National Transportation Safety Board

Office of Marine Safety

Washington, D.C. 20594

Group Chairman's Factual Report

Engineering Group

Andrew J. Barberi

DCA-10-MM-017

~~March 1, 2012~~March 1, 2012

Brian Curtis

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1. ACCIDENT INFORMATION

Vessels:	Andrew J. Barberi
Accident Number:	DCA-10-MM-017
Date:	5/8/2010
Time:	09:18:33 Eastern daylight time
Location:	New York City Staten Island Ferry Service
Complement:	18 crew, 244 passengers, 2 NYC police officers, 2 concessionaires- 266 on board

2. ENGINEERING GROUP

Chairman	Brian Curtis Office of Marine Safety Washington, DC 20594
Member- NYC DOT Staten Island Ferry	Bobby Scamell Deputy Director of Maintenance Staten Island, New York
Member – U.S. Coast Guard	Roger Mulford Marine Inspector Sector New York Staten Island, New York
Member - Voith Turbo, Inc.	Lee Erdman Marine Systems Product Manager York, Pennsylvania

3. SUMMARY

On Saturday, May 8, 2010, at 0902 local time, the passenger ferry Andrew J. Barberi departed Slip #1 at Whitehall Ferry Terminal, New York, with 18 crewmembers, 2 NY Police Officers, 2 concessionaires, and 244 passengers for its regularly scheduled 0900 voyage to St. George's Ferry Terminal, Staten Island, New York, on an established route. At the time, there was an ebb tide and the weather was partly cloudy, with light variable winds and good visibility. At 09:18:33, the vessel allided with the boarding apron and transition bridge on Slip #5 of St. George's Ferry Terminal. 48 people received minor injuries, and both the vessel and the terminal sustained damage.

4. DETAILS OF INVESTIGATION

4.1. Launch And On-Scene Investigation.

The Safety Board learned of the accident from the NYC Office of Emergency Management on the afternoon of May 8th. An NTSB Board Member, his assistant, a public affairs officer, and a team of 5 investigators launched from Safety Board headquarters and arrived on scene later that same day. The investigation was led by the Safety Board; the parties to the investigation included the NYC Staten Island Ferry Service, the U.S. Coast Guard, and Voith Turbo, Inc. The on-scene portion of the investigation was completed on May 15th. Follow-on interviews of Ferry Service personnel were held through June 30, 2010.

4.2. Events Prior to Departure

The chief engineer boarded the vessel, which was docked at the Staten Island St. George terminal's slip 3, about 0330 the morning of the accident. He began his normal routine, including starting the ship's service generator, checking the previous day's logbook for any items of concern, and warming the vessel's main engines prior to startup.[1] The engine control room (ECR) contains the Safety Management System (SMS) startup sequence checklists for crewmembers to follow in starting the plant and engines each day.[2] About 0400 the marine engineer, the only other licensed engineering officer onboard, arrived in the engine room to assist the chief engineer in preparing the plant for startup. Shortly after, the engine room's 3 other crewmembers arrived, made rounds of the plant, and prepared to get underway. A steering and propulsion verification for both of the vessel's end propulsion units was performed one day earlier prior to getting underway[3], as was customary for crews to do on the first day of the watch cycle. That verification was done in conjunction with wheelhouse personnel. No propulsion or steering problems were identified.

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[1] DeFonce interview, page 11

[2] Spadarro, page 5

[3] 20- AJB Engine Log Book April 1 to May 8.pdf

Prior to getting underway that morning, the vessel's crew conducted a fire and boat drill. The engines were started without incident, the engine room was prepared to depart the dock, and propulsion and main engine speed control were transferred to the wheelhouse at about 0605.[4]

4.3. Engineering Accident Narrative

The Barberi loaded its passengers, and got underway for its first trip of the day from slip 3 about 0630. The first 2 ½ trips between the Staten Island St.George terminal and the Whitehall terminal in Manhattan were uneventful, with all engineering systems and operations normal. The oilers and the marine engineer made routine rounds of the plant and its associated equipment, with the chief engineer in the ECR monitoring the plant and propulsion equipment. The oilers would each make a round every 2 hours of the entire plant, including both end propulsion units.[5] While making rounds, the oilers indicated they would carry handheld radios so that they could communicate with the ECR from outside the space.[6] The marine engineer and one of the oilers had completed a round of the propulsion end units just prior to the allision, and noted no operational or condition abnormailities in the plant's operation or either propulsion end drive unit.

The Barberi departed Manhattan for the 5-mile, 22-minute return leg of its third roundtrip of the day at about 0900. As they made their approach to the Staten Island terminal, the chief engineer, the marine engineer, and 2 of the 3 watch oilers on watch were in the ECR. The ECR received a call from the wheelhouse as the Barberi passed the harbor's "KV buoy" located about 1000 yards from the slip. This call from the wheelhouse was performed as a matter of routine to notify the engine room personnel to, according to the chief engineer, "standby for docking".

[4] 20- AJB Engine Log Book April 1 to May 8.pdf
[5] Kloke interview, page 7
[6] Kloke, page 16

The Barberi was equipped with closed circuit television (CCTV), including the ECR. Because of this feature, the engineering staff could view the progress as the vessel made its approach to the dock. Shortly after passing the KV buoy, although no alarms had sounded, the chief engineer detected a noise related to the engine load that "didn't sound normal"[7] in comparison to the normal cadence and rhythm of the engines when approaching the St. George terminal. To this point, the chief stated that it had been a "normal approach" in terms of engine speed and pitch.[8] He walked toward the Human-Machine Interface (HMI) monitor, which monitors and tracks the engines' governors load and parameters, located near the engine control panel where the engine and propulsion parameters were displayed. The CCTV screen was also located near this same control panel. As he began to survey the engine and propulsion displays, one of the oilers on a settee situated in front of the panel alerted the chief engineer to the CCTV screen. The oiler noticed that the Barberi's approach speed seemed faster than normal, and that the vessel was quickly nearing the slip.

In the brief moment he had to observe the CCTV, the chief engineer could see that the vessel had already entered the slip, and he could see the rack[9] and bridge[10] (refer to fig. 1) ahead of them, and he knew they were "going to hit … and hit hard". The chief engineer looked at the screen and, realizing a hard strike was imminent, told all those in the engine control room to brace themselves. The chief engineer told investigators that the impact consisted of 2 distinct impacts- the first with a lateral movement component, and then a final hard strike, knocking him off of his feet to the control room's deck.[11]

[7] DeFonce, page 42
[8] DeFonce, page 41
[9] The wooden structure which assists in guiding the ferry into its slip
[10] The adjustable structure to which the vessel's embarkation deck mates to allow passengers to offload to the terminal
[11] DeFonce, 15

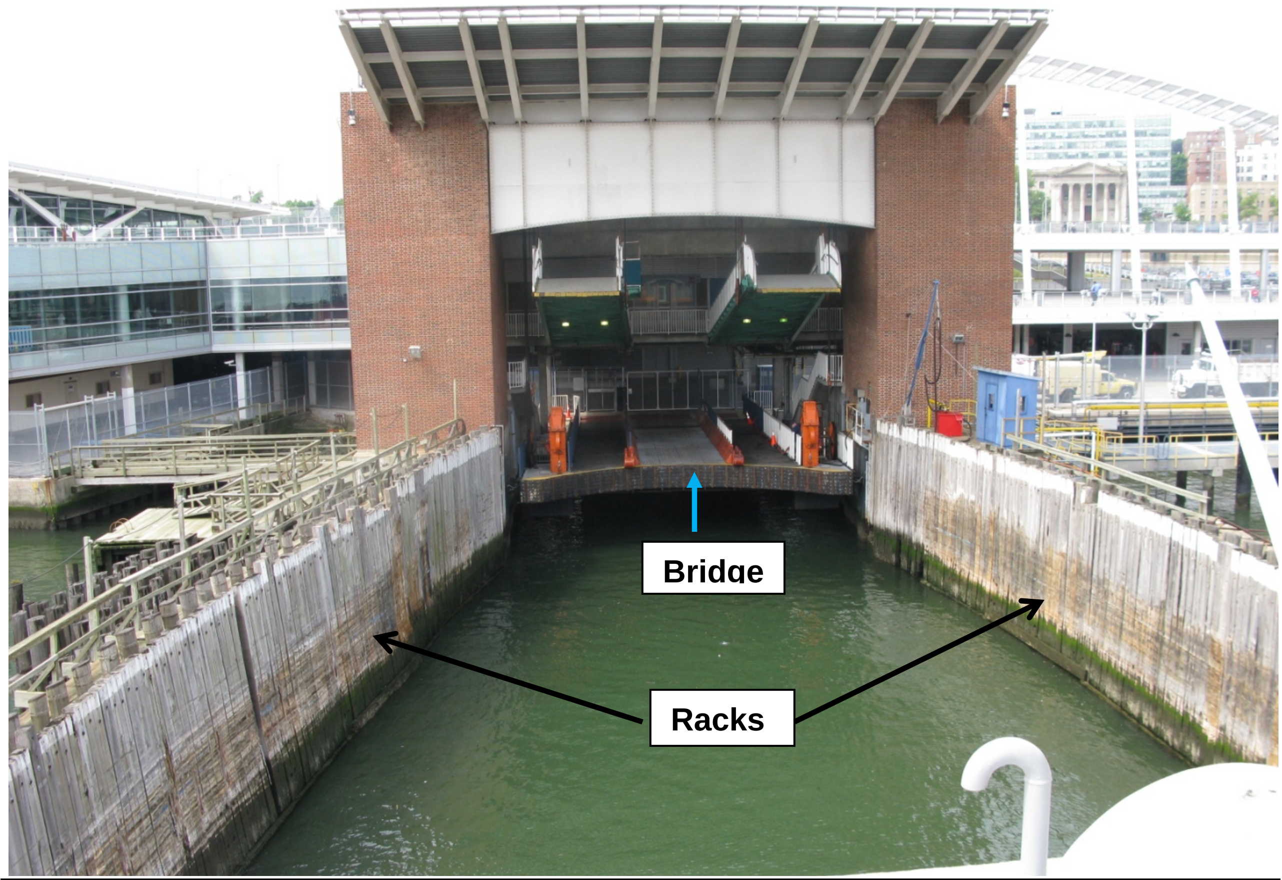

Figure 1- St. George Staten Island Ferry slip

4.4. Events Post-Accident

Immediately following the impact, and having made sure the crew was safe and without injury, the chief engineer noticed the #3 and #4 engines had stopped for unknown reasons. These engines provided rotation power to the Staten Island propulsion drive unit, the end towards the dock. The New York end propulsion unit engines, #1 and #2, were still operating properly. He quickly sent his crew to go out and get those engines restarted to restore propulsion capability to that end unit. After initially being unable to restart the engines, the chief engineer called the wheelhouse to inform them that the engineering crew were not injured, as well as of their inability to get the 2 engines refired, and that he was taking control of the engines back to the ECR. Once taking over control, the engineering crew was able to quickly refire the 2 engines, and the chief once again called the wheelhouse, and returned the engine speed control back to them.[12] The diesel-driven generator supplying electrical power for lights and all onboard equipment never stopped or failed to supply electrical power to all the vessel's operational and lighting circuits throughout the event.

Having restarted the 2 stalled engines, the chief engineer next turned his attention to assessing vessel damage from having struck the dock. He tasked one of the 3 oilers to check the engine room bilge levels, another to go about the vessel, sounding all tanks, and report back with those sounds, and the third oiler to go about the vessel and check for any breaches and/or seawater entry. He had his marine engineer, after having restarted the 2 engines, maintain checks on the plant in general. The only damage reported back to the engineers was that in the forward propulsion space, with no hull breaches below the waterline.

At that point, a Staten Island Ferry employee that was employed as a chief engineer on this same class vessel, and happened to be riding the ferry, came to the ECR, offering to relieve the chief engineer, allowing him to do his own assessment about the vessel. At about this same time shoreside emergency personnel began arriving in the engine room.[13]

The chief engineer first went to both ends to assess any damages, and identified the hull and deck above had been breached in the Staten Island end propulsion unit space. By this time, there were many of SIF's management team, as well as shoreside emergency response personnel on the vessel.

The chief continued his walk about the vessel by visiting the wheelhouses. When he arrived in the Staten Island wheelhouse, the wheelhouse which had been controlling the vessel and propulsion systems at the time of the allision, he checked the forward/aft thust control levers for both end propulsion units. The operator command levers were positioned in neutral, or effectively at zero thrust. The chief engineer then looked at the meters indicating the actual

[12] Defonce intervierw, pages 16-17
[13] DeFonce interview, page 18

applied thrust at the time for both end units. He noticed that the Staten Island end propulsion unit was at zero ahead pitch, but the New York end propulsion unit meter was still indicating it was thrusting 50% ahead. The #1 and #2 main engines were still running at this time. To verify whether or not the meter was reading correctly, he then walked down to the New York end, looked over the vessel's stern, and could see that the New York end propulsion unit was in fact still thrusting ahead as evidenced by the water it was pushing, even though the wheelhouse command lever was positioned at zero and calling for no thrust. At this time, now nearly noon, the Deputy Director of Maintenance came aboard, met the chief, and was told of the chief's findings. The deputy then went to the engine room, called the wheelhouse, and transferred the ship's propulsion back to ECR control, and successfully brought both end thrust components to zero.

The crew, under the supervision of Coast Guard inspectors, moved the *Andrew J. Barberi* to a maintenance slip after the passengers had disembarked and had insured the vessel wasn't taking on any water from hull damage. The propulsion control remained in engine room control, and only the New York end propulsion unit was used to back it from the slip. Once out of the slip, the propulsion was secured, and tugs were used to move and secure the Barberi to the maintenance pier. While being controlled by the engine room station, the NY end propulsion unit performed and responded without any problems being observed.[14]

At the maintenance pier, the *Andrew J. Barberi* crew and Coast Guard inspectors conducted a dockside operational check of the propulsion units, confirming that the New York-end propulsion unit was not responding properly to pilothouse commands.

4.5. Post-accident testing

[14] Scamell 5-10-10 interview, page 13

4.5.1. Onboard post-Accident testing of propulsion system

On May 10, NTSB investigators—with assistance from Voith Turbo, the NYC DOT Ferry Division, the Coast Guard, and a technical service representative familiar with the configuration of the propulsion control system (the engineering group)—tested the two pilothouses' ability to control the pitch of the vessel's propeller blades. These tests were conducted without running the engines and without producing actual thrust. Instead, the engineering group used the propulsion units' electric standby oil pumps to drive the hydraulic controls and change the propeller pitch. From the Staten Island-end pilothouse, the engineering group commanded full forward pitch of both end propulsion units (which, if the engines were running, would create full ahead thrust). Both propulsion units responded properly by positioning the pitch of the propeller blades at 75 percent ahead thrust, the maximum attainable percentage while powering the system with the electric standby pumps. The engineering group verified the blade pitch on the propulsion units and then compared it to the pitch response shown on the propeller pitch indicators in the pilothouse; doing so confirmed that the propeller pitch indicators were accurate. The engineering group then commanded both propulsion units to return to zero pitch position (no ahead or astern thrust). The Staten Island-end unit responded properly; however, the New York-end unit remained stuck at 75 percent ahead thrust. The engineering group then transferred control of both propulsion units to the ECR, and when the command for zero pitch was given from there, the propeller blades on both of the propulsion units returned to zero pitch as commanded.

The engineering group was thus able to replicate and confirm the New York-end unit's "sticking" problem: After ahead thrust was applied and the control levers brought to zero, the New York-end propulsion unit failed to return to zero pitch. This same anomaly existed when tested from both the Staten Island- and New York-end pilothouses. When ahead/astern thrust was commanded from the ECR, the New York-end propulsion unit responded normally.

The 24 volt direct current (dc) electrical signals from each of the wheelhouses was checked for proper continuity and voltage, and found to be in good order between the wheelhouse control levers and the terminations at the propulsion unit control panels.

The engineering group then proceeded to focus their efforts on the NY end propulsion control panel. The purpose of the panel is to transform the bridge's electrical signal to a hydraulic oil flow output using electro-hydraulic solenoid valves to control the hydraulic circuit flow. The control panel is pictured in figure 5 in section "4.7.5 Propulsion" of this report with an explanation of the control panel's operation. The panel contains 2 electro-hydraulic solenoid valves, the one situated to the left as you face the panel which controlled the forward/astern thrust component, and one on the right side of the panel to control the port and starboard thrust component. The incoming electrical signal from both wheelhouses to both solenoid valve connections was tested, and found to be proper.

Seeing that the wheelhouse signals were being satisfactorily transmitted, and having previously confirmed that the propulsion unit itself was responding properly to command signals from the engine room control station, it was decided to remove the entire NY end propulsion control panel with its oil filters, and return it to the NTSB materials laboratory at headquarters for further examination. At the time of the accident, the right oil filter was online and in service. It was further determined from crew and engineering staff interviews and a review of maintenance records that no evidence existed of the left filter ever having been in service, or the cartridge in the right side filter ever having been changed.

Once the operational testing of the equipment in service at the time of the accident was completed, both end propulsion control panels were removed and replaced with entire new control panels. On May 13th, once the replacement of the control panels was complete, the engineering group tested both end propulsion units for wheelhouse command response, and both ends performed satisfactorily. The other vessel in the Barberi class, the *Samuel I. Newhouse*, had already had its propulsion control panels replaced during its previous shipyard.[15]

Following the operational testing, the engineering group took oil samples from various points in the NY end propulsion unit for further evaluation as well, in the event that contaminated oil may have been at fault for the improper operation of the unit. Samples taken were:

- A clean sample of unused Shell Omala 150, the same as used in the control and operation of the NY end propulsion unit.
- A sample from the NY end propulsion drive sump, which supplies oil to the control panel through its oil filters
- A sample from each of the 2 oil filters cartridges on the control panel.

The samples were sent out for independent lab testing. The sample results were scored on a 0 to 4 scale, 0-1 being normal, and 4 being critical. The results of the samples from the NY end sump and the right side control panel oil filter, the 2 system components that were in-service at the time of the accident, both returned with registered results of a score of 1, or "normal". For further detail of the independent lab reports and testing results, see "Material Lab Factual Report number 11-063".

4.5.2. History of Barberi class propulsion control board solenoid valves

The maintenance history for the Barberi's propulsion system was downloaded and reviewed for the period between July 30, 2007 and the accident, and there was no record found of maintenance, either preventive or reactive, had been performed on the propulsion control solenoid valves during that period.

The engine room logbooks for the period April 1, 2009 through the accident date were also reviewed, and no propulsion-related anomalies or failures were discovered.

[15] Scamell 5-10-10 interview, page 4, line 22

In an interview with the senior port engineer for the Staten Island Ferries, he stated that the propulsion control boards and solenoid valves were currently being replaced on the Newhouse and Barberi to upgrade the systems, but not because they had encountered problems with the system. A review of maintenance records and engine logbooks by investigators confirmed that no mention existed of propulsion control problems that would have initiated plans to replace the control boards and solenoids. In the Deputy Director of Maintenance's interview, who had held that position for approximately 6 months at the time of the accident, he stated that he had never seen a propulsion control solenoid valve having been replaced in his 15 years with the company.

Investigators spoke with the solenoid valve manufacturer's product management specialist familiar with the solenoid valve, who indicated that this type solenoid is very popular, and used in thousands of applications. He further indicated that the design limit for cycles of this valve is 20 million.

4.5.3. Materials Lab testing of propulsion control components

The NTSB Materials Lab work included: 1) sending the aforementioned oil samples out for independent testing, and; 2) conducting a physical examination of the NY end propulsion unit pitch control panel. For discussion and details of the lab's examination results, refer to "Material Lab Factual Report number 11-063". The following is a bulleted summary of the findings from the lab's examination of the control board's components:

-The control board contained 2 electro-hydraulic solenoid control valves to alter the propulsion units propeller blade pitch- 1 solenoid valve to control the ahead/astern propulsion blade pitch component, and 1 to control the port and starboard steering control component.

-Both solenoid valves were similar in operational design. The valves shuttled between three positions but normally resided in a neutral state in which no oil flowed through the system. The motion of each valve was controlled by two electrically-actuated solenoids, one on each end of the valve. Each solenoid contained an internal bronze ring.

-Both of these solenoid valves were similar in operational design, both containing 2 internal bronze rings, one at each end, to facilitate the solenoid valves' operation

-. The bronze rings inside each propulsion valve solenoid were designed with six narrow tabs evenly spaced around the ring. The bronze rings inside each steering valve solenoid were designed with three wide tabs evenly spaced around the ring.

- -The 2 bronze rings in the propulsion solenoid valve were both found broken, with the ring debris located within the valve's body
- -The 2 bronze rings in the steering valve were found fully intact
- -The right oil filter (online at the time of the accident) was examined and found to contain no perforations to damage to the inner cartridge through which the oil passes in the hydraulic circuit.

4.6. Crew Information

4.6.1. Engineering crew makeup

The engineering crew consisted of 5 people: one licensed chief engineer, one licensed assistant marine engineer, and 3 unlicensed oilers. 2 oilers had worked for the ferry service since 2005, and the third oiler had been with them since 2007. The Barberi's Certificate of Inspection (COI) called for the engineering complement to be at a minimum one chief engineer, one other licensed engineer, and 2 oilers.

4.6.2. Chief Engineer

The chief engineer was 43 years old, and a 1988 graduate of the United States Merchant Marine Academy in Kings Point, New York. Since his graduation, he had worked both as an engineering officer on vessels for various companies, as well as having worked 10 years from 1996 to 2006 in a shoreside fleet management position for Marine Transport Lines out of Weehawken, New Jersey.

He held a current United States Coast Guard license as a Chief Engineer of motor vessels (diesel), unlimited horsepower, with a restriction to near coastal waters (out to 200 miles). He also held a United States Coast Guard license as a First Engineer of motor vessels, unlimited horsepower, and as a Third Engineer of steam vessels, unlimited horsepower.

He began working for the Staten Island Ferry service in February of 2006, and had worked on most of its vessels as engineer. At the time of the accident, he had been assigned as a permanent chief engineer to the Barberi for about 3 months. His schedule consisted of working Friday through Mondays. Friday's and Sunday's his hours were 0700 until 1500. On Saturday, he would work from 0630 until1430, and Monday's he would work from 1400 to 0200.

He provided the following information when asked about his 72 hour sleep/work cycle:

Wed. (May 5)- 1500-0300, working
Thur. (May 6)- 0400-0900, sleep
0900-2000, home off work
2000, sleep
Fri. (May 7)- 0315, awake
0500-1530, working
1700-1930, home off work
1930, sleep
Sat. (May 8)- 0315, awake, to work

4.6.3. Marine Engineer

The marine engineer, the chief's assistant was 61 years old, and held a US Coast Guard third assistant engineer's unlimited horsepower motor license. He had worked in the marine industry nearly his entire life, including working on US Navy destroyers during the Vietnam war.

He started working with the Staten Island Ferry service in 1979 as an oiler, and began as an engineer on the vessels in 1985, and had worked on most of the service's vessels.

He worked the same schedule as the chief engineer, that being Friday through Monday.

He indicated he had a lot of experience working on the Barberi class of vessels, having worked on them since they came out in 1981. When asked if he considered the propulsion system on the Barberi as robust, he replied: "bulletproof".[16]

[16] Hild interview, page 31

He provided the following information when asked about his 72 hour sleep/work cycle:

Wed. (May 5)- 1100-2200, at home
2200- to sleep
Thur. (May 6)- 0700, awake
0700-2230, home off work
2230, to sleep
Fri. (May 7)- 0300, awake
0500-1730, working
1730-2000, home off work
2030, sleep
Sat. (May 8)- 0400, awake, to work

4.7. Vessels Description

4.7.1. General

At the time of the accident, the NYCDOT Staten Island Ferry Service fleet was comprised of a total of 9 vessels in 4 different classes of ferryboats: the Kennedy, Molinari, Barberi, and Austen classes. The vessel involved in this accident, the Andrew J. Barberi, is a member of the Barberi class of vessel.[17]

Equitable Shipyards, Inc., in New Orleans, Louisiana, built the Andrew J. Barberi in 1981. It was the first vessel constructed in its class. Its design capacity is 6,000 passengers. It is a welded steel, double-ended vessel. It has a displacement of 2721 long tons, is 310 feet in length, 70 feet in breadth, and has a design draft of 12' 6".

4.7.2. Hull

The hull is all welded construction, transversely framed on 30-inch centers, and subdivided by watertight bulkheads to provide end ballast tanks, voids, propulsion gear rooms, and machinery spaces. The hull is symmetrical about the midships transverse section; frame numbers are

[17] Scamell 5-10-10 interview, page 21

designated such that Frame 0 is located at midships, and extending out to frame 58 in either direction.

There are 10 watertight compartments. The engine room, containing the bulk of all main and auxiliary machinery, is located amidships between frame 12 NY end (NYE) and frame 12 of the Staten Island end (SIE). The 4 main engines and auxiliary equipment are located in this space. Also installed in this same space are the engine control room (ECR), auxiliary boilers, and the vessel's electrical generators.

Next to these spaces are voids between frames 12 and 20 on both ends. On the NYE, this void contains the crew locker rooms, sewage treatment plant, and CO2 bottle room. On the SIE, this void contains diesel oil storage and service tanks. At both ends between frames 20 and 31 are voids as well. In the NYE this void is a potable water tank. Between frames 31 and 40, there are void spaces as well at both ends.

The next compartment on both ends, from frames 39 to 52, form the propulsion gear spaces. These spaces contain the pumps, controls, and reduction gears to drive the cycloidal propellers.

The spaces from frames 52 to both ends form ballast tanks; below the ballast tanks at each end there is a fixed, plated steel skeg which protects the cycloidal propeller from impacts with debris as well as improves directional stability and provides structural support for when the vessel is drydocked.

Between frames 12 and 40 at each end is a shaft tunnel, containing 2 propulsion line shafts and 12 line shaft bearings.

4.7.3. Superstructure

There are 3 decks for passenger use and one open deck restricted to use by the crew. Embarkation is at 2 levels, the main deck and upper embarkation level. Ramps are provided between bridge deck and upper embarkation levels, and stairs are provided between the upper embarkation level and saloon deck, and between the saloon deck and main deck.

The enclosed portion of the main deck seats 1630 passengers and has an open boarding area at each end protected by the upper embarkation level above. Seating is arranged with longitudinal seats on centerline and on the outboard sides, with the remaining space being occupied by groupings of transverse seats. Four large hinged doors open the cabin to the boarding space at each end. Enclosed stairwells forward and aft lead up to the saloon deck.

The saloon deck is completely enclosed and has seating accommodations for 1258 passengers. Seating is arranged similar to the main deck. Enclosed stairs lead from the saloon deck to the upper embarkation levels; ramps lead from the upper embarkation levels to the bridge deck.

The bridge deck is divided by 2 longitudinal bulkheads to provide a convertible promenade area to the port and starboard of the enclosed center. This deck has longitudinal seating on the centerline and on the outboard side of the interior longitudinal bulkheads. The bridge deck seats 784 passengers.

The wheelhouses and stack are located on the Hurricane deck. The stacks provide space for the engine casing and passenger space ventilation fans.

4.7.4. Vessel particulars

Vessel Name	**Andrew J. Barberi**
Owner/Operator	NYC DOT Staten Island Ferry Service
Port of Registry	New York City
Flag	US
Type	Ferry vessel
Built	1981
Official number	629314
Classification society	American Bureau of Shipping (ABS)

Construction	Steel
Draft	12' 6"
Length	310'
Beam	70'
Gross tonnage	3335
Engine power and type	4- General Motors EMD 16-645E6 (1750 HP each)
Persons on board	266
Injuries/fatalities	None
Damage cost	Vessel- $168,625 Terminal- $13,613

4.7.5. Propulsion

The Andrew J. Barberi is equipped with 2 cycloidal propeller systems, one at each end, rated at 3500 horsepower each. The cycloidal propulsion units installed on the Barberi class are the only 4 units of this size. The propellers provide virtually equal thrust in any direction. For this reason, the cycloidal propellers are used to accomplish both propulsion and steering of the vessel. Cycloidal propulsion is a unique system allowing quick and precise direction and speed control of the vessel. Fig. 2 is a photo of the propeller on the Andrew J. Barberi. The vessel's control system is such that the magnitude and direction of thrust of each propeller is separately and manually controlled. Each of the 2 wheelhouses can control both propellers. An automatic control system maintains the speed of the main engines at approximately 750 RPM when the vessel is underway and prevents any of the manual commands to the cycloidal propellers from overloading the engines. The propellers themselves turn at approximately 55-60 RPM when the engines are running at full speed, as the reduction ratio of the gearing between the main engines and the propellers is 13.7:1.

Since the vessels came into service in 1981, maintenance and inspection of the Barberi class propulsion units and related control system components has been coordinated by NYCDOT Ferry Division personnel under the supervision of vendors. This includes both shipyard periods and periodic maintenance performed outside of shipyard periods. During all the shipyard periods for the Barberi class vessels, a manufacturer's representative was brought in to conduct inspections and maintenance of the cycloidal propulsion units.

During the 2009 shipyard period, NYCDOT Ferry Service contracted for Governor Control Systems to check the propulsion units control systems prior to the vessel going back into service. The report from that service visit indicated that the sea trial was completed with no problems and the system operated as designed.

Two main engines are coupled to each end's cycloidal propeller through a hydraulic coupling and a length of line shafting. Two main engines drive the NY end propeller, while the other two main engines drive the Staten Island end propeller. Draining a hydraulic coupling permits declutching its associated engine thereby driving its associated cycloidal propeller using a single engine when required. The propellers each have an right angle reduction gear, as the axis of the propeller rotor is vertical.

Figure 2- Andrew J. Barberi cycloildal propulsion unit controls

Both forward and aft propulsion systems can be controlled from any of 3 stations- the engine control room, or either of the 2 wheelhouses. To gain wheelhouse control, it must be transferred from the engine control room to either of the 2 wheelhouses. From this point on, control can be transferred back and forth between the 2 end wheelhouses. To accomplish the transfer of control from one station to the other takes 2 individuals, one in the sending station, and one person in the receiving station. The person in the sending station presses a transfer button. They notify the individual in the receiving station that this task has been accomplished, at which time the person receiving control presses an “accept” button in his station to complete the transfer operation. Figures 3 is a photo of the engine control room propulsion control station, and figure 4 is a photo of a wheelhouse control station located on each bridge.

Figure 3- Engine Control Room propulsion control station

Figure 4- Wheelhouse propulsion control station

Control of the propulsion propeller pitch is accomplished via a 24 volt direct current electrical signal being transmitted from the controlling wheelhouse control station lever and handwheels to the propulsion unit hydraulic control panel (See figure 5) located in the propulsion end unit.

The control panel in figure 5 effects propeller blade pitch by the following method. There is one control panel for each end propulsion unit. Pressurized oil is pumped from the propulsion unit's sump first through the control panel's oil filter. Only one of these oil filters is online at any given time, and a selector valve is used to select the online filter to allow for periodic filter cartridge change of the offline filter. After passing through the filter, the oil is then piped to the electro-hydraulic solenoid valves located over the oil filters on the panel. There are 2 of these solenoid valves on the panel, one to control the ahead propeller blade pitch thrust component, and one to control steering, or side to side component of the resultant blade pitch. The output oil pressure from these 2 solenoid valves working in tandem position the hydraulic control rams to properly pitch the propeller blades to result in the commanded direction of thrust.

When in engine room control, this signal from the wheelhouse control station is bypassed, so the engine room control station, through mechanical linkages and hardware, directly positions the hydraulic rams at the end propulsion units in their respective spaces, and subsequently positions the blades for the desired resultant pitch.

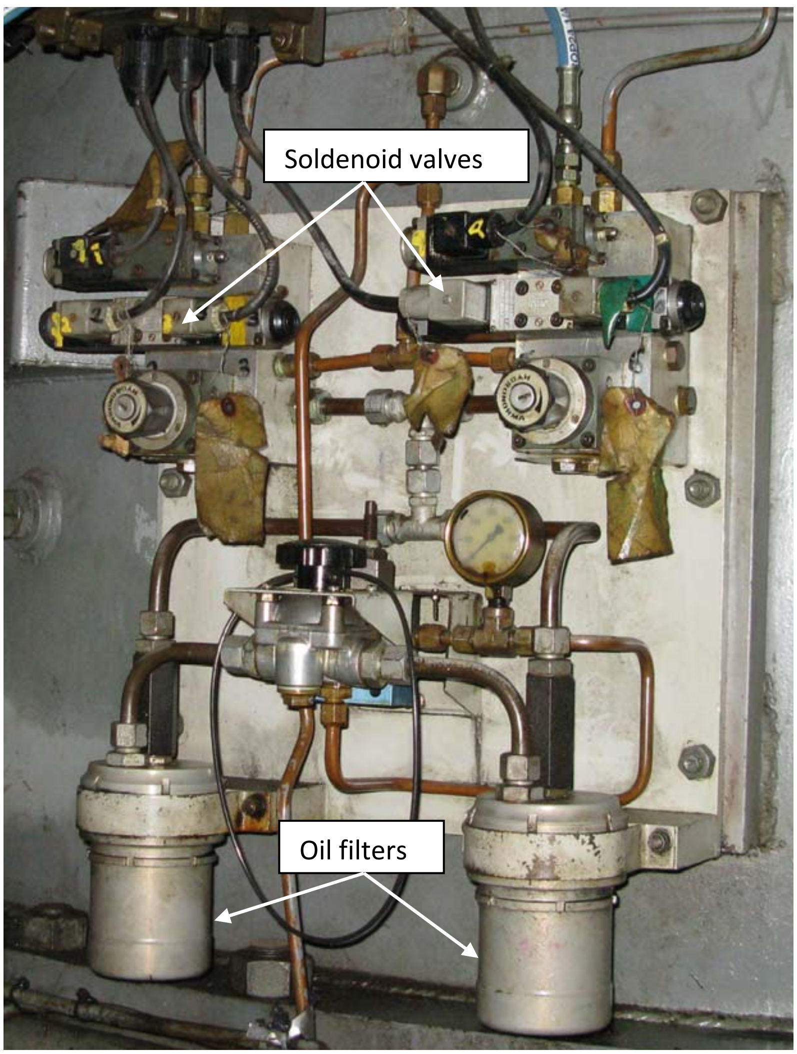

Figure 5 – Propulsion system control panel

4.7.6. Main Engines

The 4- 16-cylinder main engines are manufactured by General Motors EMD Electromotive Division. They are rated at 1750 horsepower each. Their maximum rated speed is 800 RPM, however their normal operating speed is 725-750 RPM. They are 2 cycle engines, incorporating roots blowers, started with air motors.

4.8. Damage

4.8.1. *Andrew J.* Barberi.

A representative of the American Bureau of Shipping (ABS) conducted a damage survey on May 9, 2010 following the Barberi's allision with the dock to ascertain damages and necessary repairs to the Barberi. [18]

Because the *Andrew J. Barberi* is a non-conventional double-ended vessel symmetrical from midships toward each end of the vessel and the damage occurred at the Staten Island end of the vessel, the following text refers to the Staten Island end and its port and starboard sides in reference to that end of the vessel.

Damage to the vessel was generally sustained symmetrically to the port and starboard sides from the point where it impacted the dock's rack pilings on both sides from frames 48 to the vessel's end. Damage to the port and starboard side, respectively, are shown in Figure 6 and 7. Damage to both the vessel's sides involved the hull being breached in that end's space containing the cycloid propulsion unit. All damage was contained to above the vessel's waterline, and in the confines of the frames of the propulsion space.

The damage to both sides included:

[18] ABS Damage Survey- 5-9-2010

1) deformation and tearing to the the port and starboard main deck plating above the propulsion space,
2) “ “ “ to the port and starboard bulwark[19] betweens frames 48 and 54,
3) main deck mooring chock on the port side was displaced,
4) the watertight bulkhead port and starboard was buckled,
5) transverse web frames at frames 51 and 53 were deformed,
6) port and starboard rub rails were torn and/or deformed.[20]

The hull breaches port and starboard occurred at the rub rail level.

Damage was also identified at the bridge deck level port and starboard of the wheelhouse. This damage resulted from the vessel having struck the retracted ramps that would typically be lowered into position once the vessel was docked to allow passenger disembarkation. On the starboard side, the manhole leading into the battery void below sustained damage. On the port side of the wheelhouse over this same battery void, damage was observed to the manhole cover, as well as a vent tube being broken off, and a natural exhaust trunk broken free from its mount. This damage was essentially considered to be cosmetic in nature.

The repairs were completed, the ferry service conducted a sea trial with Coast Guard and American Bureau of Shipping inspectors onboard, and the vessel returned to service on June 23, 2010. The cost to repair the Barberi was $168, 625[21], according to SIF officials.

A local dive company performed an underwater hull survey the day following the allision, and found no anomalies or hull damage below the water's surface[22]. A video examination was also performed on the propulsion blading that same day by the propulsion systems manufacturer, and found no damage to either end's underwater propulsion components.

[19] Bulwark is a vertical outside bulkhead above the main deck
[20] SIFSteel work repairs- 6-8-10
[21] Email of damage costs for Staten Island Ferry Service dated 7-19-2011
[22] Randive Underwater Survey Report- 5-9-10

Figure 6- Damage to vessel's port side

Figure 7- Damage to vessel's starboard side

4.8.2. *Terminal*

The Staten Island Ferry Service shoreside terminal #5 slip where the allision occurred sustained damage to its steel ladders and walkways. The transition bridge, which the ferry connects to upon its arrival at the slip (figure 1), was pushed forward and displaced upon impact, but sustained no damage. The bridge is designed to absorb impact forces and be displaced in the event of a hard landing such as the allision. In the days following the accident, the bridge was rigged back into place, and ladder and walkway steel damage was repaired. The cost to repair the slip was $13,613.

4.9. <u>Other information</u>

4.9.1. Safety Management System (SMS)

The International Maritime Organizations (IMO) requires the implementation of a Safety Management System (SMS) on all vessels engaged in international voyages for those countries that are signatory to the IMO's conventions. Although not required by code, because the Staten Island Ferry service does not engage in international voyages, the SMS was created and instituted at the ferry service as a result of an NTSB recommendation resulting from the 2003 Andrew J. Barberi dock allision. The SMS received its full certification, its Document of Compliance, in October of 2005[23].

4.9.1.1. Critical Equipment

Section 10.3 of the International Safety Management (ISM) Code calls for companies to "identify equipment and technical systems the sudden operational failure of which may results in hazardous situations" on their vessels. Each vessel in the ferry services' fleet had its own individual critical equipment list. The ferry service had in fact, in form 31-B of their SMS, listed all those Barberi systems and equipment pieces, to which they referred to as "critical equipment".[24] The list of critical equipment included all 4 of the Barberi's main engines, its 2 cycloidal propulsion units (1 at each vessel end), and the controls for the propulsion units. The critical equipment also included other engine room equipment such as fire and bilge pumps, emergency generators, and main engine start air compressors.

4.9.1.2. Engineering maintenance procedures

Section 10.1 of the ISM Code requires a company to ensure it's equipment is maintained in conformity with the relevant rules and regulations. The ferry service had a system whereby the work performed on each piece of the vessel's engineering equipment was tracked by a preventive maintenance (PM) program. The system had established PM maintenance procedures, called work orders, for each piece of equipment, including the procedure to conduct the maintenance, and the frequency at which the maintenance should be conducted (daily, weekly, monthly, etc.). The company employed "planned maintenance coordinators" to maintain and track its vessel equipment maintenance within its program, and to identify any maintenance

[23] 6-10-10 interview, page 21
[24] Appendix A- SMS FORM-31B, Barberi Class Critical Equipment List

items that were outstanding or overdue. The system tracked both preventive and corrective maintenance for all the equipment, and was capable of tracking Key Performance Indicators (KPI's) used in measuring and benchmarking performance areas related to the completion of preventive and corrective maintenance work on the vessels.

During the onscene investigation, questions arose regarding the frequency of oil filter cartridge changes for the propulsion control panel oil filters. These were duplex filters where one filter was online at any given time, and a selector valve was located on the panel to allow the operator to isolate one filter while maintenance could be performed on the offline filter. Engineering crew and staff were interviewed regarding the maintenance of these filters, and maintenance logs were reviewed, but no evidence could be found to indicate that these filters had ever been changed. Upon further investigation, it was found that no preventive maintenance procedure existed in the maintenance system to account for this maintenance item. However, a review of the manufacturer's control/maintenance instruction manual[25] acquired from the Deputy Director of Maintenance's office, recommends the propulsion control panel oil filters be changed weekly while the propeller is operating.

4.9.1.3. Engineering casualty scenarios

The ferry service' SMS also contained emergency preparedness scenario drills as required by section 8.1 and 8.2 of the ISM Code, calling for companies to identify potential emergency shipboard situations, and establishing drills and exercises to respond to them. The ferry service' SMS included 12 different emergency training scenarios, including one accounting for loss of propulsion and steering, and one addressing a vessel response to collisions and allisions.[26] Following the allision, the chief engineer sent his engineering personnel out to check for hull damage and breaches, sound all tanks, and report back to him, all in accordance with the company SMS requirements contained in the emergency response to a collision or allision.

[25] Control/Maintenance manual, VSP-06.02.03e

[26] SMS: "Emergency Procedures Manual" section, section 3.4 and 3.5.

4.9.2. Actions taken since accident

4.9.2.1. Preventive Maintenance Program modifications

During the onscene investigation, it was discovered that no preventive maintenance procedure existed for the periodic changeover and filter cartridge replacement of the propulsion system hydraulic control panel oil filters. Investigators reviewed the manufacturer's equipment instruction manual and were able to identify the recommended weekly change of the control panel oil filters. After identifying the maintenance in the manual, the Staten Island Ferry service Director of Maintenance created a recurring PM work order for both end propulsion units, as well as for the sister vessel *Samuel I. Newhouse*, based on the corresponding with the manufacturer's recommended frequency.[27] In March of 2011, having changed and inspected the control panel oil filters on a weekly based since the previous June, the PM work order was altered to change the frequency to once every 3 months due to the clean condition of the filter being changed each week, as well as from reviewing the regularly scheduled oil analysis for the unit sumps. The maintenance history records indicated all oil changes conducted as scheduled on the Barberi form June of 2010 through June of 2011.[28]

NYCDOT did quarterly sample and analyze the cycloidal propulsion sump oil. The oil sample report dated 06-May-2010 indicated the oil condition for the NY end sump as "normal".

Whereas the propulsion control panel oil filters were a component part of an SMS-identified piece of "critical equipment", investigators wanted to clarify why the oil filter changes had been overlooked and missing as a regularly schedule PM work order. In speaking to the SIF's senior port engineer, he related that to initially indentify all the PM work order procedures related to each vessel's critical equipment, a library was assembled for each vessel in the fleet containing all of its equipment maintenance manuals for each piece of equipment on board, especially its critical equipment. An outside contractor was then hired to review the manuals, and extract the

[27] 69- PM Work orders for Prop control panel oil filter change

[28] PM control panel oil change status report for 6-12-2010 through 6-17-2-11

manufacturers recommended maintenance items for each piece of equipment from its respective manual, and create a PM work order, which was then entered into the system. Once the missing PM work order for the control panel oil filter change was discovered, the maintenance personnel went back and discovered that the manual in the vessel's library did not have the control panel maintenance section included in it, as the copy investigators previously reviewed from the Deputy Director of Maintenance's office. This section was subsequently added to the vessel's library maintenance manual for the propulsion system on the Barberi.

Realizing the potential for improper or missing PM work orders for their vessels' critical equipment, SIF's Director of Engineering, in conjunction with the SIF's senior port engineer, conducted a review of the fleet's vessels critical equipment maintenance procedures in the maintenance tracking system during the summer of 2010. This was accomplished by ferry personnel comparing the maintenance manuals against the existing work orders for their equipment. Their goal going forward is to initiate a periodic maintenance effectiveness review of their PM work orders as compared to the manuals for their equipment designated as critical in their SMS. At the time of this report, the task for the effective review program is written, and SIF is in the process of getting funding and approvals to proceed.[29]

4.9.2.2. Propulsion control upgrades

Plans are currently underway to modify the 2 Barberi class vessels' propulsion operator stations from the existing handwheels for steering and levers for ahead/astern speed control to a single joystick control station manufactured by Bosch-Rexroth. This joystick control will allow 360 degree directional and 0-100% thrust magnitude control of the vessel from a single lever. Each wheelhouse will have 2 joystick controllers, one to control each end propulsion unit. The engine room controls will also be changed out to the joystick controllers. The project is being done under a contract with the propulsion system manufacturer, Voith Turbo, Inc., with Bosch-

[29] SIF Director of Engineer email to engineering group chairman dated 7-29-2011

Rexroth as a subcontractor doing the installation of the system. The system will incorporate redundant power supplies, to facilitate automatic failover in the event of failure of either of the online power supplies. The system will also utilize electric screwjack actuators to change propeller blade pitch at the propulsion end units, replacing the hydraulic control panels, thereby totally eliminating the control panel oil filters and electro-hydraulic solenoid valves currently being used. The *Andrew J. Barberi* work has been initiated, and is due to be completed during the vessel's out of service period in 2012. The *Samuel I. Newhouse*, the remaining Barberi class vessel, is scheduled to have the system installed during an out of service period to coincide with its drydocking in 2012.

4.9.2.3. Installation of propulsion pitch deviation alarm

A review of the wheelhouse CCTV image recorder transcript reveals the details of the operator's actions and the times they occurred just prior to the accident. From the transcript, it was apparent that they were not aware of the NY end propulsion system's improper response to his ahead/astern thrust commands during their approach to slip #5 that morning. Beginning at 09:16:11, the operator began introducing reduced throttle commands to slow the vessel on its approach. He gave his first SI end command to reduce forward thrust at 09:16:16. At 09:16:52 he began reducing the pitch control to both ends. Between then and the allision, the operator repeatedly reduced thrust commands to both end propellers until 09:17:45, at which time the transcripts states that both ahead/astern propulsion levers were an an astern positionAt 09:18:04, shortly before impact, both levers were in the full astern position, and the operator was seen pushing downward (in the astern direction) several times before impact. The allision occurred at 09:18:33.

Vessels can be fitted, at installation or retroactively, with what is referred to as a pitch deviation alarm. Its design purpose is to visually and audibly alert the wheelhouse operator when their commanded input to the propulsion units is not resulting in the intended response, such as when the operator commands the ahead propulsion to full ahead, but the propulsion unit fails to properly respond, or does not do so in an acceptable timeframe. Although propeller blade pitch commanded settings and actual propeller blade pitch position indicators are required by regulation on vessels with CPP's[30], the regulations do not require an unacceptable difference between them to audibly or visually alert the operator. At the time of the accident, the *Andrew J. Barberi* did not have a propulsion pitch deviation alarm in its wheelhouse, nor was one required by regulation for vessels with controllable pitch propeller, or cycloidal propulsion systems. The wheelhouse control stations had analog dial gauges that indicated both command signals initiated by the operator, and the response position of the propellers' blade pitch to his commands, which met applicable regulations[31], but there was no audible or visual alarm capable of making the operator aware of deviations between his command and the propulsion systems response. In the moments leading up to the accident, the wheelhouse operator commanded the NY end propulsion unit to transition from ahead to astern pitch (or thrust) as he approached the St. George terminal slip, but was unaware that the NY end propulsion unit was not responding to his commands.

One feature of the impending upgraded propulsion control system will be a pitch deviation alarm. The time lapse between command and response will be programmable at the operating station.[32]

The Barberi's propulsion system manufacturer was contacted, and indicated that their new cycloidal propulsion control system installations scheduled for 2012 have included in their control systems a pitch deviation alarm alerting the operator to unacceptable time lapses between the operator's commands and the propeller blade pitch response. The manufacturer, recognizing the potential improvement to the safe operation of vessels with its propulsion

[30] 46 CFR 62.35-50
[31] 33 CFR 164.35(m)
[32] Discussion summary with SIF Dep. Dir. of Maintenance- 8-5-11

systems, is notifying companies with its propulsion systems installed of the available control systems incorporating propeller pitch deviation alarms.

In March of 2008, the NTSB Office of Marine Safety investigated a large fish processing vessel, the *Alaska Ranger*, which sunk in the bering sea about 100 miles west of Dutch Harbor, Alaska. In that accident, the vessel experienced an unexpected loss ofcontrol of of its controllable pitch propeller (CPP). Prior to sinking, the vessel began to thrust in the astern direction while the operator had commanded a forward direction of thrust. The vessel, with a crew of 47 onboard, was taking on water, and began preparing to abandon ship to its liferafts. The captain had commanded the vessel in the ahead direction, and launched the liferafts, anticipating they would come alongside the vessel at the embarkation locations on the deck once the sea painters had become fully extended due to the forward motion of the vessel. Due to a loss of electrical power and the subsequent change to the astern direction, while waiting for the liferafts to come alongside the crew had to jump overboard and swim to the liferafts as opposed to climbing down a ladder directly into them. The captain was not aware that the CPP had not responded to his command for ahead thrust, and was in fact thrusting astern. The accident resulted in 5 deaths.

X

Brian Curtis
Engineering Group Chairman