UNITED STATES COAST GUARD

REPORT OF INVESTIGATION INTO THE SINKING AND LOSS OF FOUR CREW MEMBERS ABOARD THE COMMERCIAL FISHING VESSEL LADY OF GRACE

IN NANTUCKET SOUND ON JANUARY 26, 2007

MISLE ACTIVITY NUMBER: 2863457

U.S. Department of Homeland Security
United States Coast Guard

Commandant
United States Coast Guard

2100 Second Street, S.W.
Washington, DC 20593-0001
Staff Symbol: CG-545
Phone: (202) 267-1430
Fax: (202) 267-1416

16732
23 January 2008

INVESTIGATION INTO THE SINKING AND LOSS OF LIFE OF FOUR CREW MEMBERS ABOARD THE COMMERCIAL FISHING VESSEL LADY OF GRACE IN NANTUCKET SOUND ON JANUARY 26, 2007

ACTION BY THE COMMANDANT

The record and the report of the investigation of the subject casualty have been reviewed. The record and the report, including the findings of fact, analysis, conclusions, and recommendations are approved subject to the following comments.

ACTION ON RECOMMENDATIONS

Recommendation 1: Recommend that the Coast Guard re-evaluate the need to amend the applicability requirements in 46 CFR 28.550 to lower the stability requirements for commercial fishing vessels from 79 feet and greater in length to 50 feet and greater in length.

Action: We concur with this recommendation. We have indicated our intention to establish stability standards for commercial fishing vessels less than 79 feet in length in the Federal Register on several occasions leading up to our current regulatory project (CG Docket 03-16158). We expect to publish a Notice of Proposed Rulemaking soon.

Recommendation 2: Recommend that the Coast Guard re-evaluate the weight of assumed ice on each surface above the waterline for all fishing vessels as specified 46 CFR 28.550(b). Additionally, recommend that the Coast Guard re-evaluate the weight of assumed ice on each surface above the waterline for fishing vessels operating North of 42° but South of 66° 30' North latitude or South of 42° but North of 66° South latitude as specified 46 CFR 28.550(c).

Action: We concur with this recommendation. The current values used for the weight of assumed ice are consistent with those used for all vessel types internationally. In light of this incident, we will undertake a study to determine if the current values are the most appropriate for commercial fishing industry vessels.

Recommendation 3: Recommend that the Coast Guard re-evaluate the latitudes specified in 46 CFR 28.550 that state the weight of assumed ice has to be a factor in stability calculations when a fishing vessel operates north of 42 degrees North latitude. This case highlights the fact that significant ice accumulation occurs south of 42 degrees north latitude.

Action: We concur with this recommendation. The current latitudes in which the weight of assumed ice accumulation must be accounted for in stability calculations are consistent with those used for all vessel types, both domestically and internationally. In light of this incident, we

will undertake a study to determine if current values are the most appropriate for commercial fishing industry vessels.

Recommendation 4: Recommend that the Coast Guard evaluate the need to study alternatives and create guidance (NVIC) that advises commercial fishing vessel operators on ways to ensure that inflatable life-rafts and EPIRB are able to function as designed during icing conditions.

Action: We do not concur with this recommendation. We believe the current requirements of 46 CFR 28.125, which require each inflatable liferaft to be "stowed so as to float free and automatically inflate in the event the vessel sinks," as well as the requirement in 46 CFR 28.140, which require that each item of lifesaving equipment "must be in good working order, ready for immediate use, and readily accessible...at all times when the vessel is operated," provide adequate direction to vessel operators for the proper stowage and readiness of inflatable life-rafts and other lifesaving items. In cases where the liferaft and Emergency Position Indicating Radio Beacon and the inflatable liferaft are not deployed properly, one must look to the operator. Icing is not new to the commercial fishing industry in New England and Alaska. Those responsible for crew safety, when operating in the conditions like those experienced by the LADY OF GRACE, should understand the risks and mitigating factors. An operator has both the responsibility for ensuring safety aboard the vessel and the only realistic opportunity to take actions to ensure equipment is ready for use in an emergency.

Recommendation 5: Recommend that the Coast Guard review the current stability formulas in 46 CFR, Part 28 for accuracy. Although, not a factor in the sinking of the LADY OF GRACE, during the technical review of the LADY OF GRACE casualty the Coast Guard Marine Safety Center discovered typographical errors in 46 CFR, Part 28.

Action: We concur with this recommendation. We are aware of the typographical errors in the stability criteria in 46 CFR 28.575 and will initiate a technical amendment to the regulations to correct it.

[redacted]

W. D. RABB
By direction

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SUMMARY

On January 26, 2007, the 75-foot commercial fishing vessel LADY OF GRACE sank in Nantucket Sound during severe winter weather conditions while transiting to the vessel's homeport of New Bedford, MA. The casualty resulted in the deaths of all four crew members and the total loss of the vessel.

The vessel departed New Bedford, MA on January 23, 2007, for Cultivator Shoal on the George's Bank, on a routine ground fishing trip. On January 26, 2007 at 1753 local time the master contacted the vessel owner and stated he was cutting the trip short and heading back to New Bedford, MA due to deteriorating weather conditions. The National Weather Service offshore weather forecast for January 26, 2007, predicted gale force wind gusts 25 - 30 knots with gusts up to 40 knots. Seas were forecast to be between 6 - 9 feet with freezing spray likely. The Captain also reported the vessel was icing up. At 2256 on January 26, 2007, BOATRACS received their last contact position ping from the vessel and when the scheduled 30 minute automatic ping failed at 2330, an automated two hour position alarm countdown was initiated.

The owner of the LADY OF GRACE had previously opted for a BOATRACS service option to contact other vessels operating in the vessel's vicinity upon a two hour loss-of-contact. BOATRACS contacted the commercial fishing vessel LISA ANN II, but not until more than three and half hours has passed, requesting they attempt to contact the LADY OF GRACE via marine radio. The LISA ANN II responded to the request making several unsuccessful attempts to contact the LADY OF GRACE before contacting the Coast Guard Sector Boston's Command Center at approximately 0500 on January 27, 2007. This information was then passed on to Sector Southeastern New England Command Center who initiated a Search and Rescue case. On the morning of January 27, 2007, a Coast Guard helicopter discovered an oil sheen on the surface of the water in the vicinity of the LADY OF GRACE'S last known position.

On January 28, 2007, divers from the Southeastern Law Enforcement Council located the LADY OF GRACE submerged in approximately 56 feet of water at the bottom of Nantucket Sound, resting on her port side. During subsequent dives in late January and February 2007 by the Massachusetts State Police Dive team, two of the deceased crew members were recovered. In late April 2007 the LADY of GRACE was raised; brought to Rhode Island by barge; searched and inspected by the Coast Guard Investigating Officer and the Massachusetts State Police Dive Team; and subsequently scrapped in May 2007. The remaining two crew members remain missing and are presumed deceased.

The primary cause of the casualty was most likely attributed to a dramatic decrease in stability due to the added weight from a significant accumulation of ice.

Section 1 - FINDINGS OF FACT

1.1 Vessel, general data

Name:	LADY OF GRACE
Owner:	Santos Fishing Corporation; The owner of the LADY OF GRACE has worked in the United States fishing industry for 27 years and currently owns three commercial fishing vessels in the New Bedford area.
Official number:	599517
Gros Tons:	153
Length	75.8 feet
Breadth:	22.0 feet
Depth:	11.2 feet
Hull design	Offshore, western rigged dragger
Hull material:	Steel, original hull plating was 3/8 inch.
Propulsion	Single Detroit diesel (12V 149) rated at 625 hp.
Build date/location	1978, Bayou LaBatre, Alabama
Flag:	United States

Photo 1: Picture of Lady of Grace taken in 2006

1.2 Vessel, layout and tank arrangement

Below the main deck, the internal hull was fitted with five bulkheads which divided the spaces into six water-tight compartments.

1. Forepeak water tank
2. Storage/machinery compartment
3. Engine room with port and starboard F/O wing tanks
4. Fish hold
5. Aft water tanks
6. Steering gear compartment

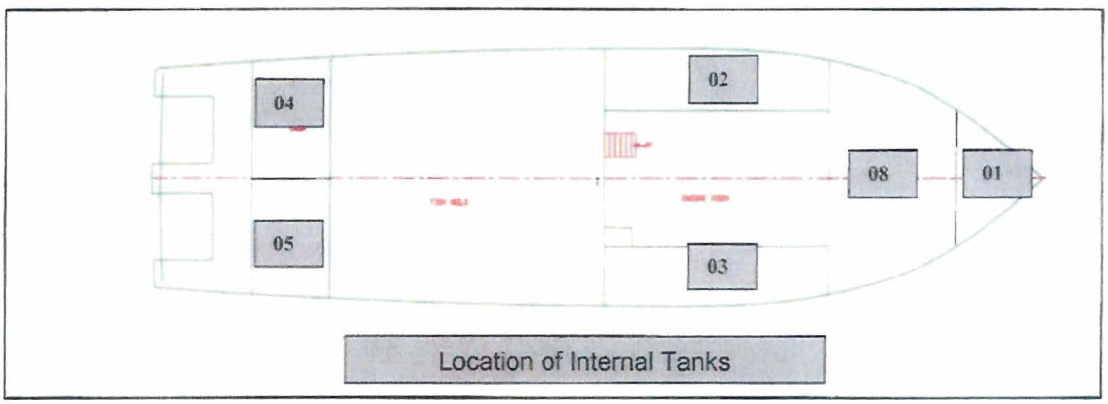
Above the main deck, there were four main areas:

1. Forward stowage area
2. Crew living spaces (three 2-man berthing spaces; toilet and shower)
3. Dining and galley area
4. Pilothouse

The bilge system on the LADY OF GRACE consisted of a common manifold system, a 3" electrically driven pump and an auxiliary engine belt driven pump. There were high level bilge alarms in the engine room, fish hold and steering compartment with both audible and visual alarms located in the wheel house.

TANK	MAX Capacity (Gallons)	EST Capacity At Time of Incident
01- Forepeak (water)	1822	1000
02 Fuel oil port	5927	3500
03 Fuel oil starboard	5927	3500
04 Fresh water port	3967	1983
05 Fresh water starboard	3967	1983
Hydraulic tank (not illustrated)	258	180
Lube oil tank (not illustrated)	166	100
08 Ballast tank (water)	2324	2324

Table 1: LADY OF GRACE Tank Capacities



Drawing 1: LADY OF GRACE Tank Locations

1.3 Vessel, Personnel

The crew consisted of four persons; all were experienced mariners within the commercial fishing industry.

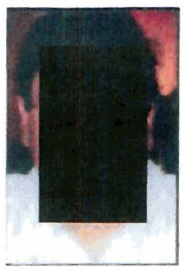
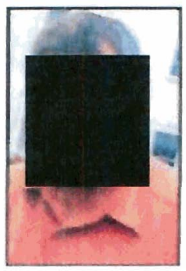
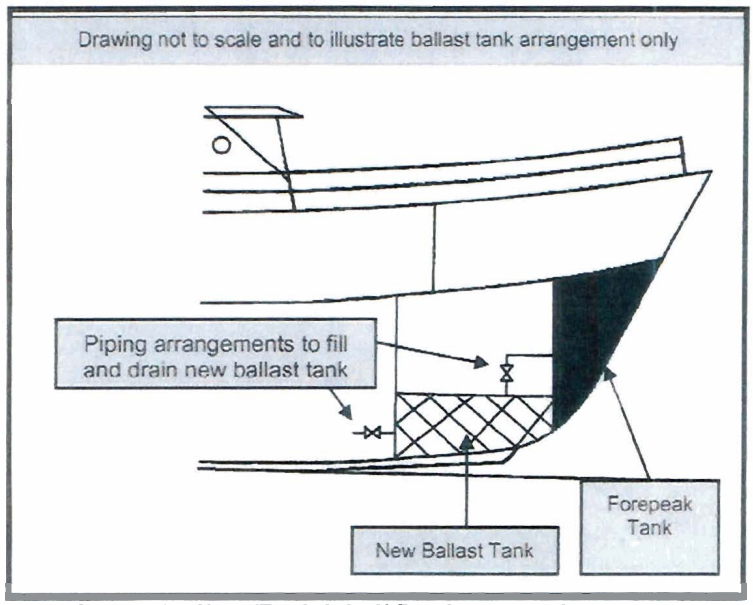
	**Crewmember:** Antonio Barroqueiro **DOB:** [redacted] **Time on vessel:** 3 years **Time in industry:** Approximately 25 years, 10 years as Master **Position on vessel:** Master Status: Deceased, body recovered
	**Crewmember:** [redacted] Brother in-law of Master **DOB:** [redacted] **Time on vessel:** Approximately 5 months **Time in industry:** Approximately 25 years (6 years in the U.S) **Position on vessel:** Deck hand Status: Missing and presumed deceased
	**Crewmember:** [redacted] **DOB:** [redacted] **Time on vessel:** 1 year. However, he also worked on the vessel for 8 years in the 1990's **Time in industry:** Approximately 25 years **Position on vessel:** Engineer Status: Missing and presumed deceased
	**Crewmember:** Mario T. Farinhas: **DOB:** [redacted] **Time on vessel:** 3 years **Time in industry:** 27 years **Position on vessel:** Cook and deckhand Status: Deceased, body recovered

Photo 2: LADY OF GRACE Crew

1.4 Vessel, modifications in 2006

During the summer of 2006 the LADY OF GRACE was modified to operate as a day scallop dragger when not engaged in ground fish dragging operations.

A new steel ballast tank with a capacity of 2,324 gallons was built integral to the vessel's hull in July 2006. The tank was constructed with one steel baffle plate through the center of the tank and was located on the vessel centerline forward of the engine room. This is located beneath the storeroom and directly behind the forepeak tank. The tank was provided with a bolted access plate for inspection and cleaning of the tank.



Drawing 2: Ballast Tank Modification Drawing

A pipe with a two-inch gate valve was installed from the aft bulkhead of the forepeak tank into the top of the new ballast tank. Filling of the ballast tank was accomplished by opening the fill valve and allowing water to gravity feed from the forepeak tank. To empty the ballast tank, the aft end of the tank was fitted with two pipes, one on each side of the tank and each fitted with a gate valve. These pipes led to the engine room bilge. The tank was drained to the engine room bilge and pumped overboard through the vessel's installed bilge system.

The Naval Architect stated he was not aware of the new piping installation or the procedure for filling the ballast tank and assumed the forepeak to be empty while the vessel was operating.

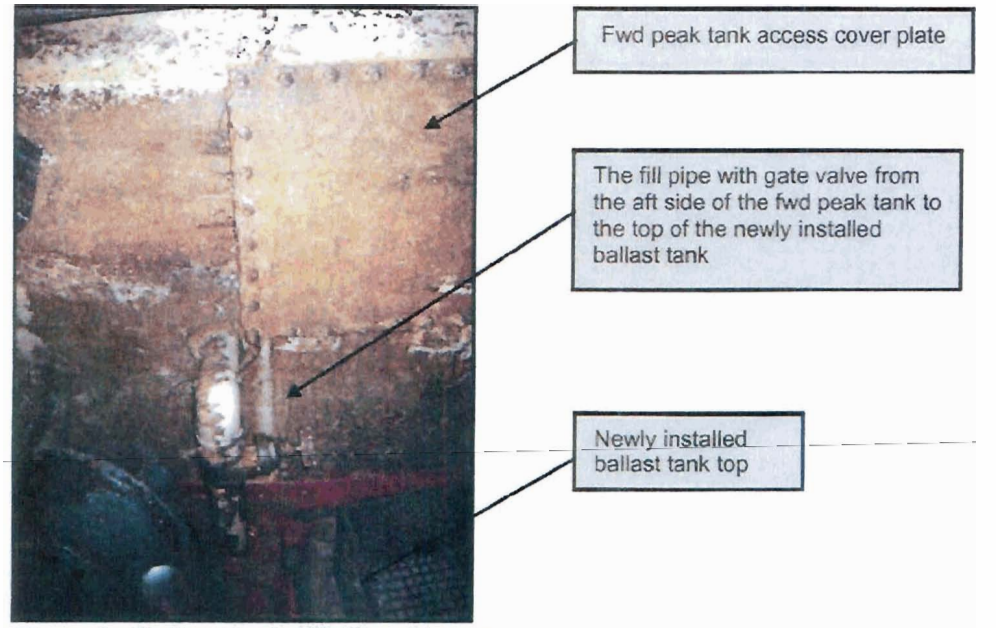
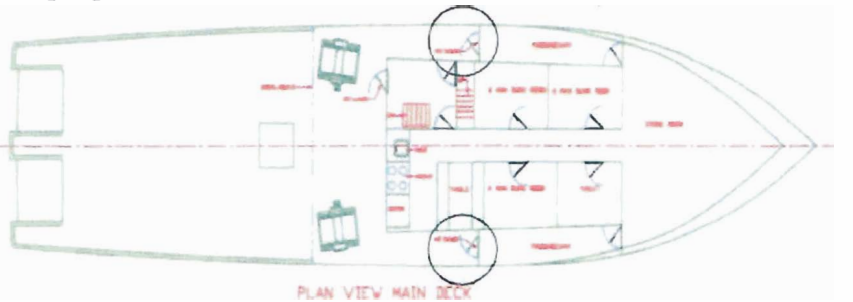


Photo 3: Ballast Tank Fill Pipe Picture

In accordance with modifications specified by the Naval Architect, hinged watertight doors were installed on the main deck, port and starboard side of the house in July 2006. These doors led to storage passageways connecting to the forward storage space.



Drawing 3: LADY OF GRACE Watertight doors fitted in accordance with new stability requirements.

The vessel's bulwarks were raised such that the main deck bulwarks were 36-inches high and extended the entire periphery of the main deck to the transom. The shelter deck bulwarks that sit atop the main bulwarks were extended to run aft from the aft foredeck (just aft of the pilothouse) to just forward of the gallows. The modified bulwarks were fitted with four freeing ports on the port and starboard sides each measuring 24-inches wide by 15-inches tall with guides and gates. The bulwarks were constructed of six-inch half pipe stanchions with ¾ inch steel plating mounted opposite ½ inch shell plating.

A 27-foot boom to be used for scallop dredging and a 1.1 long ton 10 foot scallop dredge were installed in July 2006. At the time of the casualty the LADY OF

GRACE was not carrying the scallop dredge but was rigged for ground fishing instead. However, the new boom was in place at the time of the casualty.

27 foot boom, newly installed. The boom is cradled and secured against the vessel's "A" frame gallows on the stern of the vessel, its normal underway position when not in use. The boom was installed for scallop dredging and is constructed of six inch square steel pipe of 3/8 inch wall thickness. The boom is fitted with a ladder and safety hoops for access to the blocks and cables .The boom is attached to the main mast with tabernacle and a clevis pin arrangement

Photo 4: 27 foot boom modification

1.5 Vessel, stability letter

The LADY OF Grace's regulatory length was less than 79 feet in length, therefore not subject to 46 CFR Part 28.500 (stability for commercial industry fishing vessels) and not required by current regulations to perform a stability test prior to operating.

*Note: Although actual overall length of the LADY OF GRACE was 86.75 feet, for regulatory and documentation purposes the official length is 75.8 feet. The official length is used to determine stability applicability and for documented vessels is measured from the stem of the main deck to foreside of rudder stock as required in 46 CFR Part 69.

In the summer of 2006, the vessel's owner decided to modify and outfit the LADY OF GRACE for day-boat scallop dragging, thus enabling the vessel to be configured and utilized as a scallop fishing vessel when not drag fishing.

Due to this change in service and being considered good marine practice, the Insurance Underwriters for the LADY OF GRACE required the vessel to undergo a satisfactory inclining stability test and obtain a Stability Letter prior to operating as a day scallop fishing vessel only. As this was an insurance requirement and not a regulatory requirement the vessel was only required to operate within the stability letter operating parameters while conducting day-scallop* fishing operations.

*Note: Day-boat scalloping is a general fisheries term used regarding a General Fisheries Permit 1B, which permits the operator to participate in scallop fisheries only with a trip limit of 400 pounds. The limitation is based on 400 pounds, not voyage duration.

On June 27, 2006, the LADY OF GRACE was hauled-out at Fairhaven Shipyard in Fairhaven, Massachusetts. A Naval Architect measured and compiled information used to produce a lines plan, general arrangement plan and create a computer model of the vessel for a stability analysis.

On June 30, 2006, an inclining stability experiment was performed at the New Bedford State Pier. In attendance with the Naval Architect during the test was Mr. Antonio Barroqueiro, Master of the LADY OF GRACE. Upon completion of the analysis, the Naval Architect concluded the vessel failed every intact stability criterion in all operating conditions when compared to Coast Guard stability standards in 46 CFR Part 28. However, the architect stated this is not uncommon for many commercial fishing vessels.

Upon completion of the intact stability and subsequent computer modeling technical analysis, the Naval Architect stated to Coast Guard investigators, he had informed the vessel's owner that the LADY OF GRACE would meet Coast Guard intact stability criteria when configured for day-boat scallop operations (i.e. one single side dredge and no stern trawl nets and doors) if the vessel made certain modifications and abided by certain operating restrictions. Those modifications and operating restrictions are as follows for day scallop dragging:

A. The vessel must carry 20 tons of ice in the fish hold.
B. Solid ballast must be placed under the storeroom flat.
C. The doors to the compartments on the sides of the house must be made watertight.
D. The aft water tank could not be filled more than 60%.
E. Trawl nets and doors* could not be on the vessel.
F. No water should be located in the forepeak as it was no longer needed.

* Note: Doors as listed above refer to trawl doors used to provide horizontal spread for the trawling nets.

The Naval Architect informed U.S. Coast Guard Investigators, that the owner did not want to use solid ballast and as an alternative, the architect and owner had agreed to install a segregated ballast tank under the storeroom flat. It was determined that if the tank remained completely full and the above modifications and operating restrictions were adhered to, the vessel would meet CG stability criteria when operating as day scallop dragger.

The Owner of the LADY OF GRACE informed U.S. Coast Guard Investigators he had not been informed the forepeak tank should no longer be used for ballast. The standard operating procedure following the installation of integral ballast tank was to maintain the forepeak tank at no more than 60 percent full of water and the tank had been marked accordingly.

On July 29, 2006, Thomas M. Farrell Naval Architects issued a Stability Letter, applicable only while the vessel was operating as a day boat scallop dragger. Operating conditions listed on the Stability Letter required the new ballast tank to remain pressed with water.

* Note: The Stability letter issued to the vessel incorrectly stated that the inclining experiment occurred on May 30, rather than June 30. This error was determined to be an administrative error with no relevance to this investigation.

Although the vessel stability was evaluated for the vessel when configured for day-scalloping, no such analysis was performed on the vessel for stern drag fishing, its primary fishery and the fishery engaged in at the time of the incident. Therefore, while operating as a stern dragger, the LADY OF GRACE did not have and was not required to meet the Coast Guard standards for intact stability due to vessel's regulatory length.

1.6 Vessel, lifesaving equipment

The inflatable liferaft aboard the LADY OF GRACE was a Revere 8-person self-inflatable liferaft. It was secured to the vessel by a hydrostatic release unit and designed to automatically release at approximately 13 feet of water pressure. The liferaft was stowed forward of the pilot house directly behind the spray rail on the bow of the vessel. When divers first discovered the sunken vessel resting on its port side at an estimated 60-degree angle, the liferaft was still in its cradle, the hydrostatic release and strap laying in a released condition. The liferaft came loose from its cradle and floated to the surface when a diver bumped it slightly. There were no indications of a malfunction related to the hydrostatic release mechanism.

EQUIPMENT	NOTES
(1) 8 person inflatable life raft	Inspected November 2006 Hydrostatic release exp 11/07 (S/N 15818)
(1) EPIRB category 1 (406 MHz) (Emergency Position Indicating Beacon)	Hydrostatic release exp 4/08 Battery exp 2/07 Registration # ADCD06C82450001
(4) Survival suits	Manufactured 11/05, Lights dated 4/08
(5) Type 1 Personal Floatation Devices (Lifejackets)	Serviceable, retro-reflective tape and name
(1) Ocean Service distress signal kit	(1), Para red rocket MK-3 (Exp 4/07)

	(1), Life smoke orange smoke: (Exp. 4/07) (3), Red MK-7 hand flares (Exp. 6/07)
(1) VHF-FM Radio	Radio was not equipped with Digital Selective Calling (DSC).

Table 2: Lifesaving Equipment

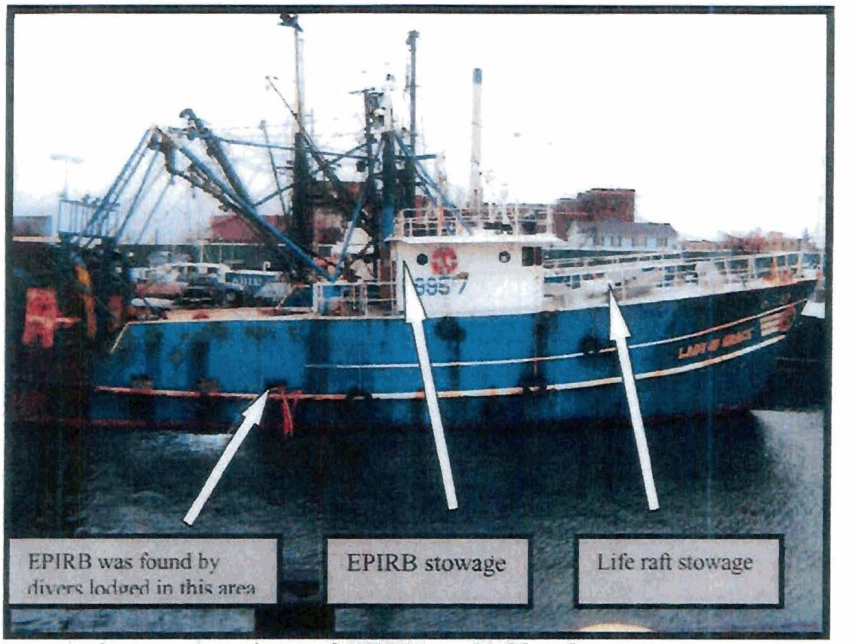


Photo 5: Storage locations of EPRIB and Liferaft

Massachusetts State Police Divers discovered the vessel's EPIRB lodged in a scupper opening in the starboard bulwark, aft of the vessel's superstructure. The EPIRB was normally mounted on the starboard side of the aft wheelhouse bulkhead and was designed to float free at 13 feet of hydrostatic pressure. Divers confirmed the release spring of the hydrostatic release had ejected fully indicating the unit had operated as designed.

1.7 Crew Training and Equipment Tests

The Master, Mr. Antonio Barroqueiro, had attended the Coast Guard phase one drill instructor Safety and Survival course. Mr. [redacted] and Mr. [redacted] had both attended phase two of the Coast Guard Safety and Survival course. Training records recovered from the LADY OF GRACE indicated that all crew members had conducted monthly emergency drills and familiarization training. The last training drill recorded was conducted January 06, 2007. A current monthly record of EPIRB testing and inspecting was also recovered.

1.8 Weather and Icing

The weather forecast issued by the National Weather Service at 0359 January 23, 2007, for the area the LADY OF GRACE was operating predicted NW winds

between 20 and 30 knots for Thursday, January 25 and Friday, January 26 with gusts up to 35 knots. Seas were forecast to be between 6 ft and 10 ft with heavy freezing spray likely after midnight on Thursday and early evening on Friday, January 26.

The weather forecast issued at 1214 on January 26, 2007, stated a powerful ocean storm would bring gale force wind gusts to the waters Friday afternoon and predicted NW winds between 25 - 30 knots with gusts up to 40 knots. Seas were forecast to be between 6 - 9 feet with freezing spray likely.

At 1607 on January 26, 2007, the National Weather Service continued the gale force warning until 2200 Friday night with winds between 20 - 25 knots with gusts up to 35 knots and a chance of freezing spray.

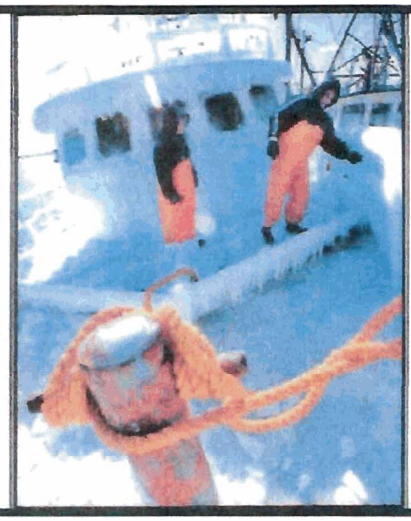
Sea-Spray Icing: A detailed description of sea spray icing, environmental conditions affecting ice accumulation and estimated icing conditions for the LADY OF GRACE is documented in Enclosure 1: USCG Marine Safety Center Stability Analysis.

The commercial fishing vessel DEBBIE SUE, a 74-foot scallop fishing vessel transited Nantucket Sound on a course similar to the LADY OF GRACE seven hours earlier. The Master of the DEBBIE SUE stated his vessel experienced severe ice build-up which required his crew to break ice on four occasions prior to reaching the vessel's homeport of Point Judith, RI. He described the following ice buildup during the transit:

- Hand rails on the top deck were covered in 10 inches of solid ice,
- Everything on deck from the waist down to the deck was covered in ice.
- The top of the pilothouse had a solid six-inch covering of ice except for the exhaust stack,
- From the floor of the upper deck on the windward side (starboard) to the water line on the outer hull of the vessel, there was four to six inches of ice hanging.

The Master stated when "those areas of ice were broken loose, the vessel actually bobbed back to port".

In addition, the 1-⅛ inch wire stays on the bow had accumulated 10 to 14 inches in diameter of ice with the lower five to eight feet of ice hanging to the deck. The outriggers which were constructed of three to five-inch tube steel had accumulated between ten to twelve inches of ice, the port outrigger bent under the weight of ice.



F/V IBERIA II

An example of ice build-up on the F/V IBERIA II, a 70.3 ft, 140 Gross Ton scallop boat. Picture was taken 27 January, 2007 while the vessel was moored in New Bedford 27 January, 2007. This vessel transited Nantucket Sound one day after the LADY OF GRACE casualty.

Photo 6: An example of significant ice accumulation

The extent of vessel icing can be predicted based on four independent factors: air temperature, water temperature, wave height and wind speed. The weather on January 26, 2007, was deteriorating due to an offshore low to the southeast of New England. A search for available historic weather data in the vicinity of the causality site resulted in six stations within a 50 mile distance. Based on the known perimeters for icing, the historic weather data, eyewitness accounts, and the NOAA model for predicting icing conditions the LADY OF GRACE was in heavy icing class where more than ¾ inches per hour of ice build-up may occur.

Icing Factors	Required Conditions for Icing	Estimated Conditions at the Time of the Casualty
Air Temp	Between 0 and 29 Fahrenheit	12.4 Fahrenheit
Water Temp	Below 45 Fahrenheit	37 Fahrenheit
Wave Height	3.9 Feet	4.6 Feet
Wind Speed	Usually greater than 18 Knots	20.0 Knots

Table 3: Comparison of required conditions for icing on January 26, 2007

For stability testing (vessels' greater than 79 feet) 46 CFR Part 28.550 describes the weight of assumed ice to be used on each surface above the waterline. For vessels operating north of 66° 30' the weight of assumed ice must be at least:

A. 6.14 pounds per square foot of horizontal projected area which corresponds to a thickness of 1.3 inches
B. 3.07 pounds per square foot of vertical projected area which corresponds to a thickness of 0.64 inches

For vessels operating north of 42° but south of 66° 30' as was the LADY OF GRACE at the time of the casualty, the weight of assumed ice is one half the required values listed above.

In addition to vessel de-stabilization, interviews with members of the New Bedford fishing community identified icing up of externally mounted life saving equipment as a common occurrence. The ice build-up if not carefully removed inhibits automatic deployment of the life raft and EPIRB, and will actually freeze them to the vessel totally encased in ice.

1.9 Commercial fishing vessel safety examination

The F/V LADY OF GRACE was an un-inspected commercial fishing vessel and as such was not required to hold a Certificate of Inspection from the US Coast Guard. However, the vessel was enrolled in the voluntary Coast Guard Fishing Vessel Safety program. On April 11, 2006, the LADY OF GRACE underwent a dockside safety exam by a fishing vessel examiner from Coast Guard Marine Safety Detachment New Bedford, MA. At that time the vessel was found to have two deficiencies:

A. The hydrostatic release for the EPIRB had past its two year expiration date (EPIRB expiration date was March 2006)

B. The fish hold high bilge alarm indicating light in the pilot house was not working.

These deficiencies were corrected April 18, 2006 and the vessel was issued a fishing vessel decal.

1.10 Roll-dampening paravanes

Roll-dampening paravanes were fitted to the LADY OF GRACE on port and starboard outriggers. The outriggers were deployed and in use at the time of the incident. Both paravanes were found to be intact and properly attached during the post casualty Coast Guard examination. There was no evidence of fouling or broaching of the paravanes.

* Note: Roll-dampening paravanes are lowered into the water port and starboard from extended outriggers while the vessel is underway, when dragged through the water each paravane exerts a downward force by the diving effect of its fin. This balanced downward pulling force at the end each outrigger makes the moving vessel more resistant to heeling forces and dampens the rolling movement.

1.11 BOATRACS (vessel monitoring system)

BOATRACS is a commercial vessel position monitoring system (VMS) designed to automatically report fishing vessel position and activity to the National Marine Fisheries Service. VMS is installed on certain commercial fishing vessels by the National Marine Fisheries Service to manage the depletion of fish stocks by

governing catch sizes, limiting allowable days at sea, and regulating certain fishing territories. BOATRACS manages satellite transmissions from fishing vessels either hourly or twice an hour depending on the fishing operation. The owner of the LADY OF GRACE had previously elected for a BOATRACS service option to contact other vessels operating in the vessel's vicinity upon a two hour loss-of-contact. The LADY OF GRACE was ground fishing and as such was on a 30-minute contact schedule with BOATRACS.

The chart below provides a visual display of the route the LADY OF GRACE followed on January 26, 2007 as the vessel transited toward its homeport of New Bedford, MA. The positions denoted on the chart represent reports that were received by the BOATRACS system.

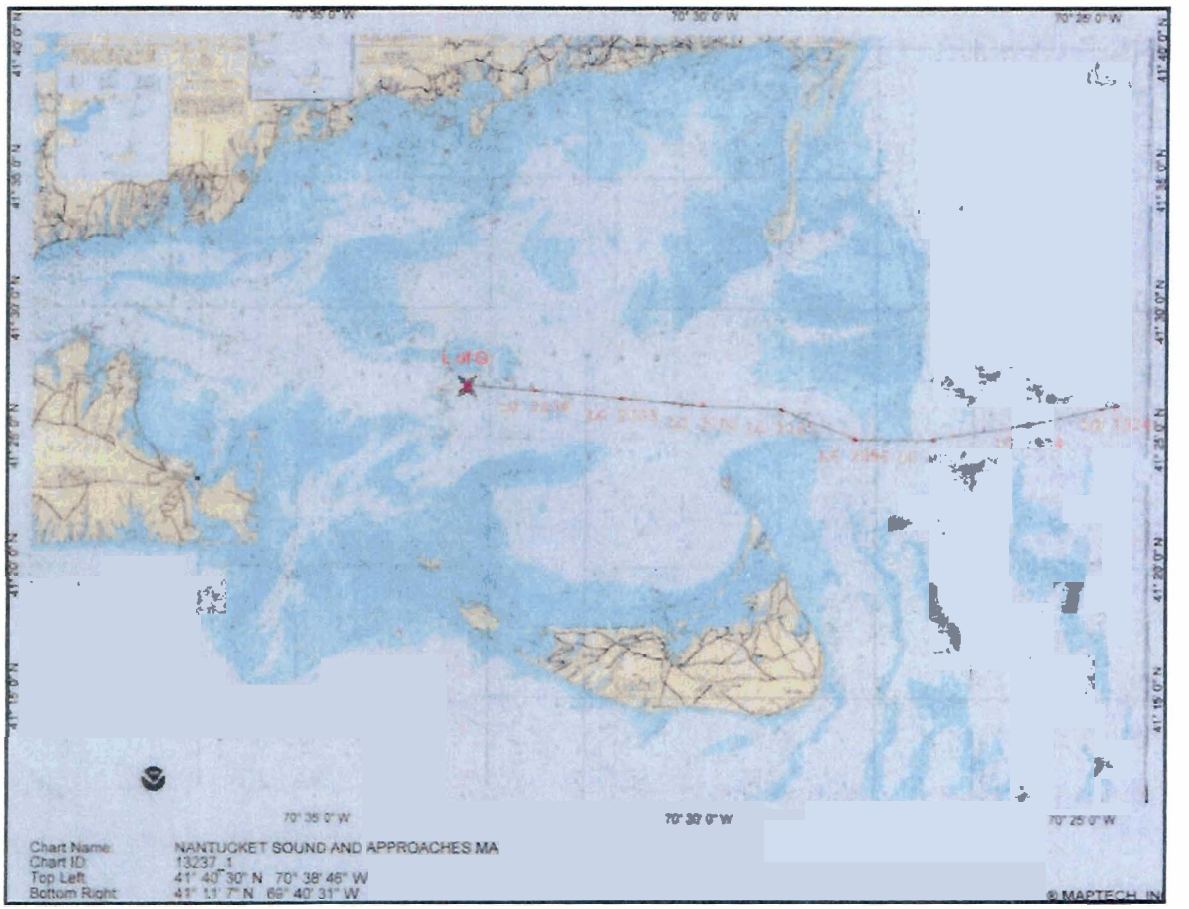


Photo 7: Charted track-line of LADY OF GRACE

Although the owner of the LADY OF GRACE had opted for a BOATRACS service option to contact him and other vessels following two hours without a contact ping; it was actually three hours and thirteen minutes following the last contact ping when E-mails were sent to other vessels in the area. E-mails were sent to three vessels: the LISA ANN II, the MEGAN MARIE and the FITZ-SEA. Successful acknowledgements of these e-mails were received from the LISA

ANN II and the MEGAN MARIE, it was later discovered that the FITZ-SEA (ME117MP) had caught fire and sank in November 2006 but was never removed from BOATRACS monitoring system.

1.12 Previous Casualty (MISLE Activity # 2852367):

* Note: Information below provided by family members of crew members, electrical and dive service contractors.

On January 08, 2007, while underway on a routine ground fishing trip, the LADY OF GRACE experienced a loss of electrical power and consequently loss of electric hydraulic steering. The electrical casualty was attributed to a chafed wire in the generator voltage regulator. Also identified during this incident was a defective alternator on the two cylinder diesel engine used as a secondary means for charging the 12/32V battery bank. Additionally, even though the Lady of Grace was equipped with a dedicated 12V DC back-up battery and charger for the radio equipment, the Coast Guard received no radio communications during this casualty. Investigators speculate the batteries became drained and the vessels radio and satellite phone system was non-operational. Crew members communicated with Coast Guard Search and Rescue Units with their personal cell phones.

Due to the loss of steering the vessel drifted south, the anchor was deployed but not holding and the vessel soft grounded. The Master was able to free the vessel from the mud/sand bank shortly before USCG took the LADY OF GRACE into tow. The tow was later assumed and completed by a commercial tug. The cause of the electrical casualty was determined to be a chafed wire in the generator voltage regulator.

A dive survey was performed to assess damage from the grounding which was determined to be minor paint scraping on the vessel's keel. This assessment was verified by a Coast Guard Inspector during the post salvage examination.

1.13 Bilge and Steering system

During the post salvage examination, all bilge suction valves on the vessel's installed bilge manifold system were found in the closed position.

A thorough examination of the vessels aft steering system revealed no obvious system failure. All hydraulic components were intact and appeared to be well maintained.

1.14 Scupper closing devices

During the dive surveys performed by the Massachusetts State Police all scupper closing devices were found to be correctly secured in the open position allowing water to properly drain from the main deck.

1.15 Watertight Doors and hatches

The newly installed watertight doors on the port and starboard main deck were discovered to be in the open position by divers. In addition, the center door from the main deck to the galley was a galley style door (bottom and upper half's swing independently). The bottom half was discovered closed by the divers, but the upper half was open. During the Coast Guard examination following the Salvage of the LADY OF GRACE, the steering gear compartment hatch was also discovered missing.

1.16 Possible hazard obstruction hazards

The nearest obstruction to the vessels charted course was the Half moon Shoal lighted bell buoy # 18 which was approximately 1.5 miles from where the vessel was located. On March 8, 2007, the buoy was hauled on deck of the USCGC JUNIPER and inspected for damage. No damage was visible on the underside of the eight-foot buoy, however the light fixture on the top was damaged and a minor dent to the framing was evident. Personnel from USCG Aids to Navigation Team in Woods Hole, had position checked and inspected all buoys in the area following the sinking, and determined that this damage was caused subsequent to the LADY OF GRACE incident.

1.17 Timeline of Key Events (all times local)

0900, January 23, 2007: The LADY OF GRACE departed New Bedford, MA for a routine ground fishing trip to Cultivator Shoal located in the western area of Georges Banks.

0814, January 25, 2007: The Master, Antonio Barroqueiro, contacted the owner, Mr. [redacted], via satellite phone to inform him they had reached the fishing grounds and were fishing.

1753, January 26, 2007: The Master contacted the owner by satellite phone. He reported that the LADY OF GRACE was returning to New Bedford early due to deteriorating weather conditions and excessive ice build-up. He mentioned the crew had already been breaking ice and specifically mentioned the removal of ice from the radar antenna. He estimated the vessel would arrive in New Bedford at 0500 on January 27, 2007. Given the approximate distance from Cultivator Shoal to New Bedford, the LADY OF GRACE would need to travel between 07 and 07.5 knots to arrive in New Bedford by the Master's ETA of 0500 on January 27,

2007. The maximum speed of the LADY OF GRACE was approximately 09 knots.

2256, January 26, 2007: BOATRACS received their last contact position for the LADY OF GRACE at 41-26.87 N, 070-12.68W.

2326, January 26, 2007: BOATRACS did not receive the automated thirty minute position communication ping from the LADY OF GRACE and the automated countdown for the two hour position alarm was initiated in accordance with the contractual agreement between the vessel owner and BOATRACS.

0130, January 27, 2007: LADY OF GRACE appeared on the BOATRACS position alarm. Personnel from the BOATRACS network operations center contacted QUALCOMM, the satellite provider and requested a manual ping to the LADY OF GRACE. The manual ping from QUALCOMM was unsuccessful.

0355, January 27, 2007: Personnel from the BOATRACS network operations center sent a standard positioning message to LADY OF GRACE.

0443, January 27, 2007: Personnel from the BOATRACS network operations center noticed positioning message for the LADY OF GRACE had failed. They scanned directory for vessels in the vicinity of the last known position of the LADY OF GRACE and sent messages to three vessels (MEGAN MARIE, FITZ-SEA, and LISA ANN II) requesting they contact the LADY OF GRACE via radio.

0506, January 27, 2007: After several unsuccessful attempts to contact LADY OF GRACE by radio, Mr. [redacted] the Master of the LISA ANN II contacted Coast Guard Sector Boston Command Center and reported the LADY OF GRACE was not responding to VHF-FM radio calls.

0510, January 27, 2007: First District Command Center subsequently passed case information to the Sector Southeastern New England Command Center and requested they make callouts for LADY OF GRACE. Callouts by Sector Southeastern New England on both HF and VHF were negative.

0525, January 27, 2007: Sector Southeastern New England attempted to call the LADY OF GRACE ship's cell phone with negative results.

0558, January 27, 2007: Sector Southeastern New England requested the New Bedford Police to check the docks and see if the LADY OF GRACE was in port. New Bedford Police were unable to locate the LADY OF GRACE.

0600, January 27, 2006: BOATRACS contacted the Mr. [redacted], owner of the LADY OF GRACE and advised that the vessel had not positioned and that

vessels in the vicinity were contacted to assist. The owner advised he would attempt to contact the vessel via cellular phone.

0949, January 27, 2007: A Coast Guard Jayhawk Helicopter departs from Air Station Cape Cod to conduct a track-line search from LADY OF GRACE'S Last Know Position (LKP) through Vineyard Sound to New Bedford. Approximately a half hour later the helicopter discovered oil sheen in vicinity of LADY OF GRACE'S LKP.

1349, January 27, 2007: Coast Guard Station Brant Point rescue boat discovers debris in position 41-26.57N, 070-14.55W.

1400, January 28, 2007: Following an extensive search and rescue effort, the Massachusetts Law Enforcement Council dive team (SEMLEC) dove and discovered the LADY OF GRACE submerged in approximately 56 feet of water, 12 miles from Wood's Hole in Nantucket Sound (position 41-26.9 N 070-16.32 W).

January 29, 2007: Coast Guard suspended the active search.

January 29, 2007: Massachusetts State Police and commercial divers (hired by the vessel's insurance underwriters) dove on the LADY OF GRACE and recovered the body of Mr. Antonio Barroqueiro, the Master of the LADY OF GRACE in the pilot house.

January 30, 2007: Commercial divers (hired by the vessel's insurance underwriters) dove on the LADY OF GRACE and plugged the vessel's fuel oil service tank vents to reduce the environmental risk the vessel presented.

January 30, 2007: COTP Sector Southeastern New England issued a letter to the Mr. [redacted] and Santos Fishing Corporation (owners of the LADY OF GRACE) regarding the hazard to navigation the vessel presented sunk in a marked navigation channel and potential environmental threat due to the estimated fuel on the vessel. The letter requested the owner present a salvage plan for the vessel to eliminate the navigation and environmental threat.

January 30, 2007: An autopsy was performed on Mr. Antonio Barroqueiro by a Medical Examiner in Boston, MA. The cause of death was determined to be drowning. Toxicology testing for the presence of dangerous drugs and alcohol was performed and found to be [redacted]

February 21, 2007: Massachusetts State Police and commercial divers (hired by the vessel's insurance underwriters) dove on the LADY OF GRACE and recovered the body of Mr. Mario Farinhas, the cook and deckhand in his stateroom.

February 22, 2007: An autopsy was performed on Mr. Mario Farinhas by a Medical Examiner in Boston, MA. The cause of death was determined to be drowning. Toxicology testing for the presence of dangerous drugs and alcohol was performed and found to be [redacted] for drugs and [redacted] for alcohol.

April 25, 2007: The LADY OF GRACE was raised by the salvage company Donjon Marine Co., Inc., (hired by the vessel's insurance underwriters) and placed on a deck barge. Investigators conducted an internal search for the two missing crewmembers and performed a preliminary assessment of the vessel's internal and external hull condition. The missing crewmembers were not found and are presumed to be deceased. The vessel's hull was determined to be in satisfactory condition with no obvious structural failures evident.

April 26, 2007: While the deck barge was moored at Quonset Pt, RI, preparing for transit to Donjon's facility in Newark, NJ, investigators from the Massachusetts State Police and USCG personnel again performed a search and examination of the vessel. No probable cause or indication of a mechanical failure was identified. All valves on the vessel's bilge manifold system were found in the closed position. Lifesaving equipment, including four survival suits (three in the pilot house cabin and one in the Master's stateroom) were found still in their stowage bags. Two containers of distress flares were located in the pilot house, and the two remaining ring life buoys were located. One life buoy was found during the initial search by divers in January 2007.

May 01, 2007: When the LADY OF GRACE was being secured to a barge for transport to another DonJon facility, approximately 7,000 gallons of nearly pure diesel fuel was removed from the vessel's fuel oil service tanks. This is the approximate amount of diesel fuel the owner estimated was on the vessel at the time of the sinking. The initial action to plug the fuel vents by divers and precautions taken during the salvage of the vessel from the seabed reduced the environmental risk the incident presented.

May 14, 2007: The LADY OF GRACE was scrapped.

Section 2 - ANALYSIS AND CONCLUSIONS

2.1 ANALYSIS: Situational Awareness (Weather and Icing)

The investigating officer agrees with the conclusions of the Coast Guard Marine Safety Center Analysis and Assumptions (Enclosure 1) and that the vessel was significantly destabilized by significant ice accretion. The environmental factors, specifically high wind speed, low air and water temperature combined with the wind direction relative to the vessel's heading during the return voyage, created a serious topside hazard from sea-spray icing. The added weight from large formations of ice generated by sea-spray contacting exposed surfaces on decks and superstructures, added substantial weight to the vessel and raised the center of gravity dramatically. This resulted in a decreased stability condition.

Although assumed ice accumulation was considered and consistent with current Coast Guard regulations during the stability analysis and testing of the LADY OF GRACE. 46 CFR 28.550 describes the weight of assumed ice to be used on each surface above the waterline on vessels when performing stability testing. For vessels operating north of 66° 30' the weight of assumed ice must be at least:

A. 6.14 pounds per square foot of horizontal projected area which corresponds to a thickness of 1.3 inches
B. 3.07 pounds per square foot of vertical projected area which corresponds to a thickness of 0.64 inches

For vessels operating north of 42° but south of 66° 30' as was the LADY OF GRACE at the time of the casualty, the weight of assumed ice is one half the required values listed above. Although assumed ice accumulation was considered as one halve the criteria listed in 46 CFR 28.550 (b) during the stability test calculations performed on the LADY OF GRACE, the actual ice accumulation during this casualty was far greater then the assumed ice thicknesses used for vessels operating north of 66° 30'

The Master had operated the LADY OF GRACE in icing conditions on many occasions in the past. He was familiar with the vessels limits, handling abilities and characteristics while experiencing ice build-up. However, the recent addition of the 27 foot boom and bulwarks provided additional surface area for a significant increase in ice accumulation. The added weight from this ice located high on the vessel most likely had a significant negative affect on the vessel's stability, specifically its ability to right itself. Also, due to the location and arrangement of the boom, the ability for crew members to effectively remove the ice from the boom would have been extremely difficult and hazardous.

While the master recognized deteriorating offshore weather conditions and decided to cut the fishing trip short and return to his homeport early. The majority of the findings of fact indicate the master and crew were not fully aware of the serious impact that the increasing ice accumulation had on the vessels stability, which was exacerbated as the vessel got closer to land. The undetected icing occurring during hours of darkness without illumination can create a false sense of acceptable stability due to a slower more comfortable roll period of the vessel.

It can be surmised that due to the light clothing found on the recovered crew members and the stowed condition of all survival suits the crew were not fully aware of the seriousness of the deteriorating conditions and was caught off-guard when the vessel suddenly sank.

2.1 CONCLUSION: Situational awareness (Weather and Icing)

Based on the findings of fact and analysis above, the LADY OF GRACE and other vessels operating in the area at approximately the same time experienced significant ice accretion far exceeding the criteria noted in 46 CFR Part 28.550.

It was determined that the primary cause of the sinking was the accumulation of ice on the vessels exterior and on the newly installed bulwarks and boom. Over time, the accumulation of ice eliminated the inherent righting effect of the vessels stability, which caused the vessel to capsize with little to no warning.

2.2 ANALYSIS: Material condition of vessel

Based on recent surveys, the Coast Guard voluntary commercial fishing vessel exam of April 18, 2006, and the post casualty inspection, the vessel appears to have been maintained in good working order and had no outstanding regulatory deficiencies. Additionally, the post casualty inspection of the vessel's bilge system found all bilge suction valves in the closed position.

At the time of the incident the LADY OF GRACE was not operating as a day scallop fishing vessel and therefore not required to maintain the operating condition in accordance with the Stability Letter. However, there was an apparent verbal miscommunication between the Naval Architects who performed the inclining stability and the owner of the vessel. According to the owner, the normal operating condition for the forward peak tank had been approximately 50% full of fresh water. Following the installation of the new integral ballast tank the owner was under the impression the forward peak tank should be maintained no more than 60% full and stated he had marked the tank at the 60% level to ensure compliance with this requirement. The Naval Architects concluded that with the new ballast tank installed, the forward peak tank should no longer be used and assumed this tank to be empty in all their stability calculations.

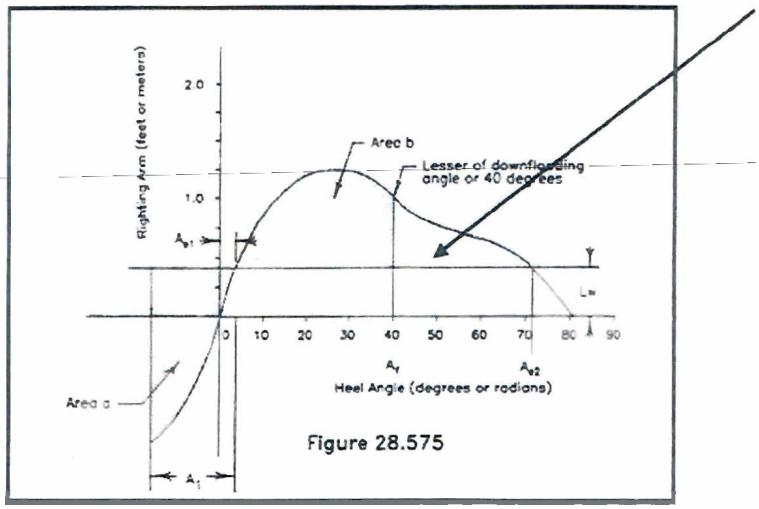
Furthermore, no operating condition, for the use of the forepeak tank, was listed in the Stability Letter. Given the loading condition at the time of the sinking, the Coast Guard Marine Safety Salvage Engineering Response Team determined the added weight and free surface moment from water in the forward peak tank was not an aggravating factor in this incident.

2.2 CONCLUSION: Material Condition of the Vessel

Based on the findings of fact and analysis above, it is determined that the vessel was in a good condition and that a breach in the hull or mechanical malfunction did not occur. Furthermore, the internal modifications that were made to the vessel in 2006 are not believed to have aggravated the situation caused by the icing. However, the addition of the bulwark and 27 foot boom did create more exterior surface area that undoubtedly increased the accumulation of ice on the vessel. However, it is difficult to speculate whether the vessel would have survived the transit without the external modifications. Although the use of the forepeak tank for ballast was not as the Naval Architect intended, it was not a factor in this casualty.

2.3 Stability Technical Review

During the stability technical review by the Coast Guard Marine Safety Center, there were two typographical errors identified in 46 CFR Part 28, specifically, the formula in 28.575 (b) $\boxed{K E_n(V_n 2A_n Z_n)/W}$ should read $\boxed{K E_n(V_n^2 A_n Z_n)/W}$ also 46 CFR 28.575 (e) (3) reads "the heel angle of 50°" which is not consistent with the heel angle graph on figure 28.575 which is listed as 40°.



Drawing 4: Graph from 46 CFR Part 28

2.3 CONCLUSION: Stability Technical Review

This office agrees with the Coast Guard Marine Safety Center findings that there are technical errors in the formula and table in 46 CFR Part 28 regarding stability calculations. Both the Naval Architect and the Coast Guard Marine Safety Center used the correct formula in their analysis.

2.4 ANALYSIS: Missing crew members

The two crewmembers that were recovered from the vessel were both dressed in light clothing. The master was discovered in the pilot house and the vessels cook was in his stateroom. As the two remaining crewmembers were not found on the interior of the vessel, it is reasonable to assume that they were on deck breaking ice. Therefore, under this scenario, the two missing crew members were immediately subjected to 38 degree water when the vessel capsized, which would have limited there survival time without exposure suits to 2.4 – 3.0 hours.

2.4 CONCLUSION: Missing crew members

Based on the findings of fact and analysis above, it is determined that the two missing crew members were mostly likely on-deck at the time of the sinking breaking ice and were immediately exposed to the 37 degree water without exposure suits, which would have limited their survivability to less than four (4) hours based on the Cold Exposure Survival Model.

2.5 ANALYSIS: Deployment of Lifesaving Equipment

During the post salvage examination four survival suits were discovered in stowage bags, three in the pilot house cabinet, their normal stowage area and one in the Masters stateroom, his personal suit. Two closed containers of distress flares were located in the pilot house and all ring life buoys were accounted for. It appears that the capsizing of the LADY OF GRACE was sudden and catastrophic as no attempt was made by the crew to use the survival suits, flares or life rings. However, the lifesaving equipment that is designed to deploy without crew assistance was prevented from deploying by the accumulation of ice, which encased the equipment. Both the life raft and EPIRB hydrostatic releases did release freeing the crucial lifesaving apparatus when the accumulation of ice melted, however when the EPIRB was eventually freed it floated up and became trapped in a scupper on the starboard bulwark. The liferaft remained lodged in its cradle due to the inclination of the vessel.

2.5 CONCLUSION: Deployment of Lifesaving Equipment

Based on the findings of fact and analysis above, it is determined that the accumulation of ice prevented the vessels inflatable liferaft and EPIRB from deploying as designed.

2.6 ANALYSIS: LADY OF GRACE Stability

In accordance with regulations the LADY OF GRACE was not required to undergo or meet the regulated stability requirements because the vessel was less than 79 feet in regulated length. However, stability test calculations performed prior to the vessel modifications identified the vessel would not meet current Coast Guard intact stability standards if they were applicable.

While the LADY OF GRACE did undergo stability evaluation in accordance with Coast Guard regulations as a requirement of the vessel's insurance underwriters, the evaluation was only for day-scalloping. The vessel initially failed the intact stability criteria, but passed for day-scalloping operations only if the vessel was configured and operated in accordance with the Naval Architect's restrictions. A comparison of the Naval Architect's restrictions and the operation of the vessel at the time of the incident are noted in the following table.

STABILITY COMPARITIVE ANALYSIS	
Naval Architect restrictions on LADY OF GRACE for ***day scalloping operations only*** to meet the Coast Guard stability standards.	LADY OF GRACE operating conditions for ***stern trawling ground fishing*** at the time of the incident on January 26, 2007. The vessel was never evaluated for meeting the Coast Guard stability requirements for ground fishing and was not required to be due to her length.
1. The vessel must carry 20 tons (40, 000 pounds) of ice in the fish hold.	1. LADY OF GRACE departed port on January 23, 2007, with 8.5 tons (17,000 pounds) of ice in the hold.
2. A ballast water tank shall be kept constructed under the storeroom forward of the engine room and this tank shall be kept full (pressed) at all times. The top of the tank shall be 7'-6" below the main deck at the aft bulkhead	2. Status unknown at the time of the incident.
3. The doors to the compartments on the sides of the house shall be made watertight.	3. The doors were made watertight, and were reported open by initial divers, including the upper portion of the center door.
4. The aft water tank cannot be filled more than 60%.	4. Status unknown at the time of the incident.
5. Trawl nets and doors ***shall not be on the vessel.***	5. Trawl nets and doors ***were on the vessel*** and the vessel had been engaged in stern trawling ground fishing.
NOTES:	
1. Day scalloping operations are limited to a maximum catch of ***400 pounds*** of scallops.	1. The LADY OF GRACE reported via e-mail on January 26, 2007, that she had ***15,000 pounds*** of fish on board the vessel.
2. When conducting day scalloping fisheries the vessel would have had the newly installed 27 foot boom and one single 10 foot side dredge, but no nets and doors for stern trawling...	2. The LADY OF GRACE was outfitted with the newly installed 27 foot boom and nets and doors for stern trawling at the time of the incident, but was not outfitted with the 10 foot scallop side dredge.

Table 4: Comparison of day-scalloping stability restrictions and operations at incident

In January 1999, the Coast Guard chartered a task force to review the current fishing vessel safety program and recommend significant measures to reduce loss of life and vessels, which produced the report "Dying to Fish Living to Fish. Recommendation 4.1 of the report recommended stability requirements for commercial fishing vessels greater than, or equal to 50 feet in length.

2.6 CONCLUSION:

We concur with the task force recommendation to require stability letters for all commercial fishing vessels greater than, or equal to, 50 feet in length.

Section 3 - RECOMMENDATIONS

3.1 Re-evaluate need for stability requirements

Recommend that the Coast Guard re-evaluate the need to amend the applicability requirements in 46 CFR 28.550 to lower the stability requirements for commercial fishing vessels from 79 feet and greater in length to 50 feet and greater in length.

3.2 Review weight of assumed ice

Recommend that the Coast Guard re-evaluate the weight of assumed ice on each surface above the waterline for all fishing vessels as specified 46 CFR 28.550 (b). Additionally, recommend that the Coast Guard re-evaluate the weight of assumed ice on each surface above the waterline for fishing vessels operating North of 42° but South of 66° 30' North latitude or South of 42° but North of 66° South latitude as specified 46 CFR 28.550 (c).

3.3 Review latitude requirement for icing

Recommend that the Coast Guard re-evaluate the latitudes specified in 46 CFR 28.550 that state the weight of assumed ice has to be a factor in stability calculations when a fishing vessel operates north of 42 degrees North latitude. This case highlights the fact that significant ice accumulation occurs south of 42 degrees north latitude.

3.4 Study alternatives to stow life-rafts in cold weather

Recommend that the Coast Guard evaluate the need to study alternatives and provide guidance that makes the commercial fishing vessel operators aware of ways to ensure that inflatable life-rafts and EPIRB are able to function as designed during icing conditions.

3.5 Review Stability Formulas in 46 CFR, Part 28

Recommend that the Coast Guard review the current stability formulas in 46 CFR, Part 28 for accuracy. Although, not a factor in the sinking of the LADY OF GRACE, during the technical review of the LADY OF GRACE casualty the Coast Guard Marine Safety Center discovered typographical errors in 46 CFR, Part 28.

U.S Department of Homeland Security

United States Coast Guard

Commanding Officer
United States Coast Guard
Marine Safety Center

2100 2nd St SW
Washington DC 20593
Staff Symbol: CG MSC-1
Phone: (202) 475-3407
Fax: (202) 475-3920

16710/P013381
Serial: H0-0702049
18 Jul 07

MEMORANDUM

From: [redacted] LCDR
Team Leader, MSC SERT

Reply to Attn of: MSC-1
LCDR Compher
(202) 475-3361

To: L. W. Clayborne, LCDR
SECTOR SOUTHEASTERN NEW ENGLAND, PREVENTION DEPT

Subj: REQUEST FOR STABILITY EVALUATION OF THE SINKING OF F/V LADY OF GRACE, O.N. 599517

1. As requested in various phone calls and email exchanges since late January 2007, a technical analysis was performed to evaluate potential factors that led to the sinking of the LADY OF GRACE, O.N. 599517 on January 26, 2007. Our study concentrated on the evaluation of the vessel's stability incorporating as much information as possible related to weather, sea conditions, assumed loadings, hull modeling, and information supplied by your ongoing investigation.

2. The results of our analysis indicate that icing was likely a dominant factor in the sinking of this vessel. Our research into the environmental conditions that were present on the day of the accident, and our technical evaluation of the likelihood of significant icing given these conditions, show that heavy icing was most likely present on the day of the casualty. These results are consistent with eye-witness accounts from other professional mariners that were nearby on the same day. Our efforts to accurately model all of the exposed surfaces and analyze the stability of the vessel as these surfaces are coated with ice demonstrated that the vessel, in it's assumed loading condition, would only be able to sustain a maximum of 2.25 inches of ice uniformly distributed about these surfaces and still remain upright.

3. Enclosure (1) is a detailed explanation of our assumptions and analysis.

4. If you have questions or need additional information on the details of the analysis performed, please contact LCDR Rob Compher of our staff.

#

Enclosure: (1) LADY OF GRACE Explanation of Analysis & Assumptions

ENCLOSURE (0 1)

ECN 2863457-ME-310

LADY OF GRACE Explanation of Analysis & Assumptions

1. Introduction

a. On January 26, 2007, the fishing trawler LADY OF GRACE capsized during heavy weather conditions while attempting to return to her homeport of New Bedford, Massachusetts. This casualty resulted in the deaths of all four crewmembers onboard the vessel. Sector Southeastern New England requested the assistance of the Marine Safety Center (MSC) in evaluating the stability condition of the vessel and the effects of the environmental conditions at the time of the casualty to determine the contributing factors that likely caused this vessel to capsize.

b. The MSC analyzed two main aspects of this casualty. In the first analysis, available weather information, coupled with known mathematical formulas, was utilized to determine the icing conditions present in the approximate time and location the vessel sank. We found that the LADY OF GRACE was likely experiencing heavy icing, 0.75 inches or more of build up per hour, in the time leading up to her sinking. The Code of Federal Regulations only requires a vessel of this size, operating in this vicinity, to include 0.325 inches of total icing in the stability analysis. Thus, icing conditions likely exceeded the amounts that the vessel was required to be evaluated to by the Code of Federal Regulations.

c. The second part of our analysis was to model the vessel as closely as possible in order to determine how much ice the vessel could accumulate and remain upright. Our computer model capsized once approximately 2.25 inches of ice was applied uniformly to all exposed surfaces above the waterline. We recognize that at the time of the casualty, icing did not likely follow a uniform distribution, with ice accumulating much thicker over areas receiving heavy sea spray, and other areas having little or no icing. In the absence of actual dimensions and distribution of icing at the time of the casualty, the permutations of asymmetric and variable thickness ice loadings are too numerous to reasonably model. However, the use of a uniform distribution provides an order of magnitude for the amount of ice required to capsize the vessel in its assumed casualty loading condition.

2. Information Received

The Marine Safety Center received the following documents that were used to develop the assumptions used in this analysis:

From Sector Southeastern New England:

- Photographs of the LADY OF GRACE taken during a shipyard availability in the Summer of 2006;
- Statement of [redacted] dated April 11, 2007 depicting the weather conditions and icing experienced by the DEBBIE SUE which traveled a route back to New Bedford similar to that followed by the LADY OF GRACE;
- Photographs of the LADY OF GRACE after it was salvaged on April 25, 2007;
- A copy of a transmittal letter from Thomas M. Farrell, Naval Architects, Inc. which included stability instructions and forwarded the Report of Inclining and Stability Calculations.

From Mr. [redacted] of Thomas M. Farrell, Naval Architects, Inc.:

- Inclining Report for the LADY OF GRACE dated May 30, 2006;
- GHS Computer Model;
- Stability Calculations for the LADY OF GRACE dated August 2, 2006;
- An AutoCAD® Drawing of Profile and Deck Plans of the LADY OF GRACE;
- Tank Capacity Tables for the LADY OF GRACE dated March 24, 2006.

3. Vessel Description

The LADY OF GRACE (O. N. 599517) is an uninspected 86.75 foot (Length Overall) by 21.8 foot by 12.6 foot steel single deck stern trawler which sank on 26 JAN 2007 (position 41.53 N 070.29 W). The vessel was built by Master Marine as Hull 209 and delivered in 1978. The vessel was modified during the summer of 2006 to operate as a day boat scallop dragger with a single 10-foot dredge. These modifications included extension of the protective bulwark aft to the gallows, addition of a 27 foot long lifting boom for handling the scallop dredge, and the addition of a ballast tank (in lieu of fixed ballast initially recommended by the naval architect) to compensate for the addition of the 1.1 long ton 10 foot scallop dredge. At the time of the casualty the LADY OF GRACE was not carrying the scallop dredge but was instead rigged for ground fishing.

4. Description of Modifications

a. The following two modifications, made in the vessel's last yard availability in early 2006, are significant because they both increase the vessels weight and vertical center of gravity as well as increase the vessel's wind profile.

b. The new boom installed on the LADY OF GRACE for scalloping was tabernacled to the main mast with a clevis and pin. The boom was 27 feet long, constructed of 6 inch square steel pipe of 3/8 inch wall thickness. The boom also had a safety ladder providing access to the installed blocks and rigging (with fall protection guards) mounted on top of it and running most of the length.

c. The vessel's bulwarks were increased such that the main deck bulwarks were 36 inches high and extended the entire periphery of the main deck to the transom. The shelter deck bulwarks that sit atop of the main bulwarks were extended to run aft from the aft foredeck (just aft of the back of the pilothouse) to just forward of the gallows. The modified bulwarks were fitted with four freeing ports on the port and starboard sides each measuring 24 inches wide by 15 inches tall with guides and gates. The bulwarks were constructed of 6 inch half pipe stanchions with ¾ inch plating mounted opposite ½ inch shell plating.

d. Following these modifications, the owner had the vessel's stability condition reevaluated by Thomas M. Farrell, Naval Architects, Inc.

5. Inclining

a. The LADY OF GRACE was inclined on May 30, 2006 in New Bedford, Massachusetts. At that time, the vessel had completed the installation of the boom for the scallop dredge and the bulwark extension. The inclining report and stability calculations were prepared by Thomas M. Farrell, Naval Architects, Inc. and sent to the owner as attachments to a letter dated July 29, 2006. The results reported by the naval architect are provided in the table below:

Naval Architect's Calculated Lightship Values

Lightship Displacement	150.944	Long Tons
Vertical Center of Gravity	12.206	Feet Above the Baseline
Longitudinal Center of Gravity	2.642	Feet Aft of Midships

b. As part of our casualty analysis, the MSC received the naval architect's electronic General HydroStatics (GHS) geometry file which was used to independently evaluate the results of the inclining experiment and perform stability calculations. In reviewing the file, the MSC found that the port and starboard ramps were deducted from the hull volume twice. As a result of this error, the reported lightship displacement was slightly lower than the actual lightship displacement by approximately 2 ½ percent. The below values were derived using the data from the naval architect's inclining experiment and a corrected GHS model. These values were used for all subsequent calculations in our casualty analysis. This difference on lightship values constituted a small error that did not significantly alter the vessel's stability and had only very minor impact on our analysis.

Marine Safety Center Calculated Lightship Values

Lightship Displacement	154.74	Long Tons
Vertical Center of Gravity	12.18	Feet Above the Baseline
Longitudinal Center of Gravity	2.52	Feet Aft of Midships

6. Initial Static Stability

a. Following the inclining of the LADY OF GRACE, the naval architect performed stability calculations in accordance with 46 CFR 28 for Uninspected Commercial Fishing Vessels and specifically Subpart E (sections 28.500 to 28.580). These stability calculations address five major areas of concern for offshore commercial fishing vessels.

- Intact stability when using lifting gear
- Icing
- Water on deck
- Intact righting energy
- Severe wind and roll

b. The results of these calculations were provided to the MSC by the naval architect, Thomas M. Farrell Naval Architects, Inc. The following excerpt shows the results of the intact stability calculations for the return condition including the winter ice on deck in the amount required by the regulations.

Loading Condition:

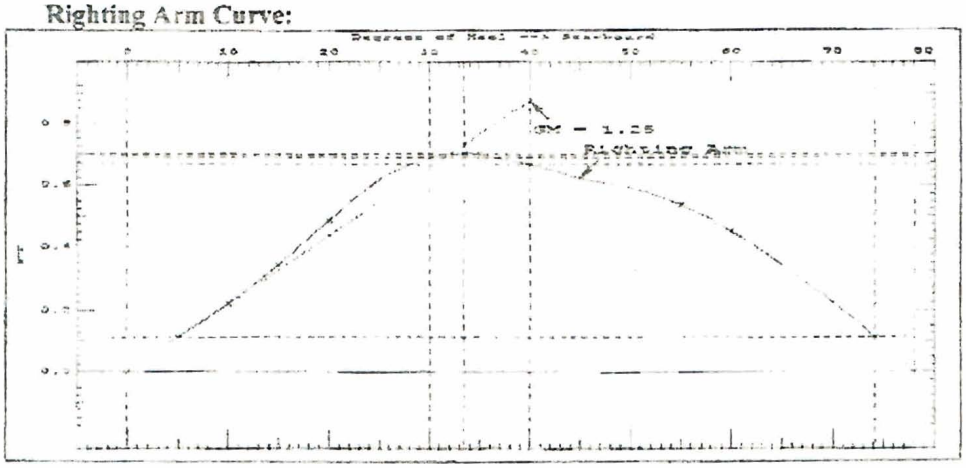
Part			Weight(LT)	LCG	TCG	VCG	
LIGHT SHIP			150.94	2.64a	0.00	10.21	
CREW AND EFFECTS			0.25	18.50f	0.00	15.75	
PROVISIONS			1.00	17.50f	0.00	15.75	
NEW TANK STRUCTURE			1.50	25.50f	0.00	6.08	
PARAVANVES UP			-1.25	7.34f	0.00	40.50	
PARAVANVES DOWN			1.25	7.34f	0.00	20.50	
ICE IN HOLD (60#)			10.71	5.89a	0.00	6.25	
CATCH IN HOLD (100#)			1.00	5.89a	0.00	6.25	
** WATER ICE **			3.46	1.76f	0.00	18.36	
Total Fixed--------->			168.86	2.38a	0.00	11.75	
	Load	SpGr	Weight(LT)	LCG	TCG	VCG	RefHt
FW_TANK.P	0.200	1.000	2.96	28.80a	3.99p	6.71	-7.46
FW_TANK.S	0.200	1.000	2.96	28.80a	3.98s	6.71	-7.46
FO_TANK#1.P	0.200	0.870	3.84	8.32f	7.42p	4.73	-5.93
FO_TANK#1.S	0.200	0.870	3.84	8.32f	7.42s	4.73	-5.95
HO_TANK.P	0.600	0.924	0.33	22.00f	3.75p	10.16	-11.79
LO_TANK.S	0.600	0.924	0.34	1.25f	5.00s	8.51	-10.32
BALLAST.C	1.000	1.000	8.66	25.45f	0.00	4.61	
Total Tanks--------->			23.13	5.43f	0.01p	5.87	
Total Weight-------->			192.00	1.44a	0.00	10.96	

46 CFR 28.570 & 28.575 Stability Criteria:

LIM	USCG_28.570_INTACT_RIGHTING_ENGERY	Min/Max		Attained	
(1)	GM Upright	>	1.25	Ft	1.25 P
(2)	Righting Arm at MaxRA	>	0.66	Ft	0.70 P
(3)	Angle from abs 0 deg to MaxRA	>	25.00	deg	33.53 P
(4)	Area from 0 deg to abs 30	>	10.30	Ft-deg	10.62 P
(5)	Area from 0 deg to abs 40 or Flood	>	16.90	Ft-deg	17.52 P
(6)	Area from abs 30 deg to abs 40 or Flood	>	5.60	Ft-deg	6.90 P
(7)	Angle from abs 0 deg to RAzero	>	60.00	deg	77.96 P
	Relative angles measured from 0.060				

LIM	USCG_28.575_SEVERE_WIND_AND_ROLL	Min/Max		Attained	
(1)	Absolute Angle at Equilibrium	<	14.00	deg	14.00 P
(2)	Res. Ratio from Roll to abs 50 deg or Flood	>	1.000		2.244 P
(3)	Residual Area Ratio from Roll to RAzero	>	1.000		2.808 P

Righting Arm Curve:



c. The LADY OF GRACE passed the intact stability requirements of 46 CFR Part 28 for this loading condition marginally. For each of the required metacentric heights

(GM) and righting area criteria, the vessel met the minimum requirement. For the icing required in this "worst case" loading condition, the requirements of 28.550 only call for a calculation of 0.325 inches of ice on each exposed surface as part of the loading condition. As demonstrated later in the analysis, the environmental conditions present at the time of the casualty created the potential for significantly more icing to be present.

d. The letter of transmittal sending these calculations to the owner of the vessel included specific limitations and restrictions in loading of the vessel to ensure the vessel would meet all of the 46 CFR requirements during a typical scalloping trip. These restrictions are reproduced in the following figure:

Text From Stability Calculation Transmittal Letter

With this data we have run a standard set of intact stability conditions comparing the vessels' stability characteristics with the current USCG intact stability criteria

Operating as a day boat scallop dragger with a single 10-foot dredge the subject vessel passes the stability criteria when operated as shown in the condition sheets with the following restriction:

1. The vessel must carry 20 tons of ice in the fish hold:
2. A ballast water tank shall be kept constructed under the storeroom forward of the engine room and this tank shall be kept full (pressed) at all times. The top of the tank shall be 7'-6" below the main deck at the aft bulkhead.
3. The doors to the compartments on the sides of the house shall be made watertight.
4. The aft water tank cannot be filled more than 60%
5. Trawl nets and doors shall not be on the vessel.

These stability calculations are only valid for the vessel operating as a day boat scallop dragger. This stability letter is not valid for running in any other fishing operation

7. Environmental Conditions and Vessel Icing

a. The extent of vessel icing can be predicted based on four independent factors: air temperature, water temperature, wave height, and wind speed.

b. The weather on January 26, 2007 was deteriorating due to an offshore low to the southeast of New England. A search for available historic weather data in the vicinity of the casualty site resulted in six stations within a 50 mile distance, though it should be noted that not all stations had complete records available. The table below summarizes the recovered weather data for the estimated timeframe of the casualty.

Weather Station Data Summary

Station	LAT	LON	Distance (nm)	Air Temp (°F)	Average Wind Speed (kts)	Wind Gust (kts)	Wind Dir	Significant Wave Height (ft)	Wave Period (sec)	Wave Dir	Water Temp (°F)
Menauhant, MA	41.55	-70.55	11.7	16.7	-NA-	-NA-	-NA-	-NA-	-NA-	-NA-	-NA-
Martha's Vineyard, MA	41.34	-70.56	16.7	12.4	14.8	-NA-	310.7	3.9	8.1	242	38.3
5051 A SE CAPE COD	41.26	-69.29	47.7	16.9	28.8	35.4	309	9.7	7.14	-NA-	44.4
Nantucket Island, MA	41.29	-70.10	17.0	-NA-	-NA-	-NA-	-NA-	-NA-	-NA-	-NA-	33.6
NOAA Data Buoy 44018	41.26	-69.29	47.9	17.1	28.0	35.6	315	9.2	5.5	-NA-	44.4
Woodshole, MA	41.50	-70.70	18.5	-NA-	-NA-	-NA-	-NA-	-NA-	-NA-	-NA-	35.4

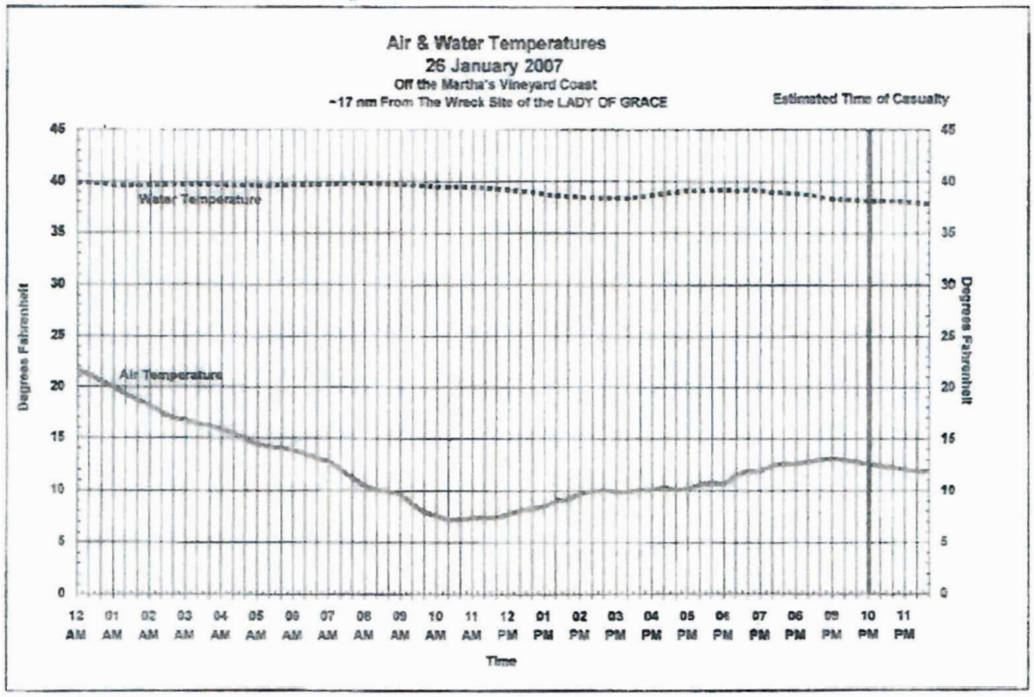
8. Temperature

a. The air temperature in the area of Nantucket Sound was dropping quickly from around 20 degrees Fahrenheit at midnight of January 25, 2007 to around 7 degrees Fahrenheit at noon on January 26, 2007. The air temperature near the time of the casualty, approximately 2200 EST, had risen to around 12 degrees Fahrenheit.

b. The water temperature followed a similar pattern, but with a much smaller shift of only 2 degrees Fahrenheit. The figure below plots the temperatures over time for January 26, 2007.

c. An air temperature of 12.4 degrees Fahrenheit and a water temperature of 38.1 degrees Fahrenheit were chosen to determine the susceptibility of icing due to weather conditions near the time the vessel was thought to have been lost.

Air & Water Temperatures around the Time of the Casualty



9. Waves

a. Wave data was available from two main sources; the Martha's Vineyard Coastal Observatory Data System (MVCODS) and the Jason-1 Satellite observations. The only source of directional information for waves was from the MVCODS data as shown in the Weather Station Data Summary above. This measuring station is within 17 nm of the location of the wreck of the LADY OF GRACE and has comparable depth of water to the site that the vessel was recovered. As a result, the wave direction and wave period were taken directly from the MVCODS data. The significant wave height however was modified based on:

- The reported Jason-1 data which provides a wide area look at the changes in significant wave height due to location; and,

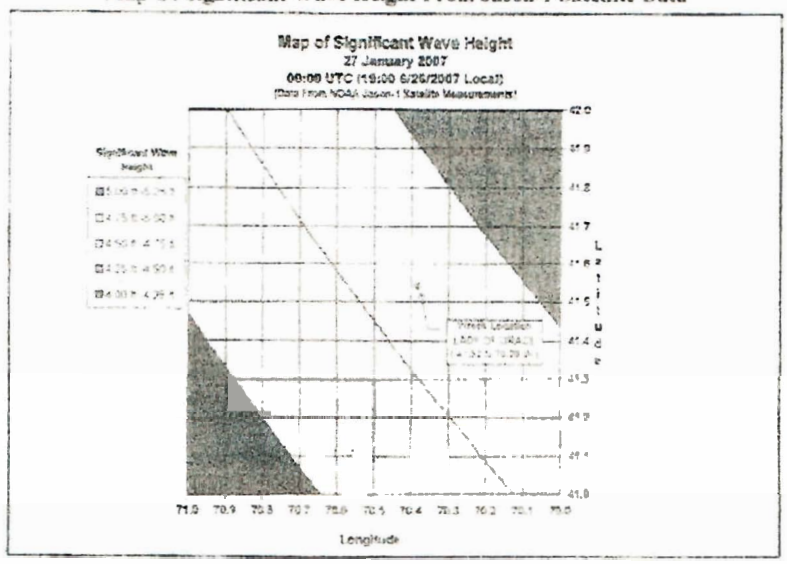
- The eye witness statement of Mr. [redacted] who was aboard the fishing vessel DEBBIE SUE which followed essentially the same course as the LADY OF GRACE had just hours before.

b. Jason-1 data is summarized in the figure below. The data from Jason-1 was downloaded from the NOAA National Oceanographic Data Center. A two dimensional interpolation function was used in Excel to fill in the latitude / longitude grid. The plotted position of the wreck of the LADY OF GRACE is shown by the red dot in the figure. The position lies almost at the middle of the 4.5 foot to 4.75 foot band for significant wave heights and so indicates a significant wave height of approximately 4.6 feet which is greater than the observed wave height at the Martha's Vineyard Coastal Observatory but still much lower than the anecdotal wave height provided by Mr. Sawyer.

c. In his account of the passage of the DEBBIE SUE, Mr. [redacted] states, "Although seas subsided quite a bit, they still were 4-7 feet on the east half of the sound with the occasional bigger swell." This statement supports the significant wave height data. The significant wave height of 4.6 feet represents the root mean square value of the wave heights, not the maximum value. The expected highest wave out of 100 consecutive waves (which will occur over 680 seconds or 11.3 minutes of time) is 7.5 feet (over 1.8 hours, the vessel would expect to see an 8.5 foot maximum wave height, and over 18.8 hours, the expected maximum would be 10.2 feet). It is not surprising that Mr. [redacted] impression of the sea state was between 4 and 7 feet since these would be the most prevalent wave sizes.

d. The calculations performed in this investigation use a range of wave heights from 4 to 7 feet.

Map Of Significant Wave Height From Jason-1 Satellite Data



10. Wind

a. The wind speeds in the Weather Station Data Summary above have an apparent disagreement, with the stations to the East indicating average wind speeds around 28 knots while the Martha's Vineyard site indicated winds of only around 15 knots. The

direction of the wind was consistent between the three stations and was from approximately 311 degrees true. The reduction in wind speed at the Martha's Vineyard station was likely due to sheltering from the island. The winds coming from the North West were blocked by the island before they reach the station which is located in the Southeast corner. Since the LADY OF GRACE was at the Western end of Nantucket Sound, it would have also been shielded somewhat by the surrounding land features. A wind speed of 20 knots was considered reasonable as a maximum wind speed for use in our stability analysis.

b. The wind speed is additive to the LADY OF GRACE's self generated wind from her forward motion at 6.5 knots. The resultant relative wind experienced by the vessel was 26.0 knots from 36.3 degrees off the starboard bow. The portion of the wind acting against the lateral plane area of the vessel was 8.5 knots. This lateral wind force is used to calculate the rate of ice growth using an equation that follows later in this report.

11. Icing

a. For marine purposes, ice accretion may be defined as the accumulation of ice formed on exposed structural components of ships or structures above the water surface either on the coast or at sea.

b. The accumulation of ice on small vessels has the potential of causing serious handling problems, leading to instability and capsizing. This is particularly true of fishing trawlers which may have tons of fish and water shifting about in their holds. Vessel icing can occur when the following environmental conditions are present:

- High Wind Speed - Usually above 18 knots, but sometimes can be lower
- Low Air Temperature - Below freezing, typically in the range of 0° to 32°F
- Low Water Temperature - Usually less than 48°F

c. Sea spray generation also depends on the wave height and period between waves. Waves, in turn, depend on the duration of the wind and fetch. Generally, the higher the wind speed for a particular critical temperature range, the greater the amount of ice accumulation.

d. The critical air temperature range for icing is between 0°F and 32°F. At temperatures below 0°F, the spray striking the structure will usually be in the form of non-adhering small dry ice crystals. The critical range of sea surface temperatures is between 28°F and 48°F. Seawater of normal salinities will generally freeze if it reaches temperatures below 28°F. The upper value of 48°F is not an impediment to freezing since sea spray can be cooled rapidly when the air temperatures are below 28°F.

e. The table below lists the typical threshold seas and winds at which ice accretion will begin for different vessel lengths. With the air temperatures dropping quickly, coupled with the fact that the LADY OF GRACE is approximately 80 feet in length, the studies indicate that icing can be expected to begin as wave heights reached approximately 3.9 feet and winds reached approximately 14.4 knots sustained.

Threshold Wind Speeds & Significant Wave Heights for Icing

Parameter						
Vessel Length (ft)	49	98	164	246	328	492
Significant wave height - $h_{1/3}$ (ft)	2	3.9	6.6	9.8	13.1	19.7
Wind Speed (kts) with a 108 nm fetch	9.7	14.4	19	24.3	29.3	38.9

f. In addition to spray blown from the wave caps, there is self generated spray caused by the vessel's motion through the water. The design of the vessel's hull will affect the amount of normal spray that is generated at any particular speed such that the total rate of ice accretion will also be affected by the design and loading of the vessel, her heading and speed relative to waves, and the relative wind.[1] Together, these factors determine which part of the vessel will be most exposed.

g. Heading and speed will affect the encounter wave period and if the dominant sea state wavelength approaches the vessel's length, vertical motion will be generated between the vessel and the sea, generating additional wave-generated sea spray. The amount of spray generated by a vessel depends on the ocean wave field, the vessel length, the vessel's sea keeping characteristics, inherent stability, freeboard, hull shape, and vessel heading and speed relative to the wave field.

h. After ice begins to accumulate on a vessel, the accumulation of ice itself will increase the rate of further accumulation. The ice already formed increases the effective cross sectional area of exposed rigging, mast, rails, and antennae.

i. In addition to the environmental factors discussed above, the severity of sea-spray icing depends on vessel characteristics. Icing can only occur when there is a source of water for wetting the deck, superstructure and other exposed parts of a ship. Many of the factors affecting ice accretion are in the direct control of the master of the vessel. These include:

- Ship Speed
- Ship Heading (with respect to wind, waves and swell)
- Ship Handling
- Ship Freeboard
- Ship Cold Soaking[2]

j. The NOAA's Marine Modeling and Analysis Branch of the Environmental Modeling Center (NCEP) Superstructure Ice Accretion Forecast System provides icing predictions based on computer program results which are run every six hours. Ice accretion predictions are disseminated through the Global Telecommunication System (GTS) and Advanced Weather Interactive Processing System (AWIPS). Ice accretion is depicted via these means year-round for forecast projections from 0000 to 1800 hours at 3 hour intervals on the 0000, 0600, 1200, and 1800 Coordinated Universal Time (UTC) cycles on AWIPS.

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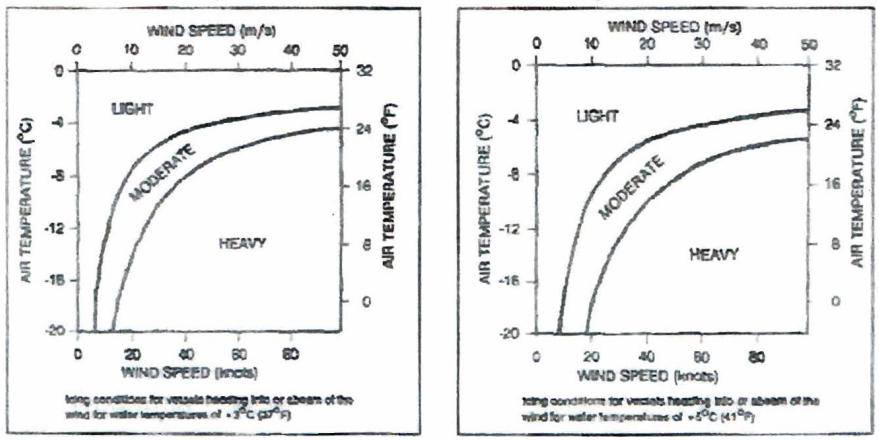
[1] Sechrist, F.S., Fett, R.W., & Perryman, D.C., "Forecaster's Handbook for the Arctic", Naval Environmental Prediction Research Facility, 1989.

[2] The Forecaster's Handbook for the Arctic defines "cold soaking" as long term exposure of the ship to subzero temperatures and near freezing seas. The ship is considered cold soaked when the heat loss rate drops to the same point as the heat production rate. A cold soaked ship traveling into warmer water temperatures would still be cold enough to accumulate icing, if the other necessary factors are present.

Icing Curves for Two Sea Water Temperatures[3]



Light Icing - Less than 0.7 cm/hr (0.3 in/hr)
Moderate Icing - 0.7 cm/hr (0.3 in/hr) to 2.0 cm/hr (0.8 in/hr)
Heavy Icing - Greater than 2.0 cm/hr (0.8 in/hr)

k. The model used by NOAA for icing prediction was adopted in 1990 and has been a reliable indication of icing as well as icing amounts. The relationship is:

$$PPR = \frac{V_a(T_f - T_a)}{1 + 0.3(T_w - T_f)}$$

Where:

PPR is the Icing Predictor (m°C/s)
V_a is wind speed (m/s)
T_f is the freezing point of seawater (usually -1.7°C to -1.8°C)
T_a is the air temperature (°C)
And T_w is the sea water temperature (°C)

l. When this calculation is performed for the case of the LADY OF GRACE with air temperature 12.4°F, sea water temperature of 38.1°F, sea water freezing point 28.8°F, and wind speed of 26 knots, the PPR value is 47.6. From the following chart, this PPR values corresponds to the Heavy Icing Class, where more than ¾ inches per hour of ice build-up may occur.

Correlation of Icing Prediction Index and Icing Rates

	Icing Class			
	Light	**Moderate**	**Heavy**	**Severe**
Icing Predictor (PPR) (m°C/s)	< 20.6	20.6 – 45.2	> 45.2	> 70.0
Icing rate (in/hr)	< ¼	¼ – ¾	> ¾	

[3] Graphics and formula taken from Overland, J. E., "Prediction of Vessel Icing for Near Freezing Sea Temperatures", 1989.

12. Vessel Condition at the Time of the Casualty

a. The LADY OF GRACE was attempting to return to New Bedford, MA via Nantucket Sound due to worsening weather conditions. At that time, she was in the middle of a ground fishing trip which began three days earlier. She had reported via e-mails that day that there were 15,000 pounds of fish on board the vessel. The vessel had embarked on the trip with 17,000 pounds of ice in the hold. Based on conversations with the lead Investigating Officer (IO) for this case, it was assumed that 75% of the ice was remaining at the time of the casualty. The weight of the crew and effects and provisions were taken from the stability report prepared by Thomas M. Farrell, Naval Architects, Inc.

b. Tank loads were assumed to be the same as those given in the "Half-trip 50% Catch" loading condition found in Thomas M. Farrell, Naval Architects, Inc. "Stability Calculations for the LADY OF GRACE," dated August 2, 2006 and provided in the table below.

c. The LADY OF GRACE was fitted with a paravane roll damping system ("Flopper-Stoppers") consisting of two 40-foot pin connected masts, one port and one starboard, mounted outboard and aft of the pilothouse. Each was fitted with a stabilizing boom mounted with one end on the mast approximately eight feet above the mast mounting foundation and the other end mounted on the deck edge at the front of the pilothouse approximately 16 feet forward of the mast foundation. Each mast supported a 150 pound nose heavy flat plate paravane ("fish") which is towed from the ends of the masts on wire rope and controlled by dedicated rigging. The combined weight of the system is 1.25 long tons as reported in Thomas M. Farrell, Naval Architects, Inc. "Stability Calculations for the LADY OF GRACE," dated August 2, 2006. For the purposes of our analysis, the paravane masts were assumed to be at angle of 10.5 degrees above horizontal which placed the ends of the masts approximately 23.5 feet above the calm water level. With the masts in this position, the vessel could roll approximately 26 degrees before the mast tip would begin to enter the water.

Assumed Tank Loading Used for Analysis:

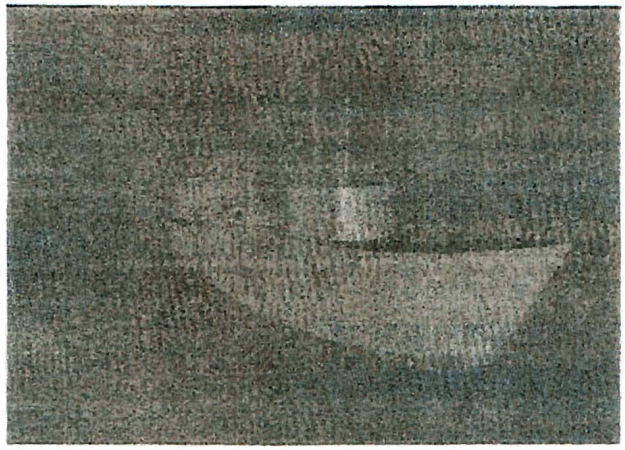
Tank	Contents (Specific Gravity)	Capacity (Gallons/ Percent Full)	Assumed Loading Percentage	Gallons in Tank at the Time of the Casualty	Weight of Liquid in Tank (Long Tons)
Forepeak	Fresh Water (1.000)	1,800 (100%)	50%	900	3.34
Hydraulic Oil	Hydraulic Oil (0.924)	446 (95%)	80%	357	1.43
Ballast Bottom	Fresh Water (1.000)	2,400 (100%)	100%	2,400	8.91
Port Fuel Oil	Diesel Oil (0.870)	5,617 (95%)	60%	3,370	14.38
Starboard Fuel Oil	Diesel Oil (0.870)	5,617 (95%)	60%	3,370	14.38
Lube Oil	Lube Oil (0.924)	245 (95%)	80%	196	0.79
Port Potable Water	Fresh Water (1.000)	3,967 (100%)	50%	1,984	7.37
Starboard Potable Water	Fresh Water (1.000)	3,967 (100%)	50%	1,984	7.37

Fixed Loading Used For analysis:

	Weight (LT)	LCG (ft)	TCG (ft)	VCG (ft)
LIGHT SHIP	154.74	2.52a	0.00	12.18
CREW AND EFFECTS	0.25	18.50f	0.00	15.75
PROVISIONS	1.00	17.50f	0.00	15.75
NEW TANK STRUCTURE	1.50	25.50f	0.00	6.08
PARAVANVES UP	-1.25	7.34f	0.00	40.50
PARAVANVES DOWN	1.25	7.34f	0.00	20.50
ICE IN HOLD (75%)	5.69	5.89a	0.00	6.25
CATCH IN HOLD (50%)	6.69	5.89a	0.00	6.25
Total Fixed--------->	**169.88**	**2.37a**	**0.00**	**11.62**

13. Vessel Geometry

The model for the LADY OF GRACE was built starting with the hull form provided by Thomas M. Farrell Naval Architects, Inc. From there, details of the superstructure and rigging were added based upon supplied photos. In order to accurately account for the precise location of icing on surfaces, it was important to build as much known detail into the model as possible. The following figure shows the finished MSC computer model in the pre-ice condition:

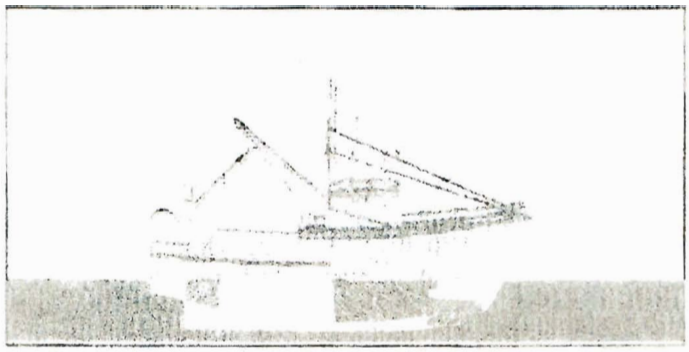


14. Icing Analysis

a. A model analysis was conducted to determine exactly how much icing would cause the vessel to capsize. Since the actual distribution of ice was not known, a uniform distribution was applied to all surfaces above the waterline. In reality, there were likely areas that had much heavier amounts of ice than our model, and conversely, some areas with far less.

MSC Computer Model in Iced Condition (green surfaces denote ice)

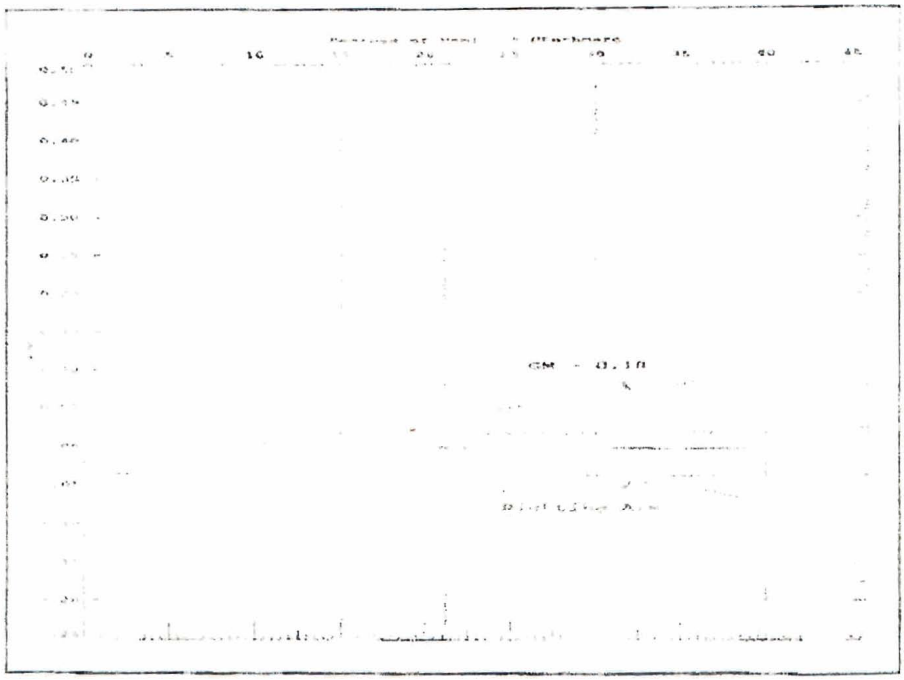
Sample Profile view GHS output (horizontal red lines denote iced surfaces)



b. It was determined that the maximum amount of icing that this vessel could sustain for this assumed loading condition and still remain upright in calm seas would be 2.25 inches. This results in a total addition of 40.7 LT of weight with an aggregate center of gravity 19.5 feet above the baseline and 5.4 feet aft of midships. When compared with the required icing loads used in the naval architect's calculations, this number represents a case that is nearly 12 times more severe than the anticipated amount of icing required by 46 CFR 28.550. It is noted that ice accumulation was likely much greater than 2.25 inches over certain portions of the vessel based on statements from crewmembers on other vessels that were operating in similar weather environments on the day of the casualty.

c. The following shows the righting arm curve for the assumed loading condition with a uniform coating of 2.25 inches of ice. It is noted from the curve that the vessel has taken on a 9 degree list to starboard. GM is 0.18 ft, and there is less than 0.15 ft-degrees of residual righting energy. At this point, the vessel would be likely to capsize in any significant sea state or winds.

Post Icing Righting Arm Curve



15. Conclusions & Recommendations

a. The results of our analysis indicate that icing was likely a dominant factor in the sinking of this vessel. Our research into the environmental conditions that were present on the day of the accident, and our technical evaluation of the likelihood of significant icing given these conditions, show that heavy icing was most likely present on the day of the casualty. These results are consistent with eye-witness accounts from other professional mariners that were nearby on the same day. Our efforts to accurately model all of the exposed surfaces and analyze the stability of the vessel as these surfaces are coated with ice demonstrated that the vessel, in it's assumed loading condition, would only be able to sustain a maximum of 2.25 inches of ice uniformly distributed about these surfaces and still remain upright.

b. The results of this analysis are limited by the assumptions that were made regarding the environmental conditions, vessel geometry, and vessel loading. However, it can still be concluded with relative confidence that icing was likely a dominant factor in the casualty.

Evidence Index F/V LADY OF GRACE Casualty:

CONTROL #	DISCRIPTION OF EVEDENCE
2863457-MF-001	CG-2692 Report of Marine Accident Injury or Death
2863457-MF-002	Marine Surveyor Condition and Evaluation Report (May 22, 2006)
2863457-MF-003	USCG Fishing Vessel Exam documentation
2863457-MF-004	Charted track-line for LADY OF GRACE prior to incident
2863457-MF-005	LADY OF GRACE General Arrangements
2863457-MF-006	Stability Letter for the LADY OF GRACE
2863457-MF-007	January 26, 2006 Weather Forecast (12:14 PM)
2863457-MF-008	January 26, 2006 Weather Forecast (4:07 PM)
2863457-MF-009	Statement from Master of LISA ANN II
2863457-MF-010	Enclosure # 01 Marine Safety Center Stability Evaluation
2863457-MF-011	LADY OF GRACE EPIRB test log
2863457-MF-012	LADY OF GRACE Safety and Orientation log
2863457-MF-013	LADY OF GRACE Emergency drills log
2863457-MF-014	Massachusetts State Police report
2863457-MF-015	Statement from repair electrician (previous casualty)
2863457-MF-016	Invoice for dive inspection services following previous casualty
2863457-MF-017	CG-2692 Report of Marine Accident Injury or Death for previous casualty
2863457-MF-018	Timeline documentation from BOATRACS
2863457-MF-019	MISLE Critical Profile for LADY OF GRACE
2863457-MF-020	Excerpt from 46 CFR 28.500 (2005) Stability Applicability
2863457-MF-021	Invoice for fabrication and installation of new ballast tank
2863457-MF-022	Autopsy report for Antonio Barroqueiro OCME # 2007 - 2277
2863457-MF-023	Autopsy report for Mario Farinhas OCME # 2277 - 4255
2863457-MF-024	January 23, 2006 Weather Forecast (3:59 PM)
2863457-MF-025	USCG boarding report conducted January 08, 2007
2863457-MF-026	Marine Surveyor Suitability for Service Report (July 24, 2006)
2863457-MF-027	Statement from Master of DEBBIE SUE
2863457-MF-028	BOATRACS Latitude and Longitude trip log
2863457-MF-029	Photographic documentation
2863457-MF-030	NMFS trip fact sheet
2863457-MF-031	MISLE Activity Summary Report # 2647381 (Fishing Vessel Exam)
2863457-MF-032	MISLE Activity Summary Report # 2647392 (Fishing Vessel Exam)
2863457-MF-033	Charted track-line for DEBBIE SUE
2863457-MF-034	Satellite phone record for LADY OF GRACE
2863457-MF-035	Timeline from Marine Safety Consultants or modifications
2863457-MF-036	USCG Investigator Statement of Findings of Fact not listed in evidence
2863457-MF-037	Fairhaven Shipyard invoice for haul and hold to perform stability measurements
2863457-MF-038	Fairhaven Shipyard invoice for deteriorated hull plate repairs
2863457-MF-039	Fairhaven Shipyard for transducer and keel repair
2863457-MF-040	Summary of events by Southeastern Massachusetts Law Enforcement Council (SEMLEC)
2863457-MF-041	Stability calculations for LADY OF GRACE
2863457-MF-042	Line diagram of maintenance & modification events
2863457-MF-043	COTP letter for wreck removal

ENCLOSURE (02)