sea condition, the master probably did not realize the extent of flooding in the cargo hold, and he had no means of detecting the flooding until the water level exceeded the height of the cargo. At 1910, the FITZGERALD reported that "We are holding our own;" however, shortly thereafter the FITZGERALD sank.

Because there were neither witnesses nor survivors, and because the scattered wreckage on the lake bottom does not indicate a definite mode of hull failure, the actual sequence of events culminating in the sinking of the FITZGERALD cannot be completely substantiated. Two possibilities are discussed below.

First, the increased weight of the flooding water could have caused a massive structural failure while the FITZGERALD was still on the surface, which caused the vessel to break into two sections. However, an analysis of various flooding conditions indicated that the stress levels from longitudinal bending moments were well below that which would cause a structural failure on the surface. The proximity of the bow and stern sections on the bottom of Lake Superior indicated that the vessel sank in one piece and broke apart either when it hit bottom or as it descended. Therefore, the FITZGERALD did not sustain a massive structural failure of the hull while on the surface.

Second, the reduced freeboard and loss of transverse stability from flooding could have caused the FITZGERALD to capsize. If three or less adjacent ballast tanks on the same side of the vessel were completely flooded, the FITZGERALD would not have capsized. The vessel also would not have capsized if water had entered only the cargo hold through openings between the hatch covers and the hatch coamings. In each case, the roll angle would not have been sufficient to produce a cargo shift. However, under the combined effects of flooding two ballast tanks, the tunnel, and the cargo hold, the FITZGERALD would have capsized within minutes. If the vessel had capsized, however, all the hatch covers would probably have been torn away by the force of the shifting taconite pellets. The underwater survey of the wreckage showed that hatchcovers Nos. 3 and 4 were still in place. The final position of the wreckage indicated that if the FITZGERALD had capsized, it must have suffered a structural failure before hitting the lake bottom. The bow section would have had to right itself and the stern portion would have had to capsize before coming to rest on the bottom. It is, therefore, concluded that the FITZGERALD did not capsize on the surface.

Possible Grounding

Safety Board investigators considered the possibility that flooding resulted from a grounding which ruptured the hull plating in the area of some ballast tanks, but rejected this possibility for the following reasons:

A reconstruction of the FITZGERALD's most probable trackline shows her path to be about 3 miles from the nearest position where grounding could have occurred.

No gouges, scraps, fractures, indentations, or other indications of grounding were visible on the exposed bottom plating on the after section of the wreckage. These observations were made during a close examination of the exposed bottom plating by underwater television from the CURV III. Damage to the bottom plating of a vessel from grounding on boulders in the rocky shoal north of Caribou Island during the severe sea conditions would probably have extended into the bottom plating of the stern section.

The FITZGERALD's full speed was reported to be 16.3 mph. At this speed, it was impossible for the FITZGERALD to pass through her 1520 position, as determined by the ANDERSON from radar observations, and reach the nearest position at which grounding could occur by 1530. Although the list was not reported until 1530, the Safety Board concludes that topside damage occurred before 1520 and that the list was caused by flooding through the topside damage for a period of time. Even if massive damage could have been sustained at 1530 and instantaneous flooding could have occurred, it is unlikely that the FITZGERALD would have instantly reported the damage. If an immediate report had been made it probably would have mentioned damage more serious than just a list, the loss of a rail, and damage to the vents.

Probable Trackline

In reconstructing the ANDERSON's probable trackline, the Safety Board relied primarily upon the ship's log entries concerning fixes taken at 1520 and 1652, the courses steered, and the reported speed of 14.5 mph. Subsequent testimony indicated a course change at 1652, which was not logged and a fix taken at 1701, which also was not logged. These times do not correlate with the other navigational data. Instead, calculations indicate that course was probably changed at 1634 and the fix probably was obtained at 1734. With these time corrections, the ANDERSON's track correlates with the fixes, times, courses, and speeds given in the testimony of the ANDERSON's master and mate.

The reconstruction of the positions of the ANDERSON and the FITZGERALD from Otter Head to the position of the FITZGERALD's wreckage shows that the most probable trackline of the FITZGERALD runs from a position 2 1/2 to 3 miles southwest of West End Light on Michipicoten Island on a course of 141 T toward Whitefish Bay. The position southwest of West End Light was confirmed by radar observations aboard the ANDERSON. A preponderance of the evidence confirms that the FITZGERALD's positions were close along this trackline at intervals from 1350 throughout the afternoon. The wreckage of the FITZGERALD was found 1 1/2 miles east of this trackline.

About 1520, the FITZGERALD was about 16 miles ahead and slightly to the right of dead ahead of the ANDERSON, a position about 7 miles north by east from Caribou Island. This position correlated well with the FITZGERALD's most probable course and speed. The master of the ANDERSON testified that between 1530 and 1540, the FITZGERALD was about 17 miles ahead and 1 or 1 1/2 points (about 11 to 170) to the right of the ANDERSON's heading flasher. During his testimony, before the Marine Board, the master indicated a position on a chart about 4 to 5 miles northeast of Caribou Island. Although these two descriptions are not compatible, in both cases the FITZGERALD would have been east of the 10-fathom curve. The relative motion of the FITZGERALD, on course 1410 T as observed from the ANDERSON on course 125 T, caused the FITZGERALD's bearing to increase to the right.

To reconstruct the FITZGERALD's probable trackline between 1252 and 1915 the Safety Board used information from the ANDERSON's logs and from radar data testified to by the ANDERSON's master and mate. An analysis of the FITZGERALD's course and speed from 1252 to a position southwest of West End Light indicates that the earliest time she could have changed course to 141T was 1359, using her previous speed of 16.3 mph. The segment of the track between 1359 and 1520 shows the FITZGERALD made 13.1 mph on a track of 144T. The

segment of the track between 1520 and 1915 shows the FITZGERALD made 11.8 mph on a track of 139 T. These calculated speeds indicate the FITZGERALD reduced speed before 1530 when she reported topside damage and a list and said she would reduce speed.

Based on radar data observed by the ANDERSON, the FITZGERALD's position at 1350 (1359), 1445, 1520, 1652 (1634), 1701 (1728), and 1915 correlate with the 141T course reported by the FITZGERALD and the Safety Board's calculated speeds. (See figure 1.)

The trackline of the FITZGERALD lies 2.75 miles east of Chummy Bank and 2.5 miles east of the 10-fathom curve outlining the shoal area north of Caribou Island known as North Bank. Some testimony placed the FITZGERALD closer to North Bank; however, the course of 141 T from West End Light to Whitefish Bay is well known to Great Lakes navigators and this was the intended track of both the ANDERSON and the Fitzgerald. The ANDERSON was navigated to return to this trackline at 1634 for the final leg of her voyage. At this time the FITZGERALD was observed to be almost dead ahead of the ANDERSON when her heading was 142 T.

Although the FITZGERALD could have departed from the usual trackline of 141 T from West End Light to Whitefish Bay to pass over the shoal area north of Caribou Island and then return to the 141 T trackline at a position observed by the ANDERSON at 1634, this departure is unlikely. The distance from the 1520 position of the FITZGERALD to the closest point where grounding could occur was 3.3 miles. To reach this point at 1530, a course change of 64 degrees and an increase of speed to 19.8 mph would have been required. The FITZGERALD's full speed was 16.3 mph.

During a taped conversation with his office, which was made a part of the record, the ANDERSON's master stated that the FITZGERALD "passed right over that 6-fathom spot." (See figure 1.) The Canadian Hydrographic Service survey shows the water depth at this charted "6-fathom spot" is 52 meters (28.4 fathoms). If the FITZGERALD, whose draft was more than

27 feet, had passed through this position on a course of 141 T the vessel would have had to pass within 3/4 of a mile of the north tip of Caribou Island and through an area where the depth is less than 21 feet. Furthermore, the position of the charted "6-fathom spot" is more than 5 miles west of the FITZGERALD's 1520 position testified to by the ANDERSON's mate and her 1540 position testified to by the ANDERSON's master. The Safety Board concludes that the statement on the tape referring to the FITZGERALD passing over the charted "6-fathom spot" is not supported by the evidence.

Other Safety-Related Findings

Although not directly contributing to the sinking of the FITZGERALD, several items were uncovered during the investigation of this accident that affect the safety of Great Lakes bulk cargo vessels and are discussed below:

Fathometers --The shoal waters near Michipicoten Island and Caribou Island, as well as other locations in Lake Superior, are not isolated spots. The bottom contour around these shoal areas is usually gradual enough that the change of water depth will provide adequate warning that a vessel is approaching a shoal area if the water depth is measured with a fathometer.

A fathometer can be used to determine a trackline made good in most areas by comparing a series of observed depths to the charted depths. This easy determination of a vessel's position and progress would be a significant aid to a mariner if other navigational instruments fail, as was the case of the FITZGERALD. A fathometer is most useful when vessels are navigating in

restricted waterways, such as the waters of the Great Lakes, where all navigational information is important.

Charts -- The small scale of Lake Survey Chart No. 9, which the FITZGERALD probably used, limited the amount of detail that could be shown on chart. The shoal area north of Caribou Island is not shown on the chart within a bottom contour line greater than 5 fathoms; and a charted depth of 6 fathoms, shown approximately 5 miles north-by-west from Caribou Island, appears to be an isolated shallow spot. The Canadian Hydrographic Service survey did not show any sounding as low as 6 fathoms in this position, and no isolated shoal spots were detected.

Canadian Hydrographic Service Chart 2310 shows this shoal area known as North Bank in considerably more detail than does Lake Survey Chart No. 9 and the bottom contour lines were confirmed by the 1976 Canadian Hydrographic Service survey of the area. No isolated spots of shoal water were located, and all soundings of less than 10 fathoms fell within the 10-fathom curve shown on Canadian Chart 2310.

Testimony that the FITZGERALD passed over a "6-fathom spot" highlights the need for additional information to be shown on Lake Survey Chart No. 9 about North Bank where the water depth is between 5 and 10 fathoms. Although the probable trackline of the FITZGERALD was east of this shoal area, greater detail of this area would be useful to mariners.

Groundings At Cargo Facilities -- Although groundings did not contribute to the loss of the FITZGERALD, testimony and visual observations by U.S. Coast Guard Marine Inspectors and Safety Board personnel indicate that the increased drafts permitted under the 1973 Great Lakes Load Line Regulations have increased the number and severity of "groundings" at loading and discharge berths because of insufficient water depth alongside.

Since Great Lakes vessels are normally drydocked only every 5 years, the extent of damage from these "groundings" will probably not be apparent for some years. They may result in reduced plate thickness or minor structural failures. Damage by "groundings" may lead to major structural failure under the stresses imposed by a seaway.

Weather Forecasting -- At 1639, on November 10, the NWS predicted for eastern Lake Superior northwest winds 38 to 52 knots with gusts to 60 knots, and waves 8 to 16 feet. The observed winds by the ANDERSON and by the Stannard Rock Weather Station during the afternoon of November 10 were in the range of 40 to 58 knots from the west-northwest, gusting to 65 knots. These observations confirm the NWS predications. However, the wave height prediction was not accurate. The ANDERSON observed waves 18 to 25 feet during the afternoon of November 10. This is 12 to 75 percent greater than the predicted maximum wave height. A NWS meteorologist testified that under the observed wind conditions, current techniques would have predicted 15-foot waves. This indicates that the NWS does not have adequate wave height prediction techniques for the Great Lakes.

Loading Information -- Testimony indicated that adequate loading information is not being provided to Great Lakes bulk carriers as required by 46 CFR 45.105. Great Lakes bulk carriers may be overstressing their hull structure during loading and unloading. Although this overstressing may not cause a massive structural failure during loading and unloading, the overstressing may cause a minor structural failure or low cycle fatigue in structural members, which could lead to a massive structural failure in a seaway.

Vessel Design -- Normally, the maximum wave heights and wave lengths encountered on the Great Lakes are considerably less than the wave heights and wave lengths encountered in the open ocean. For this reason, Great Lakes bulk cargo vessels are designed to a longitudinal structural strength standard approximately one—half that required for vessels on an ocean

voyage. The limiting sea state used in structural design also determines the requirements for freeboard and hatch cover design, even though this limiting sea state may be exceeded on the Great Lakes.

The above reflects a difference in design philosophy between that applicable to Great Lakes vessels and that applicable to ocean ships. Ocean ships are designed for the maximum expected sea conditions because they may be in the middle of the ocean when they encounter a severe storm, with no place to seek shelter. Great Lakes vessels, however, have relatively short voyages and can either delay sailing or seek shelter en route when severe storm conditions are expected or encountered. Therefore, masters must be informed of the maximum sea conditions for which Great Lakes bulk cargo vessels are designed and must be prohibited from operating under weather conditions which exceed the vessel design limits.

Emergency Position Indicating Radio Beacons -- Great Lakes vessels are not required to have emergency position indicating radio beacons (EPIRB's) and none was provided aboard the FITZGERALD. The EPIRB is a battery-operated radio transmitter designed to transmit an emergency signal when it is manually turned on. The EPIRB is installed in such a manner that it will float free if the vessel sinks. When the EPIRB floats free, its transmitter is automatically placed in operation and the emergency signal will be transmitted.

The emergency signal can be received by shore stations, aircraft, and other vessels, and the location of the transmitter can be determined by means of radio direction finders and triangulation. The location of a distress or potential distress allows search and rescue efforts to be concentrated in a small area and increases the probability of finding survivors.

Although the ANDERSON lost visual and radar contact with the FITZGERALD about 1915, the ANDERSON was not convinced that the FITZGERALD had sunk for more than an hour. When the ANDERSON became convinced the FITZGERALD was lost she advised the U. S. Coast Guard by VHF-FM radiotelephone of her concern. The reason for this delay was that there was no distress call from the FITZGERALD. If the FITZGERALD had been fitted with an EPIRB, a distress signal would have been transmitted immediately when the FITZGERALD sank. This EPIRB would have alerted rescue units sooner and reduced the search area.

As in many catastrophic marine accidents, the FITZGERALD did not have time to broadcast a distress call over its own radio equipment. Had the ANDERSON not been in contact with the FITZGERALD by radio and radar, the loss of the FITZGERALD and a good estimate of her position would not have been known for many hours and the search area for possible survivors would have been greatly expanded.

Search and Rescue -- Although not contributing to the loss of life in the sinking of the FITZGERALD, the Coast Guard's surface search and rescue capability was extremely limited on November 10. The only Coast Guard surface unit that was large enough to cope with the weather and sea conditions, that was not under repair, and that was close enough to respond within a reasonable time was the WOODRUSH, 300 miles away. The small craft designed for coastal operations, which were available in Lake Superior, were unsuitable for searching 15 miles offshore under the prevailing sea conditions. Additional surface search and rescue units on the Great Lakes that are capable of operation in severe weather conditions are needed.

CONCLUSIONS

Findings

1. The FITZGERALD's hatch covers were not weathertight and allowed water to enter the cargo hold over an extended period. This water was not detected because it migrated down through the cargo. There was no method provided for sounding the cargo other than visual observations, nor was there any method for dewatering the cargo hold with the vessel trimmed by the bow.

2. Amendments to the Great Lakes Load Line Regulations in 1969, 1971, and 1973 allow Great Lakes bulk carriers to load deeper. This deeper loading increased deck wetness which caused an increase in the flooding rate through nonweathertight hatches or other nonweather-tight openings.

3. The topside vents and fence rail were damaged before 1520 either by a heavy object coming adrift on deck or by a floating object coming aboard with the seas. The FITZGERALD's hull plating probably was damaged also; the damage propagated and caused flooding of the ballast tanks and tunnel.

4. Flooding of ballast tanks and the tunnel caused trim and a list. Detection of ballast tank flooding prompted the ballast pumps to be started. However, the flooding rate through the hull damage, which was propagating, increased and exceeded the capacity of the pumping system.

5. The hull stress levels, even with a substantial amount of flooding, were low enough that the hull girder did not fail before the sinking.

6. The forces on the hatch covers caused by boarding seas were sufficient to cause damage and collapse. These forces increased as flooding caused a list and reduced the vessel's freeboard.

7. Flooding of the cargo hold caused by one or more collapsed hatch covers was massive and progressed throughout the hold. Flooding was so rapid that the vessel sank before the crew could transmit a distress call.

8. The vessel either plunged or partially capsized and plunged under the surface. The hull failed either as the vessel sank or when the bow struck the bottom.

9. The availability of a fathometer aboard the FITZGERALD would have provided additional navigational data and would have required less dependence on the ANDERSON for navigational assistance.

10. The most probable trackline of the FITZGERALD, from west of Michipicoten Island to the position of her wreckage, lies east of the shoal areas north and east of Caribou Island; therefore, damage from grounding would have been unlikely.

11. The shoal area north of Caribou Island is not shown in sufficient detail on Lake Survey Chart No. 9 to indicate the extent of this hazard to navigation. A contour presentation of this hazard would allow mariners to better assess this area and would help to eliminate the erroneous conclusion that there are isolated spots of shallow water, where in fact there is a large area of shoal water less than 10 fathoms deep.

12. Insufficient water depth has been observed at some loading and discharge piers. "Groundings" of vessels at these locations induce hull stresses of unknown magnitudes and create the potential of undetected hull damage and wear.

13. Although the National Weather Service accurately predicted the direction and velocity of the wind expected over the eastern end of Lake Superior on November 10, 1975, the predicted wave heights were significantly less than those observed.

14. Loading information on the FITZGERALD and other Great Lakes bulk cargo vessels was not adequate.

15. Great Lakes bulk cargo vessels normally can avoid severe storms. The limiting sea state for Great Lakes bulk cargo vessels should be determined, and the operation of vessels in sea states above this limiting value should be restricted.

16. The presence of an EPIRE aboard the FITZGERALD would have provided immediate automatic transmission of an emergency signal which would have allowed search units to locate the position of the accident. The accurate location of this position would have reduced the extent of the search area.

17. Installation of trim and list indicating instruments on the FITZGERALD would have provided the master an early indication of flooding that would have an adverse effect on the vessel. These instruments would have given an indication of whether the master's corrective action was adequate.

18. The surface search and rescue capability of the Coast Guard on November 10 was inadequate.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the sudden massive flooding of the cargo hold due to the collapse of one or more hatch covers. Before the hatch covers collapsed, flooding into the ballast tanks and tunnel through topside damage and flooding into the cargo hold through nonweathertight hatch covers caused a reduction of freeboard and a list. The hydrostatic and hydrodynamic forces imposed on the hatch covers by heavy boarding seas at this reduced freeboard and with the list caused the hatch covers to collapse.

Contributing to the accident was the lack of transverse watertight bulkheads in the cargo hold and the reduction of freeboard authorized by the 1969, 1971, and 1973 amendments to the Great Lakes Load Line Regulations.

RECOMMENDATIONS

As a result of its analysis of this accident, the National Transportation Safety Board made the following recommendations:

-- to the U.S. Coast Guard:

"Insure that all hatch covers, hatch coamings, and vents are in good repair and are capable of being made weather— tight during the annual inspections of all Great Lakes bulk cargo vessels before the spring shipping season and at inspections before the winter load line season. (Class II, Priority Action) (M—78—l0) (Issued March 23, 1978)

"Use the ship—rider program by Coast Guard Marine Inspectors and hatch cover inspections at cargo loading facilities to prevent sailing of any vessel found lacking in weathertight integrity. (Class II, Priority Action) (M—78—ll) (Issued March 23, 1978)

"Report the number of hatch cover inspections made of Great Lakes bulk cargo vessels and of sailings prevented or restricted due to nonweathertight closures over the next 2 years so that an accurate accounting can be made of the problem in reassessing minimum freeboard requirements. (Class II, Priority Action) (M—78—12) (Issued March 23, 1978)

"Investigate, together with the American Bureau of Shipping, the effects that the deeper drafts permitted under the 1969, 1971, and 1973 amendments to the Great Lakes Load Line Regulations, have had on the structural strength of Great Lakes bulk cargo vessels. Note any damage or bottom plating wear over the next 2 years caused by the groundings of these vessels during loading, unloading, or navigation in restricted— depth waterways. Evaluate the effect this damage and wear might have on the structural strength of these vessels in a seaway, and jointly report the finding. (Class II, Priority Action) (M—78—13) (Issued March 23, 1978)

"Determine if reduction in the minimum freeboard requirements for Great Lakes vessels permitted by the 1969, 1971, and 1973 amendments to 46 CFR Part 45 increases the potential for vessel flooding because the designs of weathertight closures are not adequate, and report the findings. (Class II, Priority Action) (M—78—16)

"Initiate a design study to improve the current weathertight hatch cover and clamp designs used on Great Lakes bulk cargo vessels with a view toward requiring a more effective means of closure of such fittings. (Class II, Priority Action) (M—78—l7)

"Insure that the masters of Great Lakes bulk cargo vessels have the loading information required by 46 CFR 45.105, including the proper sequences for simultaneous loading and de-ballasting or unloading and ballasting. (Class II, Priority Action) (M—78—18)

"Require that the masters of all Great Lakes cargo vessels that are not required by 46 CFR 45.105 to have loading information be provided with such information, including the proper sequence for simultaneous loading and de-ballasting or unloading and ballasting. (Class II, Priority Action) (M—78—19)

"Require that a Great Lakes cargo vessel meet a minimum level of subdivision and damage stability to prevent the foundering of the vessel because of flooding through one hatch or flooding because of damage in a limited area of the vessel. (Class II, Priority Action) (M—78—20)

"Require a means of detecting water in the cargo holds of a Great Lakes vessel so that her master will have an early indication of flooding and can take any necessary corrective action. (Class II, Priority Action) (M—78—21)

"Amend 46 CFR 56.50—50 to require an effective bilge pumping system on Great Lakes bulk cargo vessels so that if the vessel has trim by the bow and is listing, water can be removed from any portion of the cargo hold. (Class II, Priority Action)

(M—78—22)

"Require instruments in the wheelhouse to detect changes in both trim and heel on Great Lakes bulk cargo vessels so that changes in trim and heel caused by the presence of water or changes in cargo configuration can be detected. (Class II, Priority Action) (M—78—23)

"Require that the information supplied to the master of Great Lakes cargo vessels on loading and stability also include information on the vessel's ability to survive flooding (e.g., trim and heel results after assumed damage) so that the master can take appropriate corrective action or formulate timely plans to effect crew evacuation. (Class II, Priority Action) (M—78—24)

"Require that Great Lakes vessels have emergency position indicating radio beacons (EPIRB's) so that vessels lost or in serious danger can be located rapidly and accurately. (Class II, Priority Action) (M—78—25)

"Determine, in conjunction with the American Bureau of Shipping, the limiting sea state applicable to the design of Great Lakes bulk cargo vessels including freeboard and longitudinal strength, and report the findings. (Class II, Priority Action) (M—78—26)

"Prohibit the navigation of Great Lakes vessels in wind and wave conditions which exceed the limiting sea state used for vessel design. (Class II, Priority Action) (M—78—27)

"Determine, in conjunction with the American Bureau of Shipping, the design criteria used to determine the structural adequacy of hatch covers and report the findings. Evaluate the design criteria and impose more stringent standards if indicated. (Class II, Priority Action) (M—78—28)

"Require that all Great Lakes bulk cargo vessels have a fathometer. (Class II, Priority Action) (M—78—29)

"Increase the surface search and rescue capability on the Great Lakes during severe weather periods. (Class II, Priority Action) (M—78—30)"

--to the American Bureau of Shipping:

"Insure that the closures on the freeboard deck of all Great Lakes bulk cargo vessels are capable of being made weathertight in accordance with the annual survey requirements of 46 CFR 42.09—40. (Class II, Priority Action) (M—78—14) (Issued March 23, 1978)

"Investigate, together with the U.S. Coast Guard, the effects that the deeper drafts permitted under the 1969, 1971, and 1973 amendments to the Great Lakes Load Line Regulations have had on the structural strength of Great Lakes bulk cargo vessels. Note any damage or bottom plating wear over the next 2 years caused by the 'groundings' of these vessels during loading, unloading, or navigation in restricted—depth waterways. Evaluate the effect this damage or wear might have on the structural strength of these vessels in a seaway, and jointly report the findings. (Class II, Priority Action) (M—78—15) (Issued March 23, 1978)

"Determine, in conjunction with the U.S. Coast Guard, the limiting sea state applicable to the design of Great Lakes bulk cargo vessels including freeboard and longitudinal strength. (Class II, Priority Action) (M—78—31)

"Determine, in conjunction with the U.S. Coast Guard, the design criteria used to determine the structural adequacy of hatch covers. (Class II, Priority Action) (M—78—32)"

--to the National Oceanic and Atmospheric Administration:

"Revise Lake Survey Chart No. 9 showing the areas between Michipicoten Island and Caribou Island in Lake Superior to reflect the findings of the survey performed by the Canadian Hydrographic Service. (Class II, Priority Action) 01—78—33)

"Evaluate the current methods of forecasting wave heights on the Great Lakes to determine if these methods accurately predict actual wave heights. (Class II, Priority Action)

(M—78—34)"

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING

Chairman

/s/ FRANCIS H. McADAMS

Member

/s/ ELWOOD T. DRIVER

Member

/s/ PHILIP A. HOGUE

Member

KING, Chairman, filed a concurring statement. (See concurring statement below.)

HOGUE, Member, dissented. (See dissenting statement below.)

Concurring Opinion of James B. King, Chairman:

I agree fully with the report adopted by the majority, but because of the importance of the accident and the controversy it has engendered, I believe it worthwhile to address in some detail the contentions which the dissent raises. The dissent offers eight contentions to support its version of the probable cause, and this opinion will discuss each in turn.

The first contention, upon which the dissent principally rests, is that Captain Cooper of the ANDERSON stated after the accident that he believed that the FITZGERALD had grounded north of Caribou Island. This statement: (1) was contradicted by Captain Cooper himself under circumstances more likely to elicit a correct recollection and (2) is inconsistent with the independent navigational evidence. The statement upon which the dissent relies was not made under oath, was made without benefit of charts, with no other witnesses present, and without cross— examination. When Captain Cooper had an opportunity to testify before the Marine Board and to refer to navigational charts, he contradicted his statement concerning a grounding, and

charted a trackline for the FITZGERALD which corresponds to the trackline presented in the report.

At the Marine Board Captain Cooper and Chief Mate Clark both testified that the FITZGERALD was not near the shoal area. Captain Cooper testified that at 1540 the FITZGERALD was in the position the ANDERSON reached when she changed course to 141T. This position is well clear of the shoal. Chief Mate Clark testified that when the ANDERSON changed course to 141T the FITZGERALD was right on their heading flasher and "Maybe he didn't go in there (close to Caribou Island)."

Moreover, the "grounding" statement is inconsistent with the independent navigational evidence. First, the "6-fathom spot" to which Captain Cooper referred to is noted in Lake Survey Chart No. 9 but was later determined by hydrographic survey not to exist. Second, the FITZGERALD could not have passed over the "6-fathom spot" on a course of 141T without coming and remaining hard aground just north of Caribou Island in less than 4 fathoms of water. Moreover, it would have been physically impossible for the FITZGERALD to travel from her 1520 position obtained by the ANDERSON to a position in which grounding would have been possible by 1530. Such a journey would have required that the FITZGERALD proceed through mountainous seas at a speed greater than her top speed, nor is there any evidence of grounding in the approximately 270 ft of exposed bottom plating on the FITZGERALD stern.

The dissent's second contention is the Captain McSorley's report of a list and vents and fence rail down occurred when the FITZGERALD was in the shoal area, and indicates that the FITZGERALD had grounded. As mentioned above, the probable trackline shows that the FITZGERALD was not near a shoal area. In any event, a grounding could not have caused loss of the two vents. The two vents are massive, and a heavy impact above the deck level would have been required. The reported list, which the dissent takes to indicate grounding at that moment, could not have developed instantaneously. Whatever event caused the list had to have occurred sometime before 1520.

The dissent's third contention, closely parallel to that just discussed, is that loss of the fence rail must have been caused by hogging. As discussed above, impact by a heavy object would have been required to knock down the vents. The object which knocked down the vents could also easily have knocked down the fence rails. Thus, although hogging could have caused loss of the fence rail, it could not have caused loss of the vents. On the other hand, impact by a heavy object could have caused the loss of both.

As a forth contention, the dissent cites the testimony of Mr. Steam and Captain Webster. These two opinions, of course, are speculations of persons who were not near the FITZGERALD at the time of the casualty. As mentioned previously, these opinions are inconsistent with the navigational evidence.

The fifth contention is that because Captain McSorley was a competent master he would have insured that all hatch covers were secured. Captain McSorley's competence was unquestioned, but investigations have disclosed that a number of competent Great Lakes bulk cargo vessels do not maintain weathertight hatches. During the lay-up period of 1976-1977 the Coast Guard conducted an extensive program of hatch cover inspections to insure that the clamps were properly adjusted and that the hatches were weather-tight. The hatch clamps were frequently adjusted while the Coast Guard inspector was still aboard to show that the hatch covers would pass a hose test for weathertightness. Many times the hatch clamps were tightened to the point of failure without achieving the weathertightness of the closure. Furthermore, even after this extensive program, Safety Board investigators found loose clamps and nonweathertight hatch covers on Great Lakes bulk cargo vessels during the fall of 1977.

Moreover, dogging the hatches closed does not insure weathertightness. The clamps must also be properly adjusted. Although Captain McSorley may have insured that the FITZGERALD hatch were dogged closed, the clamps were not properly adjusted. Evidence of improper clamp adjustment is seen in the video tapes of the wreckage at hatch No. 5 where the hatch cover is missing and of a series of 18 consecutive hatch clamps only 2 are damaged and the remaining 16 are undamaged and are in the open position. Had these clamps been properly adjusted, they would all have been damaged or the hatch would have remained in place.

Calculations indicate that each of the 68 clamps on FITZGERALD's hatch covers must apply about 2,400 pounds at force to insure a tight seal from the gasket. Furthermore, Great Lake masters believe the weight of the hatch cover alone, about 14,000 pounds, would make the hatch cover weathertight. Calculations indicate more than 178,000 pounds is required.

A sixth contention, also concerning hatch covers, is that there is not testimony to insure that the FITZGERALD ever arrived in port without dry cargo. Although there is no testimony concerning wet cargo, 26,116 tons of taconite could absorb 4 to 6.7 percent water by weight (1044 to 1750 tons) without any free water being seen in the cargo hold. On occasions Great Lakes bulk cargo vessels have arrived in port with 2 to 4 inches of water in the cargo hold.

The dissent also argues that the tracklines of the ANDERSON and the FITZGERALD and their relative positions could not be reconstructed as stated in the Coast Guard Report. After extensive analysis of the testimony, the tracklines in the report of the vessel were reconstructed using logged times and positions. Although the data used were not of the "navigation textbook quality" the testimony does match the reconstructed tracklines if some times are adjusted. By calculating courses and speeds from positions "logged as normal course of business" the errors of time are evident.

The differences in relative bearing as observed by the ANDERSON's master and mate can be explained by the fact that the two bearings were taken 20 minutes apart. Furthermore, the motion of the FITZGERALD relative to the ANDERSON, on courses 141T and 125T, respectively, would have caused the bearings to drift right.

The dissent's final contention is that the FITZGERALD was steering various courses between Michipicoten Island and Caribou Island between 1359 and 1520. The standard usually accepted trackline for this route is 141T. Great Lakes vessels depart from the recommended tracklines to take advantage of the lee provided by shore as did the ANDERSON and the FITZGERALD. The ANDERSON changed her course to 230 T while north of Michipicoten Island to allow for a predicted wind shift to the northwest and to allow herself more searoom from a lee shore. At the time of this wind shift the FITZGERALD was south of Michipicoten Island and had no reason to alter course from the accepted track of 141T. Any course change the FITZGERALD would have made to reduce the rolling of the vessel would have been to the east. A course change to a course more southerly than 141T would have produced more pronounced rolling and would have been unacceptable to the master.

I have reviewed the dissent carefully and given careful consideration to Member Hogue's opinions, but I am unable to find the evidence in the testimony or reports which would permit me to join him.

s/ JAMES B. KING

Chairman

May 4, 1978

Dissenting Opinion of Philip A. Hogue, Member:

The most probable cause of the sinking of the SS EDMUND FITZGERALD in Lake Superior on 10 November 1975, was a shoaling which first generated a list, the loss of two air vents, and a fence wire. Secondarily, within a period of 3 to 4 hours, an undetected, progressive, massive flooding of the cargo hold resulted in a total loss of buoyancy from which, diving into a wall of water, the FITZGERALD never recovered.

In its conclusions, the Coast Guard, on p. 94 of its report, states, "At sometime prior to 1530 on 10 November, FITZGERALD experienced damage of sufficient magnitude to cause the Master to report topside damage and a list. Significantly, the Master of FITZGERALD reported the damage rather than the incident which caused it. (Underscoring supplied.) It is the opinion of the Marine Board that the incident, while possibly of a serious nature, was not of such extent as to have caused, by itself, the loss of the vessel and further, that the full extent of the incident was not perceived by vessel personnel." I totally concur with that Marine Board opinion.

The record indicates that the FITZGERALD was in all respects seaworthy prior to the commencement of her final voyage. Testimony as to the prudence and competence of her Master, Captain McSorley, is abundant. Paraphrasing the words of various witnesses, he was the best captain of the best ship in the fleet operated by the Oglebay-Norton Company. In recognition of this reputation, crewmembers specifically sought employment on the SS EDMUND FITZGERALD. Further, available evidence indicates that Captain McSorley would not commence a voyage into predicted bad weather without first insuring that all the hatch covers were effectively secure.

Like the Marine Board of the Coast Guard or the majority of the Members of the National Transportation Safety Board, I could speculate or surmise in the first instance that flooding into the cargo hold took place through ineffective hatch covers or in the second instance that flooding took place due to the failure of hatch cover Number One due to massive seas. I reject these arguments because neither of them is fully cognizant of the ramifications of the first reported list, the loss of two vents and fence railing at approximately the precise time the FITZGERALD was reportedly in or over shoal waters.

Between the first reported damage and the time of the sinking, approximately 3 to 4 hours later, seas of 25 to 30 feet and winds gusting to 80 knots were variously observed. Without exception, expert testimony has affirmed the fact that seas in shoal waters are inherently more violent and wild than in open water. It follows, therefore, that subsequent to her initial sustained damage, the FITZGERALD suffered progressive damage from laboring, rolling, and pitching for the next 3 to 4 hours as it proceeded toward Whitefish Point Light.

At or about 1730, Captain Woodard aboard the Swedish vessel AVAFORS received a report from Captain McSorley stating the FITZGERALD had a "bad list," had lost both radars and was taking heavy seas over the deck in one of the worst seas he had ever been in. In approximately 2 hours from the initial report of a list, the FITZGERALD had acquired a "bad list" and sustained the loss of both radars.

Approximately 1 hour 40 minutes later at or about 1910, the FITZGERALD reported it was holding its own. This was the last transmission ever heard from the FITZGERALD. Aside from the expert testimony elicited at the Coast Guard Marine Board hearing, it is self-evident that Captain McSorley had a damaged ship, and that he did not know how damaged she was.

It is true that initial damage to the FITZGERALD could have been sustained by other means, but it would be a most unlikely coincidence that damage was sustained at the same approximate time that she was reported by Captain Cooper of the SS ANDERSON to be in close or over shoal waters.

Despite the difficulty experienced, in retrospect, by Captain Cooper days later before the Coast Guard Marine Board, in pinpointing the position of the FITZGERALD over various and sundry shoals, the fact remains that in his most fresh, spontaneous and free report of the accident to his company less than 24 hours after the accident, Captain Cooper variously stated, "I AM POSITIVE HE WENT OVER THAT SIX (6) FATHOM BANK!" and "I KNOW DAMN WELL HE WAS IN ON THAT THIRTY—SIX (36) FOOT SPOT, AND IF HE WAS IN THERE, HE MUST HAVE TAKEN SOME HELL OF A SEAS." "I SWEAR HE WENT IN THERE. IN FACT, WE WERE TALKING ABOUT IT. WE WERE CONCERNED THAT HE WAS IN TOO CLOSE, THAT HE WAS GOING TO HIT THAT SHOAL OFF CARIBOU, I MEAN, GOD, HE WAS ABOUT THREE MILES OFF THE LAND BEACON."

In other testimony before the Coast Guard Marine Board, Captain Cooper testified that he told the Mate on watch on the ANDERSON that the FITZGERALD was closer to the six (6) fathom shoal north of Caribou Island than he wanted the ANDERSON to be.

No one knows of a certainty how long the FITZGERALD had a list or had other topside damage prior to the conversation between Captain Cooper and Captain McSorley at or about 1530. Neither does anyone know for sure exactly which vents were initially lost.

It is reasonable to assume, from all that is known of Captain McSorley, that his first report of damage was based on damage sustained immediately prior to 1530 and that it was no small consideration that caused Captain McSorley to ask the ANDERSON to stay with him, saying, "I will check down so that you can close the distance between us."

Quoting from the Coast Guard Marine Board on pp. 90 and 91, the following information is deemed highly relevant:

"The only information available on the position and trackline of Fitzgerald is in the weather reports sent by FITZGERALD and in testimony of the Master and Watch Officers of the SS ARTHUR M. ANDERSON, which was following FITZGERALD, in voice radio communication with it, and observing it visually and on radar. The weather reports from FITZGERALD scheduled at 1300 and 1900, 10 November, were not received.

"The position of FITZGERALD relative to that of ANDERSON cannot be reconstructed. Information available is based on the recollections of the Master and Watch Officers on ANDERSON, since the relative position of FITZGERALD was observed intermittently on the radar, but not recorded. Testimony on these observations is inconsistent. For example, the Officer on watch on ANDERSON recalled that FITZGERALD was a shade to the right of dead ahead,' as FITZGERALD passed northeast of Caribou Island, while the Master thought it was a point and a half to the right at that time.

"The Master and the Watch Officers on ANDERSON testified at length as to the position and trackline of ANDERSON in the afternoon and evening of 10 November. An analysis of this testimony shows that the vessel was navigated by radar ranges and bearings, that, at times, positions were determined but not logged, that course changes were made without simultaneous determination of position, that positions were determined as much as twenty minutes from the time that course changes were made, and that the courses steered varied from course logged because of the expected drift. The Marine Board attempted to reconstruct the trackline of ANDERSON and found that in order for the vessel to have steered the courses and have been at

the positions at the times testified to, the speed of the vessel would have varied from a low of 5 mph to a high of 66 mph. But the Master testified, and the engineering log confirmed, that throughout the period, ANDERSON maintained a steady speed, turning for 14.6 mph. Accordingly, it is concluded that the times and positions reported by officers of ANDERSON were not sufficiently accurate to allow the trackline of either FITZGERALD or ANDERSON to be reconstructed."

In order for me to concur with the Safety Board's majority, I have to assume that the true positions and tracklines of the FITZGERALD were those that would have been pursued in normal weather and that she remained well clear of shallow water and shoals.

I strongly doubt that was the case because Captain Cooper and Captain Pulcer, the former Master of the FITZGERALD, both testified that despite the general use of traffic lanes on Lake Superior, heavy weather contributed to the selection of ship courses. Indeed, on the day of the sinking, Captain Cooper of the ANDERSON originally intended to clear Michipicoten about 2 to 2 1/2 miles off. Nonetheless, due to weather, he finally cleared Michipicoten West End Light by 7.7 miles. Thereafter, he steered a number of courses ranging from 125 degrees to 141 degrees. All factors considered, it is my assumption that the FITZGERALD was variously steering various courses and for approximately the same reasons. In fact, if the FITZGERALD had also been 7.7 miles off Michipicoten, instead of 2.2 miles as estimated or recollected, and steering 141 degrees, she certainly would have been in the shoal waters Captain Cooper reported to his company.

Considering the fact that no testimony has ever been produced to show that the FITZGERALD had ever arrived in port without dry cargo and the overall success of the hatch covers generally in use on the Great Lakes for many years, I have great difficulty accepting the argument that one or more of the hatches on the FITZGERALD on the day of the accident were either nonwatertight or that they failed prior to the first report of damage. If, in fact, hatch failure or loss of weathertight integrity occurred prior to the FITZGERALD's sinking, I can only surmise that such failure or failures occurred subsequent to the first list reported on or about 1530 and prior to the sinking on or about 1910.

I place great credence in Captain Cooper's testimony that the FITZGERALD was in proximity or over shoal waters; first, because his judgment is the most expert to be found at the scene and as much as anything else, the FITZGERALD reported her first casualties at that almost exact time. I could have doubts of one fact or another, but putting two and two together plus the subsequent events, I am strongly convinced that the FITZGERALD received her first damage as I have indicated and that from that time until the sinking, the FITZGERALD's condition deteriorated beyond the Captain's knowledge and beyond recovery.

Naval Architect Richard A. Steam, on p. 1227 of the Marine Board of Investigation stated, "If there was a list, it must have been-- if it was any substantial amount of list, it must have been from a fracture in the hull caused by grounding or other means."

Captain Cooper on pp. 565 and 566 of the Marine Board of Investigation Report stated, "I believe that she was cracked somewhere. She was taking water fast enough because what he told me was that, 'I have a list and I am taking water' and I said, 'Have you got your pumps on?' and he said, 'Both of them."'

On p. 2140, Captain Cooper stated, "I have never known a ship to lose a fence rail in a seaway."

On pp. 2152 and 2153, Captain Cooper stated again, "The only solution I can have to a fence rail breaking is -- you can't break one by sagging a ship, but you would have to bend the ship, hog it up in the middle, to put such a tension on the fence rail that you would break it." "That is five—

eighths wire rope with three strands running in through there. You might break one, but you can't conceivably think of breaking three."

On p. 2490, Captain Delmore Webster states, "I think he set over on one of those shoals and that was the moment that his fence rail broke."

All of the foregoing expert testimony strongly supports the conclusion that the initial list and loss of fence railing were induced by shoaling.

On p. 1962, Captain Woodard, the pilot on the Swedish vessel AVAFORS stated, "It was one of the biggest and wildest seas I have ever been in, I mean fast." On p. 1963, he said, "The sea was straight up and down and a lot of them were coming at you. It was not like big rollers."

Without exception, vessels in the vicinity of the FITZGERALD's sinking absolutely refused to consider turning around in such severe wind and sea conditions.

After studying all available information, it is my firm conclusion that the FITZGERALD shoaled and sustained her initial damage shortly before 1530 and that thereafter, the various workings of the vessel and loss of watertight integrity led to her sudden and totally unexpected sinking.

/s/ PHILIP ALLISON HOGUE

Member

May 9, 1978

Appendices:

Figure 1: Trackline/Course of the SS EDMUND FITZGERALD

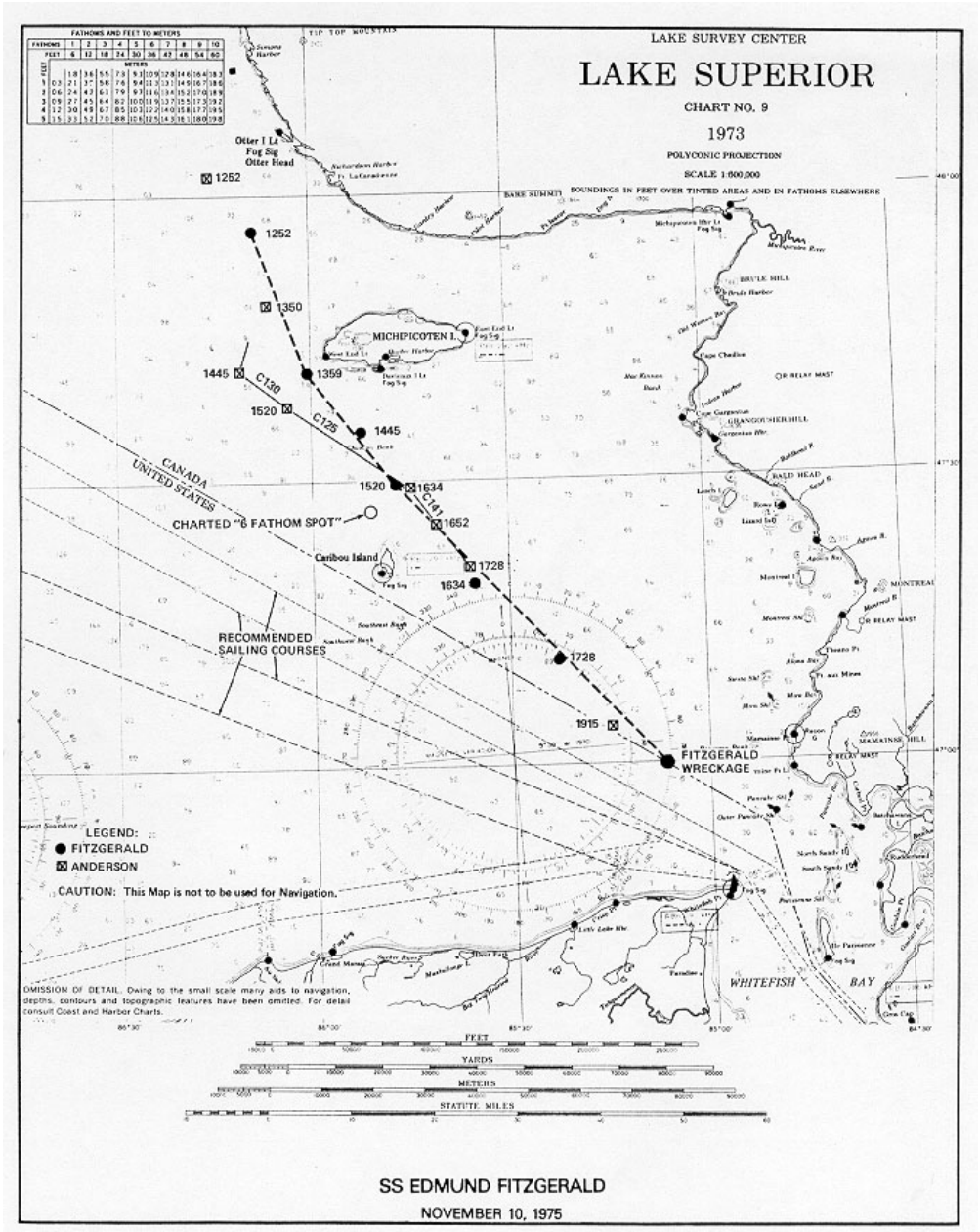

Figure 1. Probable tracklines of SS EDMUND FITZGERALD and SS ARTHUR M. ANDERSON on November 10, 1975.

Figure 2: Arrangement

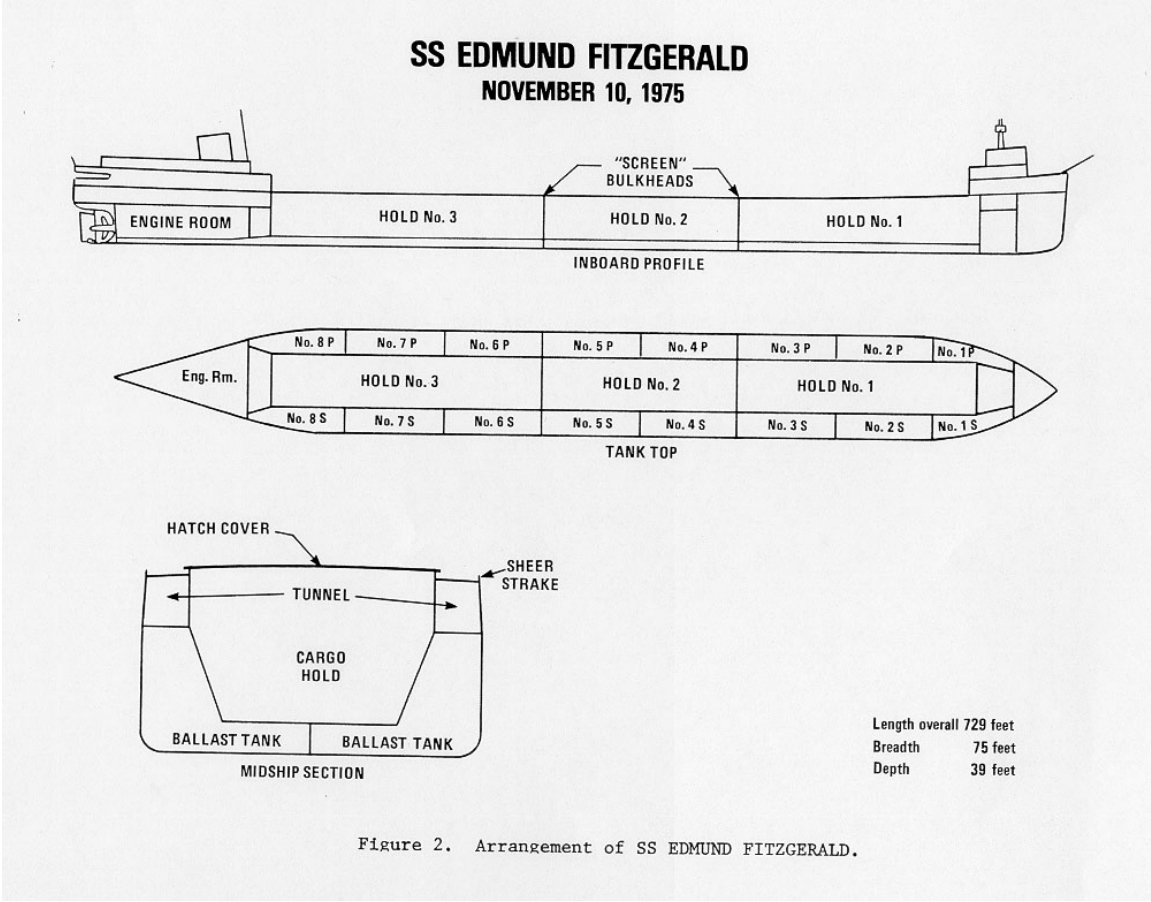

Figure 2. Arrangement of SS EDMUND FITZGERALD.

Figure 3: Sketch of the relative positions of the bow to the stern section

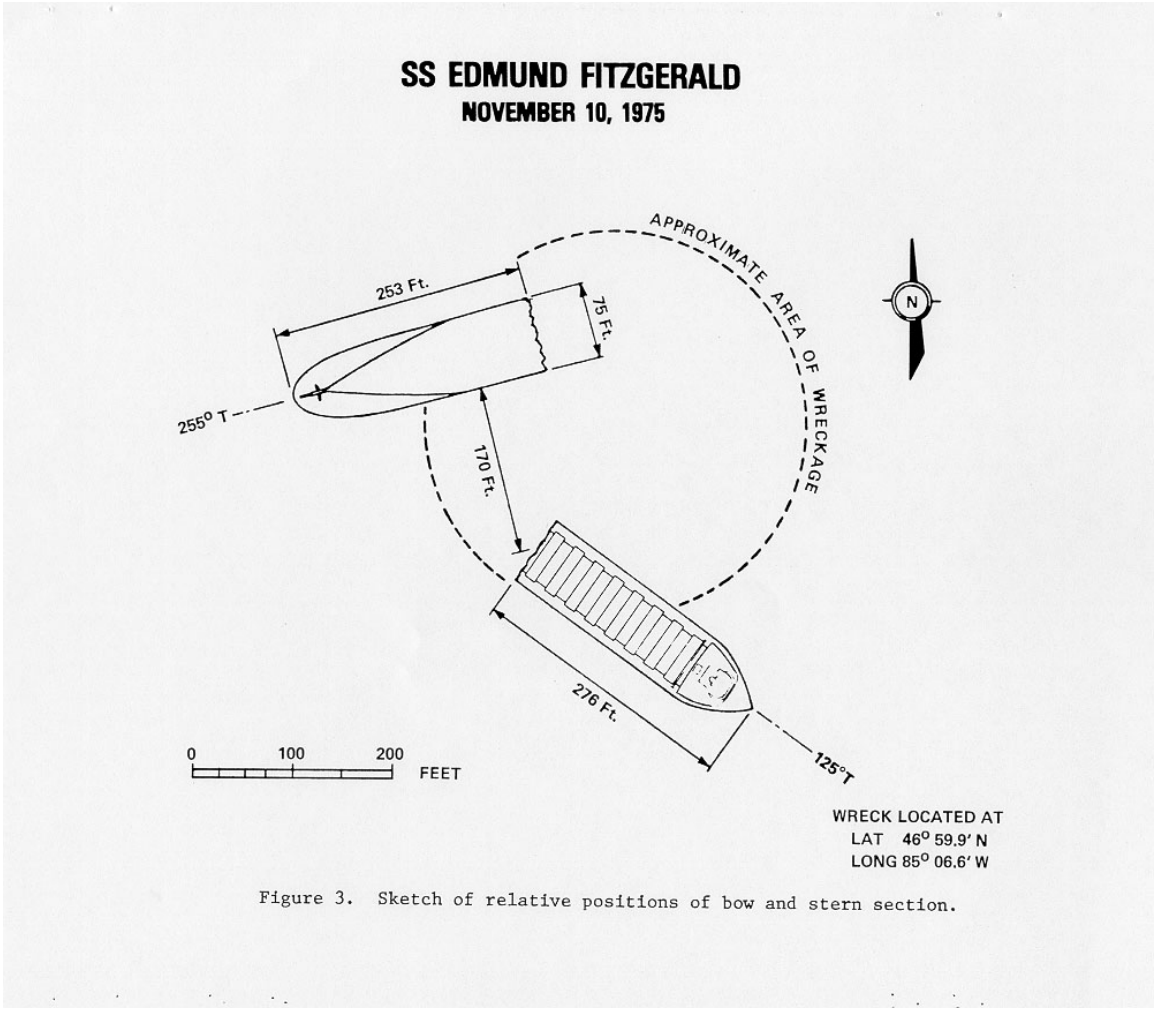

Figure 3. Sketch of relative positions of bow and stern section.

Figure 4: Sketch of bow section from starboard

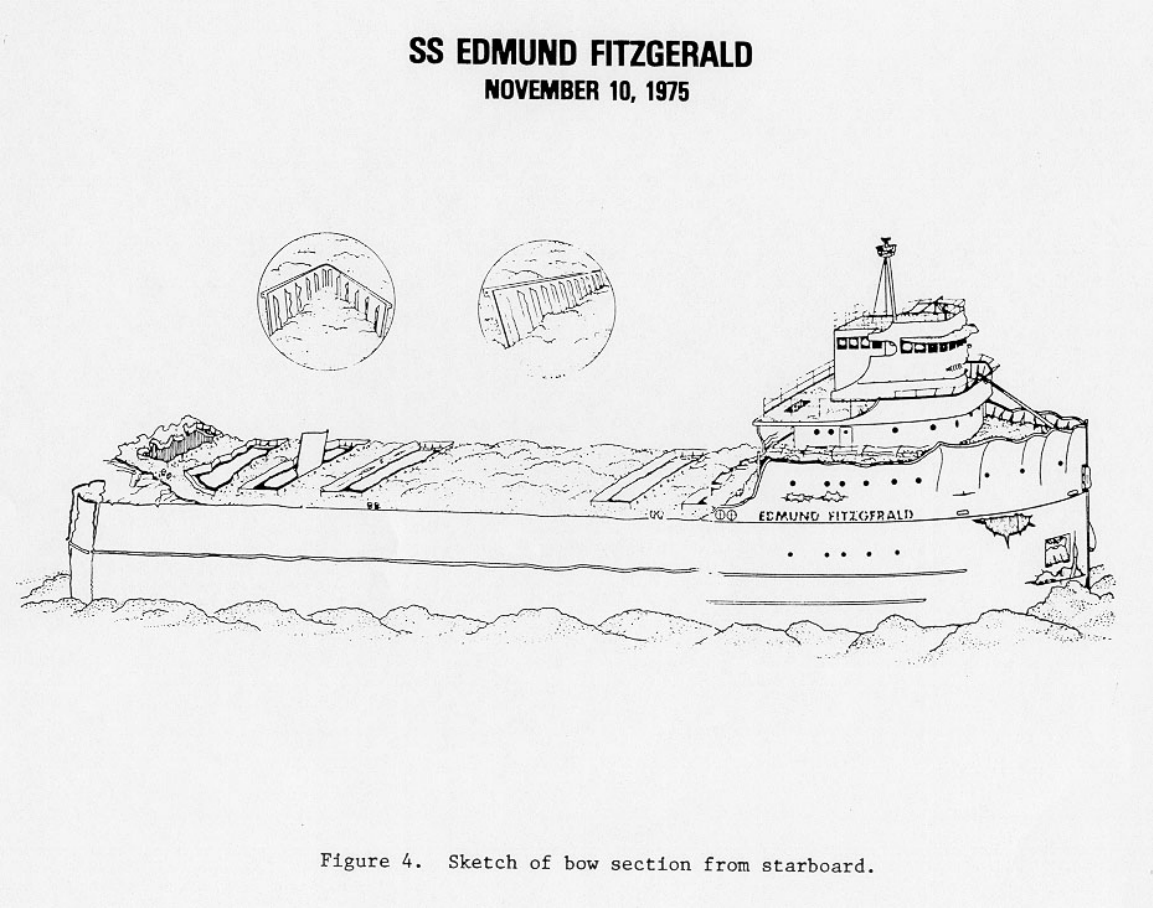

Figure 4. Sketch of bow section from starboard.

Figure 5: Sketch of bow section from ahead

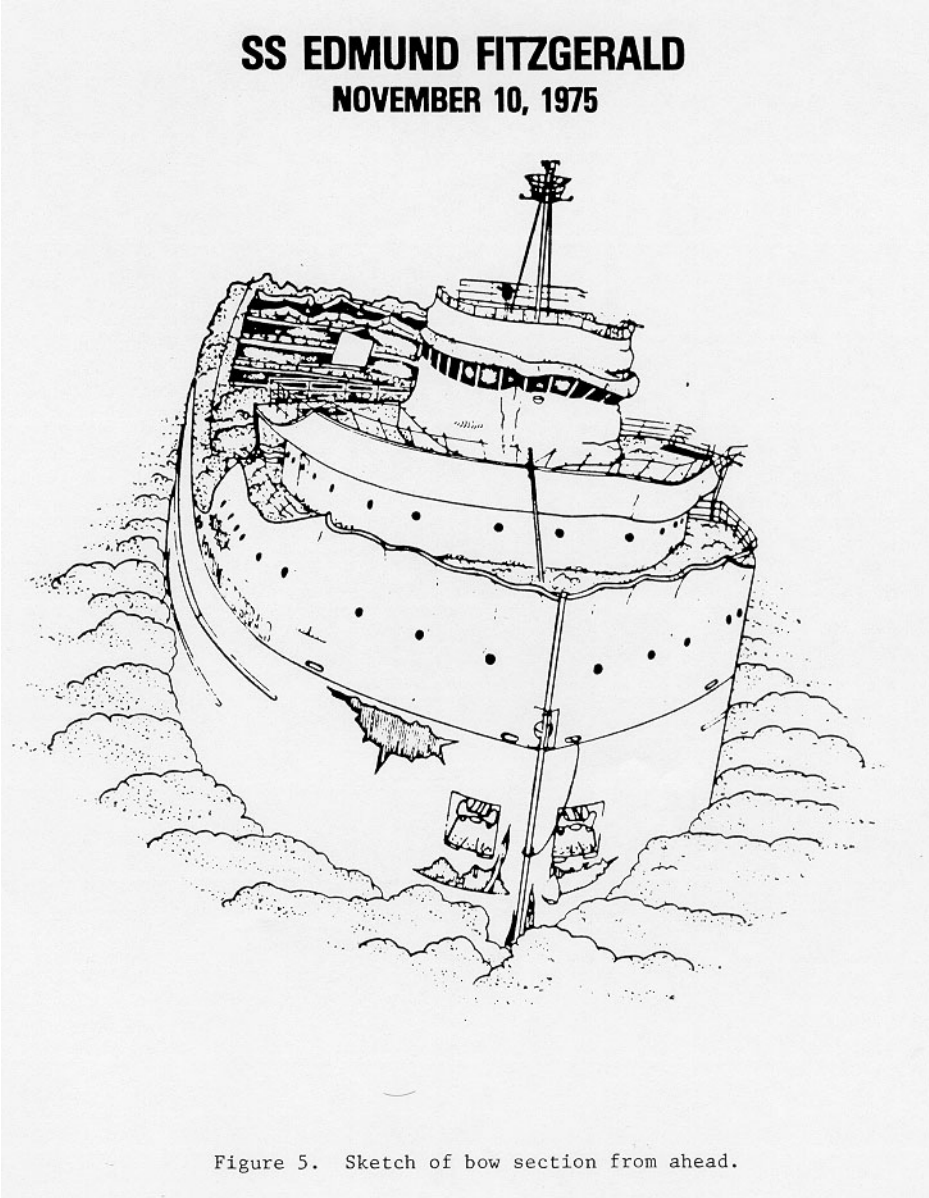

Figure 5. Sketch of bow section from ahead.

Figure 6: Sketch of bow section from astern

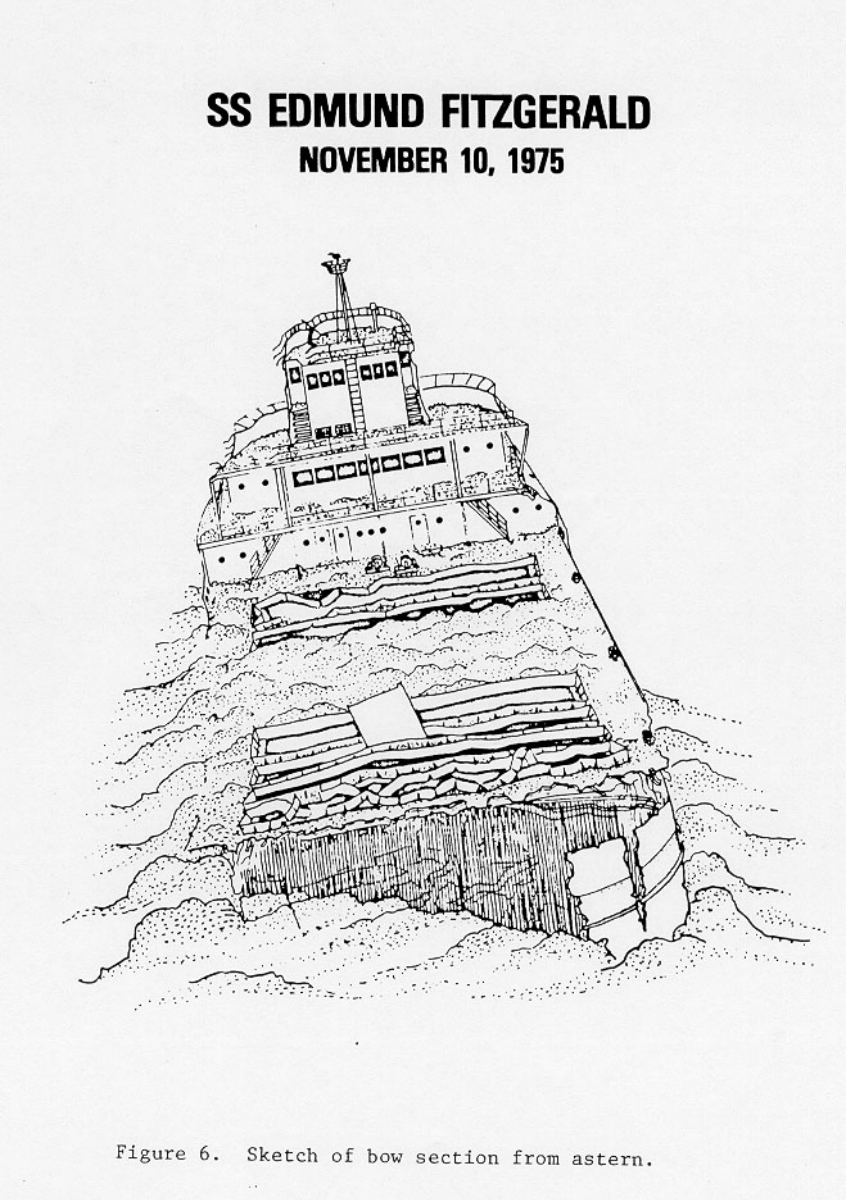

Figure 6. Sketch of bow section from astern.

Figure 7: Sketch of stern section from ahead

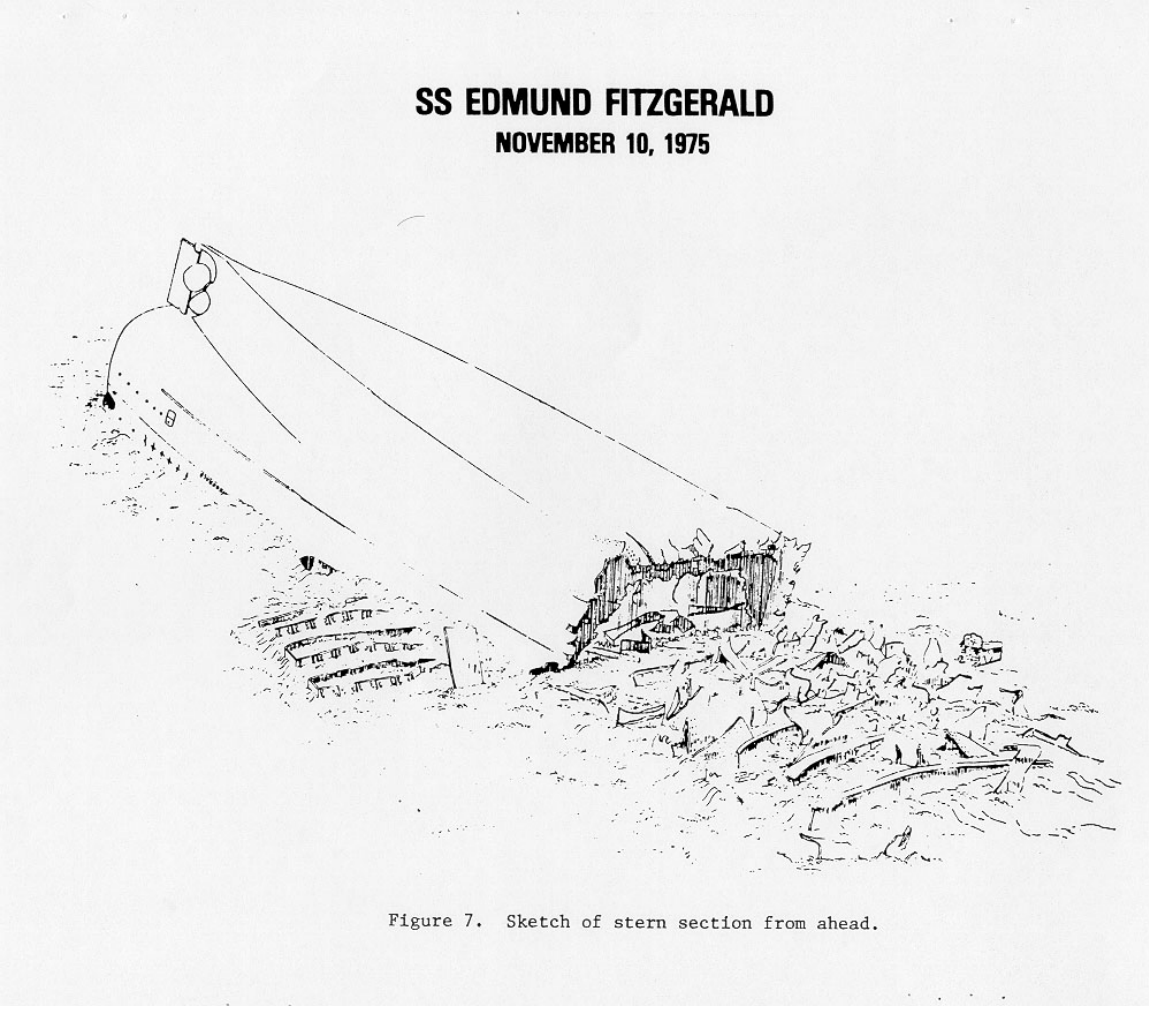

Figure 7. Sketch of stern section from ahead.

Figure 8: Sketch of stern section from astern

Figure 8. Sketch of stern section from astern.