UNITED STATES COAST GUARD

INVESTIGATION INTO THE EXPLOSION AND SINKING OF
THE CHEMICAL TANKER

BOW MARINER

IN THE ATLANTIC OCEAN ON FEBRUARY 28, 2004
WITH LOSS OF LIFE AND POLLUTION

U.S. Department of Homeland Security

United States Coast Guard

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DEC 14 2005

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COMMANDANT'S ACTION ON THE INVESTIGATION

The record and the report of the investigation into 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.

COMMANDANT'S ACTION ON THE RECOMMENDATIONS

Investigating Officer's Recommendation 1: Recommend a copy of this report be provided to the following entities:

1. The governments of Greece, the Philippines and Singapore.
2. Odfjell Asia II PTE, Ltd.
3. Ceres Hellenic Ship Enterprises, Ltd.
4. The International Maritime Organization
5. INTERTANKO
6. The International Chamber of Shipping
7. The American Bureau of Shipping (ABS)
8. Det Norske Veritas (DNV)

Action: We concur with this recommendation. We will forward copies of this report as recommended.

Investigating Officer's Recommendation 2: Recommend 46 CFR Part 4 be revised to reflect the addition of Subparagraph (d)(2) to 46 U.S.C. 6101 in 1992 and Subparagraph (g) to 46 U.S.C. 6101 in 2002.

Action: We concur with this recommendation. A rulemaking project is already underway that proposes amendments to 33 CFR Part 151 and 153 and to 46 CFR Part 4 to implement the

provisions of 46 USC 6101(d)(2). A Notice of Proposed Rulemaking was published in the Federal Register (65 FR 65808) on November 2, 2000. A Final Rule will be published soon. The addition of subparagraph (g) to 46 USC 6101 occurred after the rulemaking project was initiated. A new rulemaking project to implement subparagraph (g) will be initiated when the current project has been completed.

Investigating Officer's Recommendation 3: Recommend 46 CFR Part 32.53, Inert Gas Systems, be revised to require the inerting of all cargo tanks carrying flammable cargoes aboard vessels equipped with Inert Gas Systems, regardless of the vessel's date of build.

Action: We do not concur with this recommendation. Inert Gas System (IGS) requirements are not determined solely by the age of the vessel. Even if BOW MARINER had been built after 1986, no IGS use would have been required because of its tank size and washing machine capacity. Currently, IGS requirements do not apply to chemical tankers because the inert gas could contaminate chemical cargoes. For example, carbon dioxide produced as an inerting agent can drive certain cargoes off specification. Additionally, there are other chemical cargoes shipped with inhibitors that react with oxygen in the tank to prevent the cargo from undergoing unwanted reactions, and displacement of the oxygen through inerting can cause the breakdown of those inhibitors required to prevent these reactions.

Investigating Officer's Recommendation 4: Recommend that Ceres review their internal policies and procedures concerning workforce interaction and cooperation, including but not limited to delegation of appropriate duties to qualified officers.

Action: We concur with the intent of this recommendation. We will forward of a copy of this investigation report to Ceres for review and action as appropriate.

Investigating Officer's Recommendation 5: Recommend the Commandant approach the International Maritime Organization, the International Chamber of Shipping and INTERTANKO about forming a study group to examine the causes of all tank vessel explosions in the last five years involving tank cleaning to search for common factors.

Action: We concur with the intent of this recommendation. We will submit this issue to the International Maritime Organization's Flag State Implementation (FSI) Subcommittee, which has a standing Working Group on Casualty Analysis, and propose that the Subcommittee include a study of tank vessel explosions involving tank cleaning in the terms of reference for the Working Group. We anticipate participation by the International Chamber of Shipping and INTERTANKO in the study.

Investigating Officer's Recommendation 6: Recommend Commandant send a message to all marine safety field units emphasizing the importance of randomly verifying a tank vessel's compliance with its SMS for tank cleaning, confined space entry and tests and inspections of equipment.

Action: We do not concur with this recommendation. Routine and random Port State Control examinations do not probe to this level of detail. It is the responsibility of the flag state to ensure

that vessels comply with their SMS and have established appropriate procedures for tank cleaning, confined space entry and tests and inspections of equipment. Nevertheless, we have placed a note in the Marine Information for Safety and Law Enforcement (MISLE) records of all vessels associated with the operator of the BOW MARINER to highlight these potential concerns.

Commander, Fifth Coast Guard District's Recommendation: The Investigating Officer's narrative highlights numerous unsafe practices that may be employed by others in the maritime industry. The District recommends that this report be distributed throughout the maritime community in an effort to promote safe practices aboard ships.

Action: We concur with this recommendation. This report will be made available to the maritime industry, as well as to the general public, via the Internet. In addition, it will be submitted as an information paper to the International Maritime Organization's Maritime Safety Committee.

COMMENTS BY THE MARITIME AND PORT AUTHORITY OF SINGAPORE

Singapore was the flag state of the BOW MARINER, and the U.S. Coast Guard (USCG) requested the Maritime and Port Authority of Singapore (MPA) to review and comment on the Investigating Officer's draft report. MPA provided comments on the draft report, and the report was appropriately revised. MPA's comments and recommendations were provided to USCG with the following understandings: 1) they do not constitute findings of fact by MPA; 2) they are based solely on the investigation conducted by the USCG; 3) they are provided to the USCG for its consideration for use in its report, and 4) the USCG drew its conclusions and made its recommendations independently and without relying on MPA's comments, suggestions and recommendations. The MPA also offered the nine recommendations below:

1. It is recommended that the Company develop ship specific oil and chemical "Cargo and Ballast Operation's Manuals" with separate procedures for oil and chemical tanker operations.

2. It is recommended that the Company review the statement emphasizing the master's authority to align it with the ISM objectives.

3. It is recommended that the Company have a special audit of the SQEMS by the classification society. To make the audit more focused, the classification society should be given in advance the deficiencies found during the investigation of the Bow Mariner incident.

4. It is recommended that the Company take measures to improve the shipboard social culture to ensure social cohesiveness.

5. It is recommended that the Company debrief the signed-off crew in Greece/Philippines to obtain feedback on shipboard safety culture, social cohesiveness, and operations.

6. It is recommended that the Company emphasize the importance of crew cohesiveness to senior Greek officers in the fleet through proper training programs, e.g., team building.

7. It is recommended that the Company develop procedures for entry into contaminated tanks as required in section 3.5 of the Tanker Safety Guide – Chemicals.

8. It is recommended that the Company monitor work/rest periods of Chief Officers so as to ensure that they are not affected by fatigue and remain fit for duty.

9. It is recommended that the Company ensure crew familiarization and compliance with overlap time requirements during crew changes in accordance with the ISM procedures.

COMMANDANT'S ACTION ON SINGAPORE'S COMMENTS

Action: We concur with the comments and recommendations of the Maritime and Port Authority of Singapore. By assisting and cooperating with the USCG in the investigation of this accident, Singapore has fulfilled its responsibilities under the International Maritime Organization's (IMO) Code for the Investigation of Marine Casualties and Incidents. We encourage all IMO member states to do the same when appropriate.

W. D. Rabe
By direction

Report on the Explosion and Sinking of the Chemical Tanker BOW MARINER in the Atlantic Ocean on 28 February 2004

With Loss of Life and Pollution

Prepared by:
U.S. Coast Guard
Marine Safety Office
Hampton Roads, Virginia

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Abbreviations

ABS	American Bureau of Shipping
BCH	Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk
CAR	Corrective Action Request
CCR	Cargo Control Room
COPM	Company Operating Procedures Manual
DNV	Det Norske Veritas
DOC	Document of Compliance
EEZ	Exclusive Economic Zone
EPIRB	Emergency Position Indicating Radio Beacon
FOPM	Fleet Operating Procedures Manual
HFO	Heavy Fuel Oil
IBC	International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk
IGS	Inert Gas System
ISGOTT	International Safety Guide for Oil Tankers & Terminals
ISM	International Safety Management Code
LEL/LFL	Lower Explosive Limit/Lower Flammable Limit
LFO	Light Fuel Oil
MARPOL	International Convention for the Prevention of Pollution from Ships
MPA	Maritime and Port Authority
MTBE	Methyl-Tert Butyl Ether
NLS	Noxious Liquid Substance
SMC	Safety Management Certificate
SMS	Safety Management System
SQEMS	Safety, Quality and Environmental Management System
SQMM	Safety and Quality Management Manual
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
UEL	Upper Explosive Limit

Summary

At 1805[1] on Saturday, 28 February 2004 the chemical tanker BOW MARINER caught fire and exploded while the crew was engaged in cleaning residual Methyl Tert Butyl Ether (MTBE) from cargo tank number eight starboard. The ship sank by the bow at 1937 in position 37-52.8N/ 074-15.3W, about 45 nautical miles east of Virginia. Of the 27 crewmembers aboard, six abandoned ship and were able to make it to an inflatable life raft and were rescued by the Coast Guard. An unknown number of other crewmembers abandoned ship to the water. The Coast Guard and Good Samaritan vessels recovered three of these crewmen from the water, one deceased. The other two died before reaching a hospital. 18 crewmen remain missing and are presumed dead. The vessel's cargo of ethyl alcohol (3,188,711 gallons) was released, along with the vessel's heavy fuel oil (192,904 gallons), diesel fuel (48,266 gallons) and slops (quantity unknown).

The cause of this casualty was the ignition of a fuel/air mixture, either on deck or in the cargo tanks, that was within its flammable limits. The ignition source could not be precisely determined.

Contributing to this casualty was the failure of the operator, Ceres Hellenic Enterprises, Ltd., and the senior officers of the BOW MARINER, to properly implement the company and vessel Safety, Quality and Environmental Protection Management System (SQEMS).

Jurisdiction

The BOW MARINER exploded and sank off the coast of Virginia, within the U.S. Exclusive Economic Zone (EEZ), resulting in the total loss of the ship, loss of life and severe pollution; therefore, this casualty is a *very serious casualty* as defined in IMO Resolution A.849(20), "Code for the Investigation of Marine Casualties and Incidents" (hereinafter the "Code"). In accordance with Section 4.11 of the Code, Greece, the Philippines and the U.S. are *substantially interested states*, and Singapore was initially the *lead investigating state*. Accordingly, the Coast Guard made immediate notifications to Greece, the Philippines and Singapore. On 29 February 2004 the Maritime and Port Authority (MPA) of Singapore verbally designated the U.S. as *lead investigating state* in accordance with Article 7 of the Code, followed by written authority in a letter dated 14 April 2004.[2]

46 U.S.C. 6101 was amended in 1990 by adding subparagraph (d)(2) as follows:

> (d)(2) This part applies, to the extent consistent with generally recognized principles of international law, to a foreign vessel constructed or adapted to carry, or that carries, oil in bulk as cargo or cargo residue involved in a marine casualty described under subsection (a)(4) or (5) in waters subject to the jurisdiction of the United States, including the Exclusive Economic Zone.

[1] All times are local and based on a 24-hour clock.

[2] See Commandant message R 290520Z FEB 04, attached under ECN 2015212 #50 JRC. Also see correspondence number 22029.

46 U.S.C. 6101 was amended in 2002 by adding subparagraph (g) as follows:

> (g) To the extent consistent with generally recognized practices and procedures of international law, this part applies to a foreign vessel involved in a marine casualty or incident, as defined in the International Maritime Organization Code for the Investigation of Marine Casualties and Incidents, where the United States is a substantially interested state and is, or has the consent of, the lead investigating state under the Code.

46 CFR Part 4 has not been amended to reflect these revisions to 46 U.S.C. 6101.

The U.S. has jurisdiction over this casualty under 46 U.S.C. 6101(d)(2); however, this casualty was investigated by the Coast Guard as lead investigating state, under the authority of 46 U.S.C. 6101(g), with the consent of the Government of Singapore. The Philippines and Singapore participated in the investigation by sending a representative to Norfolk, Virginia for a portion of the investigation. The Government of Greece monitored the investigation through their Consular Office in New York.

Level of Investigation

On 29 February 2004 the Commander, Fifth Coast Guard District directed Marine Safety Office Hampton Roads to conduct an informal investigation of the BOW MARINER casualty.[3]

[3] The U.S. Coast Guard investigates casualties as either formal or "routine" investigations. Formal investigations are conducted by a single investigating officer or a marine board and are designated by a convening authority. Routine investigations are commonly referred to as "informal" investigations. See Commander, Fifth Coast Guard District message R 291920Z FEB 04, attached under ECN 2015212 #50 JRC.

1.0 Findings of Fact

1.1 Vessel Data

Name:	BOW MARINER
Flag:	Singapore
Service:	Chemical and Oil Tanker
Gross Tons:	22587
Deadweight Tons:	39821
Length Overall:	173.8 meters/570.2 feet
Breadth:	32.0 meters/105.0 feet
Depth:	15.0 meters/ 49.5 feet
Homeport:	Singapore
Date Keel Laid:	18 July 1981
Date Delivered:	18 October 1982
IMO Number:	7923512
Owner:	Odfjell Asia II PTE Ltd.
Operator:	Ceres Hellenic Ship Enterprises, Ltd.
Classification Society:	Det Norske Veritas
Propulsion:	Diesel Direct
Horsepower:	11400 horsepower

1.1.1 Vessel History

The BOW MARINER was constructed at the Brodogradiliste Split Shipyard, in what was then Yugoslavia, between July 1981 and October 1982 as hull number 306, under the name ATLAS PETROS. The ship operated as the ATLAS MARINER until July 1991, when the name was changed to BOW MARINER. Odfjell Tankers Asia II PTE Ltd. (hereinafter "Odfjell") purchased the vessel in 2000. Ceres Hellenic Shipping Enterprises Ltd. (hereinafter "Ceres") operated the ship.

1.1.2 Odfjell Asia II PTE, Ltd.

Through its various subsidiaries and joint ventures, Odfjell owns and operates parcel tankers, tank terminals and tank containers. Odfjell's core business is the deep-sea transportation of chemicals and other liquids with a fleet of 61 ships. In addition, Odfjell has 37 ships dedicated to regional trades: 13 operating in the Gulf of Mexico, the Caribbean and along the coasts of South America; eight in the inter-European trade; and 15 ships operating in Asia from Singapore.

1.1.3 Ceres Hellenic Ship Enterprises, Ltd.

Ceres is a ship management company based in Piraeus, Greece. The company manages a fleet of 39 vessels, including:

- Bulk Carriers (8)
- Liquefied Hazardous Gas Tankers (2)
- Oil Tankers (8)
- Chemical Tankers (21)

Among the 21 chemical tankers are 16 whose names begin with the word "BOW." Although they share this common naming convention, they are not all sister vessels. The BOW MARINER (1983), the BOW TRANSPORTER (1983) and BOW PETROS (1984) were all constructed in Yugoslavia and are considered sister vessels by Ceres.

A review of the Coast Guard histories of Ceres vessels that have called on U.S. ports in the last five years revealed few significant deficiencies or violations. One exception was the detention of the BOW POWER in Philadelphia, Pennsylvania in February 2004 after a boarding revealed the cargo tanks were not inerted below eight percent oxygen as required; however, the requirements for inerting tanks on the BOW POWER were different from the BOW MARINER because the BOW POWER was built after 1 July 1986. The condition was corrected by inerting the tanks.

1.1.4 Vessel Description

The BOW MARINER was a single side, double bottomed chemical and oil tanker capable of carrying 28 different cargoes with double valve segregation. Two longitudinal bulkheads and ten transverse bulkheads, forming nine center tanks and nine pairs of wing tanks, subdivided the cargo space. The number nine center tank was subdivided by a longitudinal bulkhead to form two tanks, which were designated as slop tanks.[4] The center tanks had external stiffening members and the wing tanks had internal stiffening members. The tank bottoms were sloped to facilitate drainage to the sumps. All tanks were constructed of mild steel and were coated with zinc or epoxy.[5] The total capacity of all cargo tanks was 47004.8 cubic meters at 98 percent full.

The BOW MARINER was equipped with segregated ballast tanks with a total capacity of 12266.6 cubic meters at 100 percent full. The tanks designated for ballast included five port and starboard double bottom tanks of varying lengths; the fore peak tank; the aft peak tank; and the number six port and starboard wing tanks, which were primarily used for cargo.

[4] In January 2004 two independent slop tanks, of the type typically used to carry liquids on containers ships, were installed above deck on the port and starboard sides aft of the manifold. This installation permitted more frequent use of the number nine center slop tanks for cargo.

[5] A Tank Condition Report dated 28 January 2004 is attached as ECN 2015212 #70 JRC. The report identifies the type of coating by tank and a code describing the condition of the coating. The codes are explained in Ceres Circular No. 078 – Coding for Tank Condition Reports, which is attached as ECN 2015212 #69 JRC.

Each cargo tank had independent cargo handling systems including hydraulic, self-priming deepwell pumps, cargo lines, vent lines, steam heating coils and instrumentation. Instrumentation included high level alarms, set at 95 percent capacity; high-high level alarms, set at 98 percent capacity; pressure sensing devices; and cargo temperature sensors at three levels in the cargo tanks. The vent system consisted of branch lines from each tank led to individual mast risers arranged in four groups at frames 53.5, 61.5, 70.5 and 78.5. Each mast riser was equipped with a pressure vacuum (PV) valve with flame arrestor.

1.1.5 Vessel Certificates

All regulatory certificates for the BOW MARINER were valid and properly endorsed on 28 February 2004.[6]

1.1.6 Crew Certificates

The Safe Manning Certificate was issued by the Singapore MPA on 19 February 2002 and endorsed, "This document is valid until replaced." The vessel was manned in compliance with the certificate on 28 February 2004. The licenses and certificates of all crewmembers were valid and appropriate for the position held and all crewmembers met the requirements of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW).[7]

1.1.7 Inspection History

The BOW MARINER was classed as a +1A1 Tanker for Chemicals and Oil by Det Norske Veritas (DNV) on 21 September 2002. Survey records for the five-year period before the explosion revealed the number, type and frequency of deficiencies was typical for a vessel of this age, service and route.[8] There were no outstanding conditions of class on 28 February 2004.

The BOW MARINER underwent ultrasonic thickness gauging between 27 January 2002 and 13 February 2002 in Singapore. The gauging revealed no significant wastage.[9]

The BOW MARINER underwent a flag state inspection in Singapore on 9 January 2004 with two deficiencies identified:

1. The starboard lifeboat failed to start due to a poor battery connection.
2. The fire damper for the engine room ventilation fan did not close effectively.

The first deficiency was corrected on the spot and the second was deferred to the vessel's next drydocking in December 2004.[10]

[6] Copies of 11 of the most important certificates are attached as ECN 2015212 #64 JRC.
[7] See ECN 2015212 #72 JRC for a spreadsheet documenting the status of licenses and STCW training.
[8] Survey records for the period 1999 to 2004 are attached as ECN 2015212 #74 JRC.
[9] An extract of the gauging report is attached as ECN 2015212 #71 JRC.
[10] The flag state inspection record for 9 January 2004 is attached as ECN 2015212 #73 JRC.

Coast Guard records for the five-year period before the explosion were reviewed and found to be unremarkable. The number and type of deficiencies and violations were typical for a vessel of this age, service and route. The most recent boarding history included a biennial Certificate of Compliance Exam and an annual exam.

On 14 August 2003 the BOW MARINER underwent a Certificate of Compliance – Tank Vessel Examination in Los Angeles, California. Lifeboat and fire drills were conducted and found satisfactory. One requirement was issued for marking the tops of the lifeboats, but there is no record of when this requirement was cleared. There were no outstanding Coast Guard requirements on 28 February 2004.

On 23 October 2003 the BOW MARINER underwent an annual examination by personnel from Coast Guard Marine Safety Office Philadelphia, Pennsylvania. Five deficiencies were identified:

1. The Cargo Record Book was not up-to-date.
2. The emergency pump shutdown at the port manifold and outside the Cargo Control Room (CCR) were inoperative.
3. The crew shower was inoperative; the crew was using buckets to bathe.
4. A hydraulic line at the #4C cargo tank on the main deck was leaking.
5. The high-high level alarm for the #4C cargo tank sounded before the high level alarm.

Item 1 was corrected on the spot. DNV Surveyor Christos Aspiotis cleared items 2-4 on 25 October 2003 in Wilmington, North Carolina. The disposition of item 5 could not be determined, but there were no outstanding Coast Guard requirements on 28 February 2004.

1.1.8 Lifesaving Equipment

The BOW MARINER was equipped with two 50-person totally enclosed motor lifeboats and four life rafts. A 25-person life raft was located on the first poop deck forward of the accommodations; a 12-person life raft was located on the port side of the first poop deck; a 16-person life raft was located on the starboard side of the first poop deck; and a six-person life raft was located on the forecastle deck. The ship was not required to carry immersion suits because it was equipped with totally enclosed lifeboats, but there were five thermal protective aids located in each lifeboat.[11] There were 75 life jackets stowed in locations throughout the vessel, including one in each cabin.

After the casualty Ceres surveyed their fleet and found wide disparity between vessels in the number of immersion suits. Some vessels reportedly had as many as 42 immersion suits, while others, like the BOW MARINER, had none. Ceres reports they are equipping all vessels with immersion suits.

[11] SOLAS Chapter III Regulation 32 has been revised to require immersion suits, with limited exceptions, for all persons aboard. The final date for compliance is July 1, 2006.

1.1.9 Firefighting Equipment

The BOW MARINER was equipped with a main fire pump in the engine room and an emergency diesel fire pump inside the forecastle. Monitors and hydrants, equipped with nozzles and hoses of varying lengths, were distributed throughout the vessel. The cargo deck was protected by a fixed dry powder system, and the engine room and forward paint locker were protected by fixed CO2 systems. The ship was also equipped with portable foam equipment and alcohol-resistant foam.

The ship had five fire lockers equipped with suits, boots, lifeline, fire axe, helmet and portable light. Three of the five fire lockers were on the upper deck; one in the forecastle, one in the midship deckhouse and one in the accommodations on the starboard side. There were at least 11 self-contained breathing apparatus (SCBA) aboard with an unknown number of spare bottles. The ship was equipped with a compressor for recharging empty SCBA bottles. There were also 40 emergency escape breathing devices aboard, including one in each cabin.

1.1.10 Tank Cleaning Equipment

The BOW MARINER was equipped with two fixed tank cleaning pumps located in the aft cofferdam, 10 portable tank cleaning machines for the wing tanks and 18 fixed tank cleaning machines for the center tanks. Each center tank had two fixed tank cleaning machines, except the number nine port center and number nine starboard center tanks, which had only one fixed machine per tank. The throughput of the portable tank cleaning machines was 17 to 19 cubic meters per hour at a pressure of seven to nine bars. The throughput of the fixed tank cleaning machines was 18 to 22 cubic meters per hour at a pressure of seven to nine bars. The pumps were capable of running up to eight of the fixed tank cleaning machines or nine of the portable tank cleaning machines simultaneously. Two water heaters, capable of heating 180 cubic meters of seawater per hour from a temperature of 20° Celsius (68° Fahrenheit) to 85° Celsius (185° Fahrenheit), were located in the upper level of the aft cofferdam.

Each washing machine was supplied with water from the wash water mains through a bonded, flexible hose. A number of these flexible hoses were stowed in the midship deckhouse. The electrician was required by the SQEMS to test the conductivity of the hoses prior to each use to ensure the bonding wire was intact.

The BOW MARINER was equipped with two Norclean[12] "Ejectorcleaners" (eductors) - powerful, air-powered vacuums capable of drawing liquids from tanks as deep as 30 meters. These eductors are commonly used on tank ships for final stripping of cargo tanks and deepwell sumps or cleaning up spills, because they reduce the risk of a spark. On 3 April 2003 both prime mover head assembly units were repaired and new filters installed. The Job Report stated that, "Due to lack of 1 body, fabricated and reinforced 1 barrel instead." Both units were tested on that date and found in good working condition.

The BOW MARINER was also equipped with six air driven portable tank ventilation fans

[12] Technical information on the Norclean eductor is attached as ECN 2015212 #02 CAO.

capable of producing airflow of 150 cubic meters per minute with an air pressure of 6.5 bars. These fans were used to gas free and dry the tanks after washing.

1.1.11 Wilden Pumps

The BOW MARINER carried three Wilden air-driven, double-diaphragm, positive displacement pumps, used to pump liquids in hazardous environments.[13] One large pump was intended for use as an emergency cargo pump and two smaller pumps were part of the spill response kit.

On 20 February 2004 Captain Kavouras requisitioned[14] a new Wilden T4/SPPB/TF/STF pump and additional spare parts, including several diaphragms. He made the following statement in the requisition remarks block: "On board exist tow air operated double diaphragm pums for OPA equip. The one of them is new and in good working condition the other is very old and is out of orders." [Sic]

1.1.12 Inert Gas System (IGS)

Chemical tankers[15] built before 1 July 1986, carrying flammable cargoes other than crude oil or petroleum products, are not required to have an IGS. However, the BOW MARINER was constructed with an inert gas generator, a nitrogen generator and a bottled nitrogen storage unit.

The inert gas generator produced hot inert gas in a water-jacketed combustion chamber. Sulphur oxides were washed out and the gas cooled in the cooling/washing section of the combustion chamber. The gas was further cooled and scrubbed in the washing tower, which had a demister at the top to remove water. Inert gas pressure was maintained by one of two centrifugal blowers, feeding combustion air, and a pressure control valve in the gas outlet line. The gas was cooled even further in an R-22 refrigeration unit, which lowered the temperature and removed additional water. The inert gas generator was situated in the non-hazardous area of the vessel and was equipped with non-return devices comprised of "block and bleed" valves, supplemented by a non-return valve and deck isolation valve. These valves were upstream of a pressure vacuum breaker that protected the cargo tanks from overpressure or vacuum conditions. The IGS main ran forward to the number one cargo tanks, with individual branch lines serving each cargo tank and the manifold. The IGS was also capable of providing fresh air for gas freeing using a mode selector switch on the local control panel. In this mode the burner is not ignited.

The IGS was initially capable of producing nitrogen, which was stored in an eight cubic meter storage tank in the IGS room, for use as a cargo pump purging medium or cargo padding. Inert gas was drawn downstream of the refrigeration unit by a compressor, discharged to a CO2 stripper and then stored in a compressed gas accumulator tank. However, several years before the explosion, the nitrogen generation system was disabled with the approval of DNV. The tank

[13] Technical information on the Wilden pumps is attached as ECN 2015212 #03 CAO.
[14] The requisition is attached as ECN 2015212 #87 JRC.
[15] A chemical tanker is defined as a cargo ship constructed or adapted and used for the carriage in bulk of any liquid product listed in Table 1 of 46 CFR 153, Chapter VI of the BCH Code, or Chapter 17 of the IBC Code. See NVIC 2-88, attached as ECN 2015212 #58 JRC.

remained in the IGS room but was not used.

The bottled nitrogen storage, located in the forecastle, was used to pad sensitive chemical cargoes when requested by the cargo shipper or receiver. The storage room could accommodate up to 48 compressed gas bottles, all of which could be connected to a manifold with two regulating valves to reduce the supply pressure based on whether the nitrogen was being used for purging or padding. Two supply outlets were located outside the forecastle bulkhead and were connected to the nitrogen main deck line with a flexible hose.

1.2 History of the Voyage

1.2.1 The Crossing

Voyage 2004/01 began in Al Jubail, Saudi Arabia. The BOW MARINER arrived at 0800 on 24 January 2004 and began loading cargo at 0115 the next day. Loading ended at 0430 on 26 January 2004[16] and the ship cast off all lines at 0650. At the time of departure the vessel's discharge destination was Philadelphia, Pennsylvania.

The BOW MARINER arrived at Port Said (Suez), Egypt at 1830 on 4 February 2004. The second assistant engineer signed off and a new second assistant engineer joined the vessel at 1750, "crossing on the gangway" just before departure at 1900. Ceres officials later stated that the departing second assistant engineer had been discharged for cause.

The BOW MARINER sailed from Port Said to Kali Limenes, Greece arriving at 0700 on 7 February 2004. The ship docked and took on 1200 metric tons of Heavy Fuel Oil (HFO) and departed for Algeciras, Spain at 1800.

The BOW MARINER arrived in Algeciras at 1100 on 12 February 2004. The ship took on 200 metric tons of Light Fuel Oil (LFO) from a barge while anchored, and departed for New York, New York[17] at 1600. The estimated time of arrival for New York at departure was the morning of 23 February 2004.

The BOW MARINER arrived in the Port of New York/New Jersey at 0230 on 25 February 2004, two days later than expected. The crossing was uneventful except for extremely poor weather. According to the daily position reports,[18] the BOW MARINER encountered very heavy seas and a strong gale. The vessel was rolling and pitching heavily and there was flooding on deck. The ship was forced to reduce speed and lost two days in transit. The severe weather also prevented
the deck crew from performing cleaning, painting and other maintenance planned to prepare for a scheduled charterer's inspection in Houston, Texas. There was no heavy weather damage reported in the vessel's daily e-mail position reports or by the survivors. Survivors also stated

[16] A copy of the loading plan is attached as ECN 2015212 #01 JRC.
[17] The ship received new voyage instructions sometime after departure from Kali Limenes.
[18] Position reports for the period 26 January 2004 to 23 February 2004 are attached as ECN 2015212 #66 JRC.

there were no mechanical failures, accidents or unusual alarm conditions during the crossing, describing the voyage as routine.

1.2.2 Cargo Discharge in New York

The BOW MARINER anchored in Stapleton Anchorage at 0520. The barge WESTCHESTER, operated by Reinauer Transportation, came along the starboard side at 0940. The ship discharged about 5983 metric tons of MTBE to the barge between 1200 and 2010.[19] The transfer was uneventful and the barge departed at 2145 for the Shell Motiva facility in Delaware City, Delaware.

The BOW MARINER heaved anchor at 2200 and moored starboard side to the berth at St. Linden Terminal, Linden, New Jersey at 0110 on 26 February 2004. The ship discharged about 10238 metric tons of MTBE to shore between 0315 and 2025.[20] The transfer was uneventful.

At 2030 the agent advised the BOW MARINER that their next scheduled berth at the Shell Motiva facility was occupied, so the ship sailed to Stapleton Anchorage to await a berth. However, the anchorage was not available, so the ship drifted off Ambrose Light until 0500 on 27 February 2004, when they proceeded to Motiva. The ship discharged about 5995 metric tons of MTBE to shore between 1120 on 27 February 2004 and 0055 on 28 February 2004.[21] The discharge was uneventful except for a five-minute stop at 1035, at the request of the BOW MARINER, to fix a leak at the manifold. The IGS was not operated during cargo discharge while in New York.

The BOW MARINER departed the Motiva facility at 0500. Based on a post-casualty analysis by the Singapore MPA, the ship's departure stability parameters, including bending moment and sheer force, were well within the prescribed limits of the International Maritime Organization.

The pilot departed the ship at 0700, in the vicinity of Ambrose Light. The pilot reported that at the time of his departure all tanks were closed and he did not observe any work in progress on deck.

[19] Cargo transfer records are attached as ECN 2015212 #46 JRC.
[20] Cargo transfer records are attached as ECN 2015212 #02 JRC.
[21] Cargo transfer records are attached as ECN 2015212 #03 JRC. The records include a video of the ship's arrival, connection, disconnect and departure. There is no evidence of structural or procedural problems in the video.

1.2.3. Tank Cleaning

At the time of departure on 28 February 2004 Third Officer Ortilano had the 0800 to 1200 watch. Sometime before the 1000 coffee break, when the BOW MARINER was about 14 nautical miles offshore, Captain Kavouras came to the bridge and instructed Third Officer Ortilano to have the deck crew open the 22 empty tanks, which had previously contained MTBE.[22] Third Officer Ortilano passed this order to Able Seaman Manahan, but did not personally check to ensure it was done. At 1150 Third Officer Acuna relieved Third Officer Ortilano of the watch and told him that Chief Officer Melles wanted Third Officer Ortilano to assist with tank cleaning at 1300.

Third Officer Ortilano ate lunch and reported as ordered. When he arrived Boatswain Tabilin was pumping MTBE from the number eight starboard cargo tank using a Wilden pump, assisted by Ordinary Seaman Bocalan and Deck Cadet Castano. The residual MTBE was already removed from the number nine center starboard tank and number nine starboard wing tank. The pump was lowered into the tank because it did not have sufficient lift for the depth of the cargo tank, which was 13.4 meters. Boatswain Tabilin was inside the tank, which was not gas free, wearing a SCBA. Third Officer Ortilano's job was to refill the steel SCBA bottles. Able Seaman Ronquillo and Pumpman Ventenilla were working at the port manifold, using compressed air to blow down cargo lines. Able Seaman Ronquillo's job was to open and close the air supply valve at the air manifold as directed by Pumpman Ventenilla. He stated there was a "strong smell" of MTBE on deck, but it was a familiar smell and did not bother him.

At 1330 the Wilden pump failed and Boatswain Tabilin called up to the crew to haul the pump out of the tank. Third Officer Ortilano overheard him say there was a problem with the diaphragm. Boatswain Tabilin was trying to repair the pump when Captain Kavouras, who was on deck with Chief Officer Melles supervising the operation, instructed the crew to get the Norclean eductor from the midship deckhouse. When the Norclean eductor was brought on deck Third Officer Ortilano noted the drum was collapsed in the mid-section, rendering the eductor useless. Captain Kavouras instructed Third Officer Ortilano to get two standard drums and take them to the engine room workshop, where he was to assist Fitter Senga in reinforcing the drums.[23]

Fitter Senga and Third Officer Ortilano constructed a frame using steel round bar to fit inside the drums. The frame was comprised of three rings the diameter of the drum, which were reinforced with a triangle, made of the same round bar, inside each ring. The rings were welded together with three vertical round bars, cut to the height of the drum. The resulting frame fit inside the drum with one ring at the top, center and bottom. The first drum was finished at 1500 and was taken up on deck. Third Officer Ortilano and Fitter Senga did not install a bonding wire in the drum. Electrician Bactat was not asked to install a bonding wire in the reinforced drums. Third Officer Ortilano stayed with Fitter Senga to finish the second drum. At 1705 Third Officer

[22] Ortilano stated that he knew the distance offshore because shortly before Captain Kavouras gave him the order Chief Officer Melles had come to the bridge to use the cell phone. When the cell phone would not work he asked Ortilano to plot the distance offshore to determine if they were out of cell phone range.

[23] The drum supplied with the Norclean eductor has a heavier wall thickness than a standard drum and internal reinforcement to withstand vacuum pressure in the event the hose is blocked.

Ortilano and Engine Cadet Mukod carried the second drum to the deck and found the crew had gone to dinner. When he arrived Third Officer Ortilano observed the Norclean eductor head mounted on the first reinforced drum. The suction hose was led through the Butterworth opening nearest the number eight starboard cargo tank expansion trunk, but the unit was not in operation. Third Officer Ortilano did not notice if the Norclean eductor's grounding wire was attached to the ship.

1.2.4 The Casualty

On 28 February 2004, at 1800, the M/V DAKSHINESHWAR, an empty bulk carrier, was sailing on a course of 194 degrees True, at a speed of 12.5 knots, in position 37-53.7N/074-11.4W. The BOW MARINER was 3.6 nautical miles[24] west and about two points forward of the beam of the DAKSHINESHWAR, in position 37-53.7N/074-15.2W, having overtaken the DAKSHINESHWAR at a speed of 14.5 knots. Chief Officer Das and Cadet Goyal were on watch. At 1805 Chief Officer Das observed a "yellow flash" on the port side of the BOW MARINER, forward of the manifold and about 20 meters aft of the bow. Chief Officer Das stated the flash was not accompanied by a noise, but turned into a fire that rose upward and trailed aft over the manifold area. At 1806 Chief Officer Das observed a "big explosion" in way of the manifold, followed by another large explosion.[25] The DAKSHINESHWAR relayed the BOW MARINER'S position to the Coast Guard through the commercial fishing vessel CAPT. BUCKY, and diverted to assist.

Captain Dolan, of the commercial fishing vessel KAREN L, was fishing in position 38-08.41N/074-15.28W. At about 1800 he saw and heard an explosion, followed by a series of smaller explosions and a Mayday call about 10 minutes later. He estimated he was 14 nautical miles from the explosion. He retrieved his fishing gear and diverted to assist, arriving at 1930.

Captain Carlson, of the commercial fishing vessel CAPT. BUCKY, was scalloping about 18 nautical miles away from the BOW MARINER when he saw a fireball in the distance. He did not hear an explosion. He called the Coast Guard and relayed information from the DAKSHINESHWAR. He retrieved his gear and headed toward the fire at a speed of eight knots, arriving about two hours later. About one hour after he diverted he stated he was no longer able to see a fire.

At 1800 aboard the BOW MARINER the officers and crew had just finished dinner and reported for overtime. Electrician Bactat, Third Officer Ortilano and Able Seaman Ronquillo were in their rooms, either asleep or resting. Chief Cook Marentes, Messman Rosello and Messman

[24] The distance between the vessels was determined to be 3.6 nautical miles by plotting the relative latitudes and longitudes recorded in the logbook of the DAKSHINESHWAR. In his initial interview with the Coast Guard (ECN 2015212 #03 BAG), Chief Officer Das stated the distance was 2.6 nautical miles. In an affidavit dated 22 May 2004 (ECN 2015212#01 JDL) Chief Officer Das stated the distance was "…about 3.7 nautical miles." Captain Cheema reported the distance as 3.6 nautical miles in both a telex to the vessel's owners (ECN 2015212 #01 BAG) and his written statement to the Coast Guard (ECN 2015212 #10 BAG).

[25] Coast Guard investigators interviewed Chief Officer Das when the DAKSHINESHWAR arrived in Corpus Christi, Texas. He made notations about the locations of the yellow flash, fire and explosion on a photo of one of the sister vessels, which is attached as ECN 2015212 #14 BAG.

Tagle were in the galley cleaning up after dinner. Second Assistant Engineer Aguilar was on his way to the engine room.

Second Assistant Engineer Aguilar was reaching for the handle to open the door into the engine room for his 1800 round when he heard the first explosion. He stated definitively that the explosion did not occur in the engine room. By the time he reached the interior stairwell to go to his room the ship was listing to starboard. When he arrived at his room on the fourth level his key would not work in the door, so he went to the fifth level (bridge), where he met Third Assistant Engineer Pitpit and Engine Cadet Mukod. He was the only person without a life jacket so he went to the pilot room and took the life jacket from that location. While on the bridge he heard a second explosion and saw fire in the air on the port side. He exited the bridge aft and saw Chief Cook Marentes, Third Officer Ortilano and Able Seaman Ronquillo. Second Assistant Engineer Aguilar recalled that the water temperature sensor in the engine room was reading
3° Celsius (37.4° Fahrenheit) earlier in the day and decided not to enter the water until necessary. He joined Chief Cook Marentes and Able Seaman Ronquillo on the outside of the stern railings and stayed there as the ship came back to an even keel and the stern rose in the air.[26] While there he saw many life jacket lights in the water and heard cries for help in English. He saw Third Officer Ortilano jump directly into a life raft on the starboard side, and later he tried to do the same but landed in the water and then climbed into the life raft.

Electrician Bactat returned to his room after dinner at about 1730, intending to sleep. At about 1800 he heard a noise and felt the ship rocking violently, followed by a list to starboard. He opened the blinds to his window, located on the port side of the third deck facing forward, and saw orange flames leaping past his window. He put on his coveralls and life jacket and, with some difficulty due to the list, made his way to the bridge. There he saw Fourth Assistant Engineer Ajoc, and noticed some of the bridge windows were broken. He also noticed a tear in his life jacket, so he took another one from the radio officer's room and then climbed down the aft, exterior ladders to the second level, where he saw Fourth Assistant Engineer Ajoc, Wiper Borja, Engine Cadet Mukod and Third Assistant Engineer Pitpit. Everyone was wearing a life jacket and appeared uninjured. The group descended to the starboard winch deck. Electrician Bactat estimated the list at 30 degrees to starboard at this time, making it difficult to climb down the ladders. Electrician Bactat was the last in this group to reach the winch deck, and the others were already in the water or entering the water. They did not jump but simply walked into the water. The water was cold but the seas were calm. He saw a fire forward on the water but there was no fire in the area the survivors were drifting. He found a piece of wood and drifted, eventually joined by Messman Tagle. Later they spotted the life raft about five meters away and swam to it, where they were helped inside.

Chief Cook Marentes heard a loud "boom" and felt the ship vibrate and shake violently. He saw Messman Rosello panic and told him to calm down and get his life jacket. Within a minute there was a second explosion that caused severe pain in his right ear. He went to his room on the third deck and retrieved his life jacket, but he did not go to his assigned lifeboat on the port side

[26] Interestingly, Aguilar and Ronquillo stated that when deciding to climb on the railings and stay with the ship they were not relying on any specific training in cold water survival but on what they had seen in the movie "Titanic."

because the ship was listing to starboard. Chief Cook Marentes left the accommodations and climbed down a ladder to the winch deck, where he found Second Assistant Engineer Aguilar and Able Seaman Ronquillo holding onto the stern railing. He joined them and remained there until they saw a life raft along the starboard side. The stern of the ship was in the air and the ship was sinking fast. They climbed along the railing and jumped into the water from a height of about four or five meters, then climbed into the life raft, where they found Third Officer Ortilano.

Third Officer Ortilano went to his room at 1730 to rest for his watch. At 1805 he felt the ship move violently and heard two or three very rapid "booms." This was followed in less than a minute by another significant explosion. He looked out his forward window and saw flames, and could feel the ship list to starboard. Third Officer Ortilano exited his room and saw Able Seaman Manahan in the passageway, who told him to get his life jacket. He returned to his room and retrieved his life jacket, then exited the accommodations aft, where he saw Chief Engineer Athanasiou and Captain Kavouras descending from the fourth level. Assembled at this location were Second Officer Abarra, Chief Engineer Athanasiou, Oiler Escarra, Captain Kavouras, Able Seaman Manahan, Third Officer Ortilano and Messman Tagle. Some were wearing life jackets and others were holding them. None appeared to be injured. Third Officer Ortilano approached Captain Kavouras, who was conversing in Greek with Chief Engineer Athanasiou, and asked about sending a distress call. Third Officer Ortilano stated that Captain Kavouras did not respond to his questions, so he went to the bridge. On the way there he saw Second Assistant Engineer Aguilar descending. He activated the DSC alarm in the radio room and sent a Mayday call on the radio.[27] Third Officer Ortilano exited the bridge and went to the bridge top, where he activated the Emergency Position Indicating Radio Beacon (EPIRB) and cast it overboard. While descending to the winch deck he saw many crewmembers in the water, including Chief Engineer Athanasiou and Captain Kavouras. He saw numerous life jacket lights and could hear cries for help in English. At the winch deck he clung to the control piping for the fixed CO2 system. From here he saw Second Assistant Engineer Aguilar, Chief Cook Marentes and Able Seaman Ronquillo on the stern railing. He could see the life raft on the starboard side, but he waited for the ship to sink further before he jumped directly into the life raft from a height of three or four meters. Shortly afterward Second Assistant Engineer Aguilar tried to jump into the life raft and missed. He climbed in and was followed by Chief Cook Marentes and Able Seaman Ronquillo. They located the life raft's equipment, cut the painter and tried to paddle around to pick up survivors. Third Officer Ortilano lit hand flares and heard cries for help each time he did, but could not see the people so he called out for them to swim toward the flares. They drifted near enough to Electrician Bactat and Messman Tagle that they could swim to the life raft, where they were helped aboard. Third Officer Ortilano stated that the men were so covered with oil that he did not know who they were.

Able Seaman Ronquillo went to dinner at 1645, ate quickly and was in his room by 1700 to rest for his watch. At 1800 he heard three or four rapid explosions and felt the ship rock and list. He grabbed his life jacket and put it on. The list was so bad he had to force his door open and grab the storm rails to make his way aft and out of the accommodations. As soon as he was outside he went down one deck and could already see crewmembers in the water. He went to the stern

[27] A U.S. Coast Guard recording of the Mayday, received at 1810, is attached as ECN 2015212 #93 JRC.

railings with Second Assistant Engineer Aguilar and Chief Cook Marentes, starting out inside the rail and later climbing outside as the stern lifted. He saw a life raft on the starboard side and saw Third Officer Ortilano holding onto the pipes for the CO2 system. He recalled that Third Officer Ortilano shouted to them not to jump in the life raft until the ship was lower in the water. When the ship sank further he saw Third Officer Ortilano jump into the life raft. Second Assistant Engineer Aguilar jumped next, landing in the water, and he followed. Third Officer Ortilano helped him into the life raft.

Messman Tagle was in the galley with Chief Cook Marentes and Messman Rosello when he heard an explosion, followed by an immediate list to starboard. A second explosion occurred while he was on his way to his cabin on the second level, where he found the locker doors open. He could not put his life jacket on in his room because of the list, so he exited the accommodations on the starboard side on the second deck. Here he met Second Officer Abarra, Third Officer Acuna, Fourth Assistant Engineer Ajoc, Chief Engineer Athanasiou, Motorman Bonafacio, Captain Kavouras and Third Assistant Engineer Pitpit.[28] He followed this group to the winch deck on the starboard side. While descending he was putting on his life jacket, briefly covering his eyes, and when he looked up the men were gone. While on the winch deck he heard a third explosion, and someone shouted to him in Tagalog to jump. He jumped overboard and was in the water drifting around until he was picked up in the life raft. He stated that he heard a fourth explosion while he was in the water.

1.2.5 Search and Rescue

Several Coast Guard facilities monitored and responded to the Mayday call made by Third Officer Ortilano at 1810, but Third Officer Ortilano, who left the radio to retrieve the EPIRB from the bridge top, did not respond to any of the units that answered his Mayday. The DAKSHINESHWAR was unable to establish communications with the U.S. Coast Guard, so they relayed information about the explosion through the CAPT. BUCKY between 1811 and 1815.[29]

The DAKSHINESHWAR diverted to assist at 1812, staying outside the oil slick to avoid danger of additional explosions and fire. They observed hand flares at 1845 from a life raft, so they launched a lifeboat under command of the chief officer at 1900. The lifeboat proceeded to the life raft but backed away when the Coast Guard helicopter arrived. They continued searching until they fouled their propeller with a line. The lifeboat was towed to the DAKSHINESHWAR by the fishing vessel CAPT. BUCKY and recovered at 2145. The Coast Guard released the DAKSHINESHWAR at 0045 on 29 February 2004.

[28] In his first interview Tagle circled the names of the men he saw in this group on a copy of the crew list and included Melles, but he changed this statement in a second interview. The marked crew list is attached as ECN 2015212 #92 JRC.

[29] A recording of the follow-up radio traffic is attached as ECN 2015212 #93 JRC.

Coast Guard HC-130 CG-1501 was airborne at 1843 and arrived at about 1915. The plane approached the area at 1500 feet, climbing later to 3500 feet and then to 5500 feet. The plane orbited the area in a counterclockwise direction while shooting an infrared video of the rescue, starting about 10 minutes before arriving.[30] When the plane arrived the ship was down by the bow with only the stern sticking out of the water. The water level was nearly at the bridge top. There were no fires and there were no people visible on the ship. The port lifeboat was floating upright on the port side and appeared to be attached to the ship at one end. There was a life raft, with a heat signature, attached by its sea painter to the starboard side.

At 1937 the BOW MARINER slipped beneath the sea. At the time of sinking the infrared video showed that the life raft on the starboard side and the port lifeboat were no longer attached to the ship. The port lifeboat had capsized sometime prior to the sinking, but this was not captured on the video.

Coast Guard helicopter CG-6026 arrived at about 1928. The crew stated that there were more than a dozen life jacket lights visible in the water when they arrived. They spotted a lifeboat but it turned out to be the rescue boat launched by the DAKSHINESHWAR. They also spotted a small raft that was either capsized or did not have a canopy, and a second, much larger raft, that had people inside. At 1943 a basket was lowered to the raft twice but a survivor in the door of the canopy made no effort to climb in, despite hand signals and use of the helicopter's handheld searchlight to try to coax him into the basket. At 1948 the rescue swimmer was lowered and the first hoist from the life raft was made at 1955, less than two hours since the explosion and only 20 minutes after the ship sank. The last survivor was hoisted at 2016 and the helicopter departed. During the flight one survivor, later identified as Third Officer Ortilano, was questioned by the flight mechanic about the number of people aboard the life raft, the number of people aboard the ship and the cause of the explosion. Third Officer Ortilano responded to the last question by repeating three times, "pump cleaning." The survivors were taken to Norfolk Sentara Hospital, where the survivors and rescue swimmer were treated for hypothermia and exposure to oil and ethyl alcohol. The helicopter was grounded due to contamination.

Coast Guard helicopter CG-6588 arrived at 1922.[31] Shortly after arrival they located a nearly naked body.[32] They vectored the fishing vessel KAREN L to the body using their searchlight, which recovered it. The victim was wearing only a shirt and gold necklace and had severe traumatic injuries to the head, legs and arms. The body was later delivered to a small boat from the USCGC SHEARWATER, who turned the body over to the Medical Examiner's Office in

[30] The FLIR video is about two hours long, with a one-hour gap between 2027 and 2129. The video is marked as ECN 2015212 #11 CMD.

[31] The hoist camera video from this helicopter is very dark but captured the audio of the crew, including communications with other aircraft. The video is marked as ECN 2015212 #22 MLH.

[32] This body was later identified as Chief Officer Melles. A copy of the death certificate is attached as ECN 2015212 #06 CAO.

Virginia Beach, Virginia. While hovering over the body the crew of the helicopter spotted lights a short distance away. After the KAREN L recovered the body they moved to the lights and discovered a group of four bodies, one moving slightly. The rescue swimmer was deployed at 2006 and recovered the man, who was wearing coveralls and a life jacket and was covered in oil. The victim periodically showed signs of life during the flight to the hospital, but the flight mechanic and swimmer were forced to perform CPR repeatedly to keep him alive. The victim was taken to the Ocean City, Maryland airport, where he was transferred to awaiting EMS personnel at 2051. At the time of transfer the victim was breathing on his own with respirations of seven per minute. He was taken to Atlantic General Hospital, where he was pronounced deceased. The victim was later identified as Third Assistant Engineer Pitpit, and the cause of death as drowning associated with hypothermia.[33] The helicopter was grounded due to contamination. The flight mechanic and rescue swimmer were examined at the hospital because of exposure to oil, ethyl alcohol and biological material.

At 1928 the starboard lifeboat was located in position 37-53.0N/074-15.1W. The lifeboat appeared to be damaged on the bow and stern.[34] At 2132 the fishing vessel CAPT. BUCKY secured the lifeboat alongside and found a man with his arms wrapped tightly in the lifeboat's lifelines, with only his head and arms above water. The man was delirious but was making "thank you" gestures to his rescuers. They brought him aboard at 2147, where he became unconscious. At 2154 a rescue swimmer was lowered from Coast Guard helicopter CG-6031 to Coast Guard motor lifeboat CG-47222. The rescue swimmer was transferred to the CAPT. BUCKY, where he found the victim alive, covered in oil and in great pain. The victim and rescue swimmer were hoisted to the helicopter, which took him to the Ocean City airport. During the flight the victim lost all vital signs so the crew commenced CPR. He was transferred to a Maryland State Police helicopter and transported to Peninsula Regional Medical Center in Salisbury, Maryland where he was pronounced deceased. The victim was later identified as Fourth Assistant Engineer Ajoc, and the cause of death as drowning associated with hypothermia.[35]

Other Coast Guard units participating in initial search and rescue efforts included Coast Guard helicopter CG-6579 and USCGC ALBACORE. The search continued throughout the day on 29 February 2004 using various Coast Guard aircraft and surface units. Active search efforts were suspended after dark on 29 February 2004.

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[33] A copy of the death certificate is attached as ECN 2015212 #04 CAO.

[34] A photograph taken days later revealed the bow of the starboard lifeboat was damaged by fire. The damage to the bow and stern was apparently caused when the lifeboat broke away from the falls.

[35] A copy of the death certificate is attached as ECN 2015212 #05 CAO.

1.3 Personnel Casualties

1.3.1 Record of the Dead

Name of the deceased:	AJOC, Wilfred Y.
Position:	Fourth Assistant Engineer
Age:	35
Sex:	Male
Nationality:	Filipino
Cause of Death:	Drowning Associated with Hypothermia

Name of the deceased:	MELLES, Spiridon I.
Position:	Chief Officer
Age:	43
Sex:	Male
Nationality:	Greek
Cause of Death:	Multiple Blunt Force Injuries

Name of the deceased:	PITPIT, Celerino B.
Position:	Third Assistant Engineer
Age:	53
Sex:	Male
Nationality:	Filipino
Cause of Death:	Drowning Associated with Hypothermia

1.3.2 Record of the Injured

Name of the crewmember:	AGUILAR, Edimar L.
Position:	Second Assistant Engineer
Age:	[redacted]
Sex:	Male
Nationality:	Filipino
Injury:	Hypothermia

Name of the crewmember:	BACTAT, James C.
Position:	Electrician
Age:	[redacted]
Sex:	Male
Nationality:	Filipino
Injury:	Hypothermia

Name of the crewmember: MARENTES, Dominator M.
Position: Chief Cook
Age: [redacted]
Sex: Male
Nationality: Filipino
Injury: Hypothermia, Fractured Left Little Finger

Name of the crewmember: ORTILANO, Lugen T.
Position: Third Officer
Age: [redacted]
Sex: Male
Nationality: Filipino
Injury: Hypothermia

Name of the crewmember: RONQUILLO, Ramon P.
Position: Able Seaman
Age: [redacted]
Sex: Male
Nationality: Filipino
Injury: Hypothermia, Back Pain

Name of the crewmember: TAGLE, Reynaldo A.
Position: Messman
Age: [redacted]
Sex: Male
Nationality: Filipino
Injury: Hypothermia, Back Pain

1.3.3 Record of the Missing

Name of the crewmember: ABARRA, Conrado P.
Position: Second Officer
Age: 45
Sex: Male
Nationality: Filipino

Name of the crewmember: ACUNA, Johnny D.
Position: Third Officer
Age: 44
Sex: Male
Nationality: Filipino

Name of the crewmember:	ATHANASIOU, Legantis-Eley A.
Position:	Chief Engineer
Age:	47
Sex:	Male
Nationality:	Greek

Name of the crewmember:	BOCALAN, Roy A.
Position:	Ordinary Seaman
Age:	27
Sex:	Male
Nationality:	Filipino

Name of the crewmember:	BONIFACIO, Adnresito T.
Position:	Motorman
Age:	37
Sex:	Male
Nationality:	Filipino

Name of the crewmember:	BORJA, Jose Jenil A.
Position:	Wiper
Age:	28
Sex:	Male
Nationality:	Filipino

Name of the crewmember:	CABRERA, Benedicto S.
Position:	Able Seaman
Age:	40
Sex:	Male
Nationality:	Filipino

Name of the crewmember:	CASTANO, Samuel C. Jr.
Position:	Deck Cadet
Age:	23
Sex:	Male
Nationality:	Filipino

Name of the crewmember:	CESAR, Alaric A.
Position:	Able Seaman
Age:	32
Sex:	Male
Nationality:	Filipino

Name of the crewmember:	ESGUERRA, Lito O.
Position:	Motorman
Age:	32
Sex:	Male
Nationality:	Filipino

Name of the crewmember:	HERANDIO, Joe-Ann V.
Position:	Deck Cadet
Age:	26
Sex:	Male
Nationality:	Filipino

Name of the crewmember:	KAVOURAS, Efstratios S.
Position:	Master
Age:	52
Sex:	Male
Nationality:	Greek

Name of the crewmember:	MANAHAN, Elmer B.
Position:	Able Seaman
Age:	27
Sex:	Male
Nationality:	Filipino

Name of the crewmember:	MUKOD, Romy U.
Position:	Engine Cadet
Age:	23
Sex:	Male
Nationality:	Filipino

Name of the crewmember:	ROSELLO, Isidro B.
Position:	Messman
Age:	42
Sex:	Male
Nationality:	Filipino

Name of the crewmember:	SENGA, Romeo S.
Position:	Fitter
Age:	50
Sex:	Male
Nationality:	Filipino

Name of the crewmember:	TABILIN, Aquilino S.
Position:	Boatswain
Age:	47
Sex:	Male
Nationality:	Filipino

Name of the crewmember:	VENTENILLA, Tomas L.
Position:	Pumpman
Age:	42
Sex:	Male
Nationality:	Filipino

1.4 Environmental Conditions

1.4.1 Weather

The weather data below was obtained from weather buoys located off the coast of New Jersey and Virginia.[36]

Seas:	6 feet
Sea Direction:	East
Wind Speed:	15 knots
Wind Direction:	Northwest
Visibility:	Unlimited
Air Temp:	4.4° Celsius (40° Fahrenheit)
Water Temp:	5.5° Celsius (42° Fahrenheit)

1.4.2 Cold Water Survival Model

The Coast Guard's cold water survival model was used to calculate the functional time and survival time of crewmen entering the water after the explosion. The calculations were based on a 30-year old male, weighing 160 pounds, immersed to the neck in 6.6° Celsius (44° Fahrenheit) water.[37] Based on the model, an individual wearing a long sleeved shirt and jacket would remain functional for 1.8 hours, with a survival time of 3.6 hours. The same individual in a standard immersion suit would have a functional time of 7.0 hours and survival time of 10.8 hours.

[36] Details are attached as ECN 2015212 #07 EHM.

[37] The model defaults to an air temperature of 0° Celsius (32° Fahrenheit) when the victim is immersed to the neck. Also, the model does not allow for a life jacket since they do not provide protection from cold water. The calculations are attached under ECN 2015212 #01 ABD.

1.5 Cargo

At the time of the explosion the BOW MARINER was carrying 3,188,711 gallons of ethyl alcohol in six of the 10 center cargo tanks. The remaining 22 cargo tanks had contained MTBE, which was discharged in three parcels in the Port of New York/New Jersey during the period 25 February 2004 to 28 February 2004. These 22 tanks contained residual MTBE in the tank sumps and significant quantities of vapor.

1.5.1 Cargo Regulations

The BOW MARINER was built after 12 April 1972 and before 7 July 1986, and thus was subject to the Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (BCH Code).[38] Vessels built after 7 July 1986 are subject to the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code). However, Chapters 17 and 18 of the IBC Code have been incorporated into the BCH Code.

Ethyl alcohol and MTBE are regulated by the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78). MTBE is a Category D Noxious Liquid Substance (NLS), which is a substance that presents a recognizable hazard to the environment. Ethyl alcohol is an Appendix III cargo, which is a substance that is not considered a Category A, B, C or D NLS and is not subject to the provisions of Annex II of MARPOL.[39]

1.5.2 Technical Information[40]

Common Name:	Ethyl Alcohol
UN Number:	1170
Chris Code:	EAL
IMO Pollution Category:	II
Grade:	C – Flammable Liquid
Flash Point:	65° Fahrenheit
Specific Gravity:	.79
Vapor Density (Air=1.0):	3.1
Solubility in Water:	Complete
Loading Port:	Al-Jubail, Saudi Arabia
Cargo Tanks:	2C, 3C, 4C, 6C, 7C, 9CP

[38] A complete list of applicable legislation for the BOW MARINER is contained in Ceres Circular No. 066, which is attached as ECN 2015212 #68 JRC.
[39] See ECN 2015212 #43 JRC for an analysis of the regulatory requirements for ethyl alcohol and MTBE.
[40] This information was obtained from the U.S. Coast Guard Chemical Data Guide for Bulk Shipment by Water, 1990 Edition. An extract is attached as ECN 2015212 #45 JRC.

Common Name:	Methyl Tert-Butyl Ether
UN Number:	2398
Chris Code:	MBE
IMO Pollution Category:	D
Grade:	C – Flammable Liquid
Flash Point:	-14° Fahrenheit
Specific Gravity:	.74
Vapor Density (Air=1.0):	1.6
Solubility in Water:	Complete
Loading Port:	Al-Jubail, Saudi Arabia
Cargo Tanks:	1C, 5C, 8C, 9CS, 1P, 1S, 2P, 2S, 3P, 3S, 4P, 4S, 5P, 5S, 6P, 6S, 7P, 7S, 8P, 8S, 9P, 9S

1.6 Drug and Alcohol Testing

Sentara Norfolk General Hospital tested five of the six survivors for drugs and alcohol by blood test shortly after arrival and well within eight hours of the casualty. The drug test results for one crewman, Electrician Bactat, were not recorded. Another crewman, Messman Tagle, was not tested for drugs or alcohol for unknown reasons. The results of all drug and alcohol tests taken were negative.[41]

1.7 Fatigue

96-hour work/rest histories were collected for all six survivors.[42] Deck officers below the chief officer stood four-hour watches in a three-watch system while at sea, and a modified watch system in port. Deck ratings stood a similar watch schedule, except the watch rotated periodically so that each crewman stood an equal share of undesirable watches. Engineering officers below the chief engineer were day workers and did not stand a watch. Engine ratings stood four-hour watches in a three-watch system.

When not on watch the crew performed their routine duties, which varied according to their position and rank. The crew had 15-minute coffee breaks at 1000 and 1500, and ate lunch at 1200 and dinner at 1700. Other than watch standers the crew secured from work and ate their meals together at the appointed times.

Based on the 96-hour work/rest histories the BOW MARINER was in apparent compliance with the rest standards of the STCW Convention. However, because the three senior officers did not survive, a complete fatigue analysis could not be accomplished. Of particular concern are reports from several survivors that the chief officer routinely stayed in the CCR throughout cargo operations, taking only short breaks for meals and an occasional nap in a chair. The survivors stated this was routine aboard Ceres ships they had sailed on.

[41] Test results are attached as ECN 2015212 #56 JRC.

[42] Forms are attached as ECN 2015215 #03 EHM, ECN 2015212 #04 EHM, ECN 2015212 #05 EHM, ECN 2015212 #06 EHM, ECN 2015212 #07 JRC and ECN 2015212 #54 JRC.

1.8 Pollution

Before the explosion the BOW MARINER was carrying about 3,188,711 gallons of ethyl alcohol, 192,904 gallons of HFO, 48,266 gallons of LFO and an unknown quantity of slops. Immediately after the sinking a heavy, circular oil slick, about two miles in diameter, was recorded by a Coast Guard aircraft using an infrared video recorder. The Coast Guard and responsible party conducted over flights for several days following the sinking, and observed an oil slick up to 35 miles long and 1.5 miles wide.

Between 14 March 2004 and 18 March 2004 contractors hired by the responsible party conducted a survey of the sunken BOW MARINER using underwater remotely operated vehicles.[43]
The purpose of the survey was to search for remains, chart the position of the vessel and determine whether the vessel's cargo and fuel oil were recoverable. The survey revealed the vessel's fuel oil tanks were breached and had spilled their entire contents. The six center cargo tanks containing ethyl alcohol were not accessible, but the video revealed extensive damage to the entire cargo block.

Rescuers and survivors reported a heavy, alcohol-like odor, causing nausea, dizziness and headaches in some of the people exposed to the fumes. All of the survivors and bodies recovered were coated with HFO and smelled of alcohol. Taken together this indicates that some, if not all, of the ethyl alcohol was released. Because ethyl alcohol is completely soluble in water and not regulated as a NLS, further effort to recover any ethyl alcohol that was not released was not attempted.

[43] The Salvage Field Report is attached as ECN 2015212 #76 JRC. 19 DVDs, containing nearly 57 hours of underwater video, are marked as ECN 2015212 #89 JRC.

2.0 Analysis

2.1. The International Safety Management (ISM) Code

In 1993 IMO adopted Resolution A.741(18), The International Safety Management (ISM) Code, with an effective date of 1 June 1998. The purpose of the ISM Code is to provide an international standard for the safe management and operation of ships and for pollution prevention. The objectives of the ISM Code are to ensure safety at sea, prevent human injury or loss of life and avoid damage to property and the marine environment.

The ISM Code requires that every company develop, implement and maintain a Safety Management System (SMS), including a safety and environmental protection policy; instructions and procedures to ensure safe operation of ships and protection of the environment in compliance with relevant international and flag state legislation; defined levels of authority and lines of communication between, and among, shore and shipboard personnel; procedures for reporting accidents and non-conformities; procedures to prepare for and respond to emergency situations; and procedures for internal audits and management reviews.

2.1.1 Ceres Safety, Quality & Environmental Protection Management System (SQEMS)

In accordance with the ISM Code, Ceres established a Safety, Quality & Environmental Protection Management System (SQEMS). Documentation of this system includes three basic manuals:

Safety & Quality Management Manual	(SQMM)[44]
Company Operating Procedures Manual	(COPM)[45]
Fleet Operating Procedures Manual	(FOPM)[46]

Other documents, both internal and external to the company, are incorporated by reference in the SQEMS. Examples include the Cargo & Ballast Operations Manual, Ceres Circulars, the International Safety Guide for Oil Tankers & Terminals (ISGOTT) and Dr. Verwey's Tank Cleaning Guide.

2.1.2 Audits

Ceres received a Document of Compliance (DOC) from the American Bureau of Shipping (ABS) on 12 December 2002, based on an audit completed on 24 October 2002.[47] Three non-major Corrective Action Requests (CAR) were documented.[48] The company completed its first annual external audit on 16 February 2004 with one non-major CAR documented.[49]

[44] Attached as ECN 2015212 #60 JRC.
[45] Extracts attached as ECN 2015212 #94 JRC.
[46] Extracts attached as ECN 2015212 #95 JRC.
[47] The DOC is attached as ECN 2015212 #09 JRC.
[48] The results of the audit are attached as ECN 2015212 #13 JRC.
[49] The results of the audit are attached as ECN 2015212 #12 JRC.

The BOW MARINER received a Safety Management Certificate (SMC) from ABS on 25 February 2002, with an expiration date of 19 January 2006,[50] and underwent an intermediate audit by ABS on 27 August 2003 in Ulsan, Korea.[51] No CARs were identified.

The BOW MARINER underwent an internal audit 5-7 June 2003 while the vessel was under the command of a different master. Twenty-five observations were recorded, including five pending from the previous year. One non-conformity report was issued listing ten record keeping errors, including one pertaining to failure to complete an enclosed space entry permit and another for failure to record training. The non-conformance was closed on 6 July 2003.

2.1.3 ISM Compliance

Despite this apparent documentation of full compliance with the Code, there are numerous indicators that the Ceres SQEMS was not fully implemented or functional aboard the BOW MARINER:

1. The cargo tanks were not inerted as required by Section 1.10.1 of the Cargo & Ballast Operations Manual and Section 1.5 of the IGS Manual.

2. The procedures for tank cleaning in Section 1.13.9.1 of the Cargo & Ballast Operations Manual, Tanker Safety Guide, Chemicals and Dr. Verwey's Tank Cleaning Guide[52] were not followed.

3. Procedures for confined space entry in Section 16.8 of the FOPM and Section 1.10.6 of the Cargo & Ballast Operations Manual were not followed.

4. The failure of one of two required blowers on the IGS, a critical safety system, was not reported as a non-conformance as required by Section 19.1.1.2 of the SQMM and Section 1.10.1 of the Cargo & Ballast Operations Manual.

5. Monthly fire and boat drills were not conducted as required by SOLAS Regulation 19 and Section 7.4 of the FOPM.

6. Training was scheduled and recorded in the Minutes of Safety Committee Meetings but not conducted. Survivors reported that the training scheduled for February was not conducted, and that the only training given was on the ISPS Code, which was not scheduled or recorded in the Minutes of the Safety Committee Meeting for February.

7. Second Assistant Engineer Aguilar joined the BOW MARINER in Port Said, Egypt on 5 February 2004, and was making his first voyage on a Ceres vessel. Under Section 2.1.2 of the FOPM, he was required to have an overlap of one voyage leg, but not less than 72-hours, with the departing engineer. Instead the two men crossed on the gangway and

[50] The SMC is attached as ECN 2015212 #10 JRC.
[51] The results of the audit are attached as ECN 2015212 #11 JRC.
[52] Dr. Verwey's Tank Cleaning Guide is incorporated by reference in the Ceres SQEMS. An extract is attached as ECN 2015212 #88 JRC.

had no overlap or sharing of information. Ceres officials later stated the departing second assistant engineer was discharged for cause so an overlap was not possible. However, the required overlap could have been met by retaining the discharged second assistant engineer until the BOW MARINER arrived at Kali Limenes, Greece on 7 February 2004.

8. None of the survivors went through indoctrination or familiarization as described in Section 2.1.2 of the FOPM, stating that "there was no time."

9. Officers below the grade of chief officer and chief engineer had not read applicable portions of the SQEMS. Second Assistant Engineer Aguilar reported that he was sternly rebuked when he asked Chief Engineer Athanasiou about administrative procedures.

2.2 IGS Operation

2.2.1 Principle of Operation

The basic premise of IGS operation is to reduce the level of oxygen in the cargo tank to a level that will not support combustion. A mixture of flammable gases and oxygen is flammable only when the components are in the correct balance. The explosive range falls between the Lower Explosive Limit (LEL), which is too lean to burn, and the Upper Explosive Limit (UEL), which is too rich to burn. Inert gas is a gas that will not support combustion, such as CO2 or nitrogen.

Chemical tankers are fitted with special inert gas generators, like that on the BOW MARINER, because boiler flue gas is too dirty for use with some chemicals. These generators are more expensive to install and operate because they are an entirely separate piece of machinery and burn a high grade of fuel oil. When starting to inert with an empty tank it is first purged by dilution or displacement to remove the air. Dilution is done at high velocity and requires three to five air changes of the cargo tank; displacement is done at low velocity and requires about one and a half air changes. Purging continues until the oxygen content in the tank is below eight percent. After loading cargo the IGS is operated until the tanks are pressurized sufficiently to prevent air from being drawn into the tanks. The IGS should be operated throughout cargo discharge to provide a steady supply of inert gas to replace the volume of cargo as it leaves the tanks. A properly inerted cargo tank cannot explode or support combustion.

2.2.2 Regulatory Requirements

Chemical tankers constructed before 1 July 1986 and carrying flammable cargoes "other than crude oil or petroleum products," are not required to carry or use IGS.[53] On 28 February 2004 the BOW MARINER was carrying ethyl alcohol and residual MTBE, both non-petroleum, Grade C flammable cargoes; therefore, the tanks were not required to be inerted by international or U.S. regulations.[54]

2.2.3 Ceres Company Policy

[53] See U.S. Coast Guard NVIC 2-88, attached as ECN 2015212 #58 JRC.
[54] An analysis of the IGS requirements for the BOW MARINER is attached as ECN 2015212 #59 JRC.

Although exempt by regulation from IGS requirements, the BOW MARINER was required to inert its tanks by Ceres' SQEMS. Section 1.10.1 of the Cargo & Ballast Operations Manual states:

> When vessels are fitted with IGS, it is Company requirement they operate with cargo and slop tanks in inert condition at all times. Only exception is operational requirement to enter tank for inspection or maintenance purposes.
>
> IGS must always be:
>
> - Operated and maintained in accordance with instructions contained in manufacturer's manual. Manual is required by SOLAS and is always primary IGS operating instruction.

This section goes on to require that the inability of the system to operate at optimum efficiency be reported to the Ship Manager as soon as possible.

2.2.4 IGS Manual

The BOW MARINER was provided with operating instructions by the manufacturer. Although this was an external document and not a direct part of the SQEMS, it was incorporated by reference in Section 1.10.1 of the Cargo & Ballast Operations Manual as the "…primary IGS operating instructions." Section 1.5 of the IGS Manual states:

> The basic purpose of the inert gas system is to ensure crew and vessel safety by maintaining the oxygen content in the cargo tanks at the lowest level possible under all conditions of operation, except when a tank must be gas-freed for entry or change of specific product carried. In all inerted modes the oxygen content of the tank must not exceed 8% by volume and must be maintained at a positive pressure of 100mm W.G. minimum.
>
> This means that tanks will be inerted when:
>
> 1. Loading
> 2. Discharging
> 3. On sea-passage-loaded or ballasted
> 4. Tank washing

2.2.5 Actual Practice

These manuals clearly and unequivocally establish that the cargo tanks of the BOW MARINER should have been inerted during cargo discharge in New York, based on the Ceres SQEMS in effect at that time. According to Second Assistant Engineer Aguilar and Third Officer Ortilano,

they were not. In fact, Third Officer Ortilano stated that in his experience aboard the BOW MARINER, both as third officer and able seaman, he had never known the IGS to be used.[55] This was corroborated by former BOW MARINER crewmembers that were interviewed when the investigating officer visited the BOW TRANSPORTER in Singapore. In addition, the master, chief officer, chief engineer and Ceres officials aboard the BOW TRANSPORTER confirmed that prior to the BOW MARINER explosion, they operated the IGS only when it was required by the port state or facility. When shown Section 1.10.1 of the Cargo & Ballast Operations Manual they appeared to be unfamiliar with it, and at first asserted that the section did not apply to chemical tankers. When the investigating officer pointed out the manual itself was specifically for "Tankers/Chemical Tankers," they continued to assert that they were not required to inert because of the vessel's date of build.[56] In fact, the chief officer of the BOW TRANSPORTER scoffed at suggestions that the Cargo & Ballast Operations Manual was governing, stating that his "30 years of chemical tanker experience" was all he needed to perform his job. The Ceres official then stated that they were now inerting at all times "…at company expense."

2.2.6 Condition of the IGS

According to Second Assistant Engineer Aguilar and Electrician Bactat, the IGS aboard the BOW MARINER had an inoperable blower for several months before the explosion. Second Assistant Engineer Aguilar stated that shortly after he reported aboard Chief Engineer Athanasiou instructed him to remove the number one (starboard) blower motor, which was "burned up," and replace it with the number two (port) blower motor. He could not state why this was necessary, since either blower could be used during IGS operation. Electrician Bactat recalled being asked to test the starboard motor but had not been asked to test the circuit to determine the cause of the motor failure. He opined that the motor likely failed because it was dirty. Neither Second Assistant Engineer Aguilar nor Electrician Bactat tested the motor after it was swapped out.

The vessel's preventive maintenance system required inspection of the IGS blowers at intervals of 30 months. Records indicate the blower was examined externally and operationally tested on 1 November 1998 and 28 March 2003.

A review of records from the BOW MARINER did not uncover a report of the motor failure as required by Section 1.10.1 of the Cargo & Ballast Operations Manual, nor was it reported as a non-conformance as required by Section 22.1.6 of the COPM and Section 19.1.1.2 of the SQMM. There was also no requisition for a new motor. These facts are further indication that Ceres and the senior officers of the BOW MARINER did not consider the IGS a critical piece of safety equipment.

[55] Ceres reported the BOW MARINER last inerted its tanks in January 2003 while carrying diesel fuel.
[56] Every officer gave nearly identical answers to questions about IGS, indicating some degree of preparation for the interview.

2.3 Tank Cleaning

2.3.1 Instructions for Tank Cleaning

Instructions for tank cleaning for the BOW MARINER are contained in the Cargo & Ballast Operations Manual, Procedures and Arrangements (P&A) Manual and Ceres Circulars. The SQEMS also cites Dr. Verwey's Tank Cleaning Guide and the Tanker Safety Guide, Chemicals as sources of information for tank cleaning procedures.

All of the references reviewed during this investigation recognize tank cleaning as the most hazardous operation routinely carried out aboard a chemical tanker. The Tanker Safety Guide, Chemicals, says it best:

> The additional risk created by cargo gases expelled from the tanks cannot be overemphasised. Depending on the most recent cargo carried in tanks to be cleaned, vapours that are toxic, flammable and corrosive should be expected to be released onto and around the cargo deck area. It is therefore of utmost importance that every possible care is exercised during all operations connected with tank cleaning and gas freeing, and that the operations are carried out using the approved procedures and arrangements of the ship.
>
> Personnel involved should be fully aware of the dangers and take necessary precautions, because the consequences of an inadvertent error can be serious and far reaching.

Section 13.9 of the Cargo & Ballast Operations Manual contains detailed instructions for 13 different tank cleaning methods, each designated by a letter. Each method is described in detail, and range from a cold seawater wash to use of various detergents and chemicals. The method of cleaning depends on the last cargo, next cargo and tank coating.

The P&A Manual describes the tank cleaning/gas freeing equipment and the procedures for stripping cargo tanks and lines.

Dr. Verwey's Tank Cleaning Guide is a commercial publication widely accepted in the chemical tanker trade. The Guide contains brief, generic tank cleaning procedures and extensive cleaning charts. The cleaning charts (Table 1) contain an alphabetical list of chemicals regulated by the BCH Code and IBC Code. Each product also has a number. The charts are used as follows:

1. Find the last product carried in the tank in the alphabetical listing (to the left).
2. Find the number corresponding to the next product to be carried (at the top of the chart).
3. Find the letter code for the tank cleaning procedure at the intersection of the horizontal row and vertical column for these products.

Table 2 contains the tank cleaning procedures for each of the letter codes.

2.3.2 Stripping Tanks and Draining Cargo Lines

Cargo tank cleaning serves many purposes, chief among them reducing marine pollution and maintaining cargo quality. The process actually begins by removing as much cargo as possible from the tanks and lines during unloading. The procedure for stripping the tanks and draining the cargo lines is contained in Section 3.3 of the P&A Manual.[57]

The BOW MARINER was equipped with tank bottoms that sloped toward the deepwell pump sumps and a cargo stripping system. When the bulk of the liquid cargo had been discharged, the main tank suction valve was closed and the stripping suction valve was opened in order to remove the last remaining pumpable remnants of the cargo. The remaining cargo contained in the pump stack[58] was purged into the main cargo line on deck using air, a process that took about 10 minutes and ended when an audible change in sound from the pump was heard. At that time the stripping valve and the hydraulic line to the pump were closed.

The procedure for draining or clearing the cargo piping after discharge involved blowing down the lines with compressed air. A two-inch flexible air hose was connected to the line at the tank valve. The air valve was opened and the line blown for 20 seconds at 8 bar. This procedure was repeated three times. Afterward the air was left on and the manifold valve closed for 10 seconds, then re-opened. This procedure was also performed three times. Next the air supply was disconnected from the tank valve and connected to the offshore side of the manifold. The shore line was blown ashore for 20 seconds, and the manifold valve opened and closed twice during this procedure. When done the air supply was disconnected and the manifold valve closed.[59]

It is not known whether these procedures were followed during cargo discharge in New York, but the surviving AB reported that he assisted the pumpman with a similar procedure during the day on 28 February 2004 while at sea. The boatswain and others were working on cleaning the aft sumps while he and the pumpman were at the port manifold. The AB could not describe the procedure in detail, stating only that his job was to open and close the air valve when directed by the pumpman. Ceres officials stated that cargo line draining should have been completed during discharge and could not explain the procedure described by the surviving AB.

Blowing down piping that previously contained a flammable or combustible cargo with air is not a recommended practice aboard tank vessels. Air introduced at high pressure into piping or a tank can cause static accumulation and result in an electrostatic discharge. This practice also introduces air, and thus oxygen, into the piping and tanks, potentially bringing the atmosphere into the flammable range. The recommended procedure for blowing down cargo piping that contained flammable or combustible cargo is to use inert gas or nitrogen.

[57] The P&A Manual is attached as ECN 2015212 #63 JRC.
[58] The "pump stack" is the piping that rises from the pump housing in the cargo tank sump to the top of the cargo tank and into the main cargo piping.
[59] There is no discussion in the P&A Manual of the potential for an electrostatic discharge in the section about blowing down the cargo lines with air.

2.3.3 Tank Cleaning Procedures for MTBE

Using the cargo loading plans for voyages 2004/01, 2004/02 and Dr. Verwey's Tank Cleaning Guide, procedure "D" was the proper tank cleaning procedure for the empty tanks that previously held MTBE. Table 2 describes procedure D as follows:

1. Butterworthing with cold seawater for 1 hour;
2. Flushing with fresh water;
3. Steaming;
4. Draining of tank, line and pump;
5. Drying.

This procedure corresponds in part to Code "A" of the Cargo & Ballast Operations Manual. The Code A procedure discusses seawater purity, temperature, pressure and time needed for cleaning in very general terms.

2.3.4 Actual Practice

On 28 February 2004 the BOW MARINER was not engaged in a standard procedure for tank cleaning or gas freeing. The master ordered the crew to open all of the cargo tank hatches for the empty tanks once the vessel was at sea. He did not explain these instructions and the crew did not question the order. Since neither he nor the chief officer survived, his intentions could not be determined; however, it appears that he intended to ventilate all cargo tanks at once while cleaning the sumps of residual cargo, and then mechanically ventilate the cargo tanks.

After the explosion Ceres officials asserted that the charterer's Commodity Book[60] contained instructions for gas freeing the tanks by cleaning the sumps and ventilating the tanks, and that the master may have been following those instructions. The Commodity Book reads as follows:

> VENTILATION
>
> Ventilate tank until gas free, (content in sump should be removed). Use of duct and pull vapour out from the bottom of the tank. A deionized water flush of the bottom might be required.
>
> ALTERNATIV (Sic):
>
> CLEANING WITH FRESH WATER.
>
> Clean tank using warm (50-60C) fresh water for 30 minutes. If short of freshwater, use 30 minutes warm seawater, and then freshwater for 10 minutes. For cargoes requiring high grade water white standard (Methanol MEG FG/Standard) a final rinse with deionized water or the product to be loaded may be required.

[60] An excerpt from the Commodity Book with cleaning procedures for MTBE is attached as ECN 2015212 #100 JRC.

If cold water is used, 50% more cleaning time is necessary.

These instructions lack detail and do not specify how the contents of the sumps should be removed. There is also no reference to opening the cargo tank hatches to naturally ventilate on deck. In fact, a search of the literature on tank cleaning and gas freeing procedures revealed no reference to a procedure that involved the natural venting of flammable vapors through the cargo hatches as was done aboard the BOW MARINER. The Tanker Safety Guide, Chemicals published by the International Chamber of Shipping and incorporated by reference into the Ceres SQEMS, addresses the subject as follows:

7.7.1 *Safe procedures for gas freeing after tank cleaning*

1. Venting of toxic and flammable gas during gas freeing should be through the vessel's approved gas freeing outlets, and therefore the exit velocity should be sufficient to carry the vapours clear of the deck. No escape of cargo vapours should occur at deck level before concentration within the tank has fallen below 30% LFL[61] and the relevant Threshold Limit Value. Thereafter, final clearance of the vapour mixture may continue at tank deck level through other larger deck openings.

2. If portable ventilation equipment is to be used to blow air into a tank, tank openings should be kept closed until work on that tank is about to commence.

Opening of all of the hatches for the empty cargo tanks, as was done on the BOW MARINER, fails to conform to any known customary marine practice. Because the tanks had not been washed or mechanically ventilated the concentration of vapor was very high, and certainly well above the UEL for MTBE. Opening all of the cargo tank hatches permitted vapors to escape at deck level, where the crew was actively working. This exposed them to toxic vapors and increased the likelihood of an explosion to initiate from an accidental spark. MTBE vapors are heavier than air, and there were many obstructions on deck created by the cargo systems, manifolds and midship deckhouse where pockets of vapor could accumulate, despite cross deck wind or the vessel's forward movement. It also permitted oxygen to enter the tanks, diluting the fuel-rich atmosphere and possibly bringing the mixture within the tanks into the explosive range. There is no evidence that the speed of the gas freeing process would have increased by opening the cargo hatches.

2.3.5 Post-Casualty Communications Regarding Tank Cleaning

On 8 March 2004 Odfjell issued Document No 0401 titled, "Safe operations related to cargo tank cleaning and venting."[62] The instructions reminded masters of the following:

A) Equipment on the cargo deck and in cargo tanks to be intrinsically safe and approved for use in hazardous atmospheres.
B) All hoses and equipment used on cargo deck and in cargo tanks; tank cleaning hoses,

[61] Lower Flammable Limit, which is equivalent to the Lower Explosive Limit (LEL).
[62] This document is attached as ECN 2015212 #85 JRC.

hoses for stripping pumps and ejectors, "Norclean electors", tank vents etc, to be properly grounded and in safe working condition.

C) Make sure procedures and requirements with regard to conductivity testing of these hoses and related equipment are properly carried out.

D) Assure all required flame screens are in place and in sound working condition.

E) Make sure all written procedures relating to entering enclosed spaces are strictly adhered to.

F) Operations requiring personnel to enter cargo tanks with flammable atmosphere (with relevant equipment; breathing apparatus etc;) to be in accordance with Odjfell Seachem's R&GM Doc 21 03 02, in particular sec. 5.2.3 and 5.2.4. **Such tanks not to be entered for tank cleaning.** (Emphasis not added.)

This was followed by an e-mail to all masters on 10 March 2004 that stated, "Please note that all use of Norclean equipment (air driver ejector pumps) on deck and in tanks are prohibited with immidiate (sic) effect. Further instructions will be sent within few days."[63]

On that same day Odfjell issued Document No 0402,[64] which referred to the previous communications and immediately implemented the following:

1. "Norclean" or other similar air driven ejectors/eductors shall not be used in the cargo area or other areas/confined spaces/tanks unless the atmosphere in which it is being used has been measured and verified gas free.

2. **No** entry is allowed into cargo tanks for cleaning, ejecting/educting or other purposes including positioning of portable pumps until the oxygen level has been confirmed to be sufficient and there is not any explosives/flammables or toxic gas present. (Emphasis not added.)

3. Only tanks in progress of being mechanically ventilated shall be open during gas freeing.

Document No 0402 also rescinded the earlier e-mail prohibiting the use of Norclean equipment.

Taken together these documents indicate that within a few days of the BOW MARINER casualty Odfjell had identified significant procedural errors, including confined space entry in unsafe atmospheres and opening of the cargo tank hatches.

2.4 Confined Space Entry

[63] The e-mail is attached as ECN 2015212 #84 JRC.
[64] This document is attached as ECN 2015212 #86 JRC.

2.4.1 Ceres Company Policy

Ceres policy for entry into tanks and other confined spaces is contained in Section 16.8 of the FOPM, and mentioned in Section 1.10.6 of the Cargo & Ballast Operations Manual. Section 1.10.6 states:

> **TANK IS NOT ENTERED UNTIL ENCLOSED SPACE ENTRY PERMIT HAS BEEN ISSUED AND THE PRECAUTIONS IN CHAPTER 16, SECTION 8 COMPLIED WITH.**

The chief officer was responsible for issuing the permit, after testing the space for oxygen, hydrocarbon vapors and toxic vapors.

However, Section 16.8.2 of the FOPM qualifies these restrictions:

> Entry into following spaces *without breathing apparatus and suitable protective clothing* is prohibited…(Emphasis was not added.)

This statement allows confined space entry with a breathing apparatus and "suitable protective clothing." In other words, the precautions of Section 16.8 apply only when entering a confined space without a breathing apparatus. Thus, under Ceres policy, the entry of the boatswain into the cargo tanks with an SCBA and chemical suit was permissible.

Additional guidance for confined space entry aboard chemical tankers can be found in Chapter Three of the International Chamber of Shipping's *Tanker Safety Guide – Chemicals*. Section 3.5, "Entry Into Contaminated Spaces," states:

> Unless all necessary safety precautions can be followed, spaces should only be entered by personnel wearing breathing apparatus, appropriate protection against exposure to flammable, toxic or corrosive cargo vapours and, if practicable, a lifeline.
>
> In chemical tankers, operational entry into cargo tanks may be required before the atmosphere is certified as safe. A documented system should exist to ensure safety throughout any operation when entry of a contaminated cargo tank, or one suspected of being contaminated, is necessary.

There is no further guidance in Ceres policy or the Guide about when entry into a contaminated space is permissible.

On 4 May 2004 Ceres amended Section 16.8.3 of the FOPM by adding the following statement:

> *No entry should be made into cargo tanks for cleaning, ejecting/educting or other purposes including positioning of portable pumps until there is no explosive/flammable or toxic gas present and the oxygen level has been confirmed to be sufficient.* (Emphasis not added.)

2.4.2 Actual Practice

It is not likely that Chief Officer Melles performed any tests or issued a confined space entry permit because there was little point in testing a tank that had not been washed and ventilated. In the absence of specific guidance in the FOPM, or the Guide, regarding when entry into a confined space with an SCBA is permissible, he complied with the existing policy by merely having the boatswain don a SCBA and protective suit. Entering a tank that has not been gas freed is extremely dangerous and should be limited to only the most dire emergencies. Opening the hatch introduces oxygen into the tank, potentially diluting the fuel-rich atmosphere into the flammable range. In addition, the SCBAs aboard the BOW MARINER had steel bottles, raising the possibility of a spark from metal to metal contact between the bottle and the components in the tank. Lowering a Wilden pump into the tank, which has many metal parts, likewise increased the risk of a spark.[65]

2.5 The Ignition Source

The source of ignition is not known and cannot be determined to any degree of certainty. Possible sources of ignition considered were:

Cell phones
Sabotage
Smoking
Electrostatic discharge
Mechanical sparks
Electrical sources

Cell phones are not considered a likely source of ignition because their use was prohibited on deck, very few crewmembers had them and the ship was well beyond cell phone range. Other portable devices, such as radios and flashlights, were approved for hazardous areas.

Sabotage or other criminal acts are unlikely. By all reports the crew was well paid and liked their jobs. It is not likely that a person who was disgruntled would seek revenge in a manner that would place his or her own life at grave risk. If a person was inclined to perform a criminal act, it is more likely they would do so while alongside, where the damage would be substantially greater and the possibility of escape more likely.

[65] Ortilano could not recall if the line used to lower the pump was synthetic, which has a higher risk of creating a static discharge; however, the point is moot since the explosion occurred hours after the Wilden pump had been hauled out of the tank.

Smoking is not considered a likely source of ignition. The crew collectively had a lot of experience sailing on tankers, and the dangers of smoking on deck were well known to them. Some members of the crew smoked, but all were well aware of the smoking policies. An interior smoking lounge was provided, and there was no reason to smoke on deck. None of the survivors reported ever seeing anyone smoking on deck. Furthermore, survivors who had worked on deck earlier in the day reported there was a strong odor of MTBE, so the danger of lighting up would have been very apparent.

Chief Officer Das of the DAKSHINESHWAR is the only witness who purports to have seen the initial flash, fire and explosion, from a distance of 3.6 nautical miles. He stated that he saw a "yellow flash," one to two meters above the deck, and about 20 meters aft of the bow at precisely 1805. His observations may not necessarily represent the exact location because of his distance from the BOW MARINER. Chief Officer Das was first interviewed by Coast Guard investigators when the DAKSHINESHWAR arrived in Corpus Christi, Texas on 8 March 2004. During his interview he was shown a photograph of a sister vessel and asked to mark it with the location of the flash. He circled an area just forward of the port manifold, then indicated the path of the ensuing fire upward and trailing aft to a position in way of the number six cargo tanks, where he indicated the first explosion occurred.[66] Attorneys representing the P&I Club interviewed Chief Officer Das again on 22 May 2004 in Mumbai, India. Chief Officer Das' statement was overall consistent with his statements to the Coast Guard in March, except that in this case he made notations about the location of the initial flash, fire and explosion on a general arrangement drawing of the BOW MARINER.[67] He indicated the flash and fire occurred in way of the number 2P cargo tank, trailing aft to the number 5P cargo tank, where he indicated the first explosion occurred. (The number five and six cargo tanks are located in way of the manifold.) The markings on the drawing are more consistent with his statements that he saw the flash 20 meters aft of the bow than the markings he made on the photograph, which placed the flash in the midbody. Importantly, Chief Officer Das also stated that the deck and navigation lights of the BOW MARINER were not turned on.

The location and timing of the flash provide clues to the possible ignition source. When Third Officer Ortilano brought the second drum to the deck at 1705 he found that everyone had gone to dinner. He observed the Norclean equipment set up on the first drum he helped fabricate, and noted the hose was led through the Butterworth opening that was nearest the number 8S cargo tank hatch. The unit was not in operation at this time. Neither Third Officer Ortilano nor Electrician Bactat had bonded the drum to the lid in accordance with the manufacturer's instructions,[68] a precaution to prevent electrostatic accumulation. Third Officer Ortilano did not make note of whether the bonding clamp from the Norclean equipment was properly connected to the ship. Although the steel drum was sitting on the steel deck, a good electrical connection cannot be assumed since the deck was painted and the drum was also most likely painted. Third Officer Ortilano went to dinner and then to his room to rest for his watch. The flash was observed at 1805 about 20 meters aft of the bow

[66] This photograph is attached as ECN 2015212 #14 BAG.
[67] The drawing is attached to Chief Officer Das' affidavit, identified as ECN 2015212 #01 JDL.
[68] Manufacturer's information is attached as ECN 2015212 #02 CAO.

on the port side. This corresponds to the time the crew would have reported for overtime, but is away from the two areas where the crew had been working, i.e. the port manifold and on the starboard side aft. Therefore, it is unlikely that the Norclean equipment was the ignition source. It is also unlikely that a mechanical spark from the work being performed ignited the fire since the work areas were well away from the reported location of the flash.

Earlier in the day Able Seaman Ronquillo assisted the pumpman with a procedure remarkably similar to blowing down cargo lines, something that would normally be accomplished while alongside immediately after discharging cargo. The normal safe practice in the industry is to use inert gas, such as nitrogen, to blow down cargo lines that contain flammable cargo. There is a potential for electrostatic accumulation in the air hose in this operation, which could be discharged when the hose was disconnected. There is also the potential for a mechanical spark tools used during this operation, such as steel spanner wrenches.[69] The only witness who purports to have seen the initial flash, Chief Officer Das of the DAKSHINESHWAR, gave conflicting statements about its location. In his first interview with the Coast Guard just days after the casualty, Chief Officer Das stated that the flash occurred near the port manifold, in the area where Able Seaman Ronquillo stated he had been working with the pumpman before dinner. Chief Officer Das made notations on a photograph of a sister vessel identifying the location of the flash and depicting the resultant fire and location of the first explosion. Months later he signed an affidavit stating the flash occurred about 20 meters aft of the bow. It is not known why Chief Officer Das changed his statement. If his initial statement is accepted as the most accurate, given it was taken soon after the casualty, the possibility of an electrostatic discharge or mechanical spark from the work being performed by the pumpman cannot be dismissed.

The time of the flash corresponds not only to when the crew would turn to for overtime but also with twilight. Chief Officer Das stated that the deck lights and navigation lights of the BOW MARINER were not turned on. Given that darkness was setting in it is likely the crew would request the bridge watch to energize the deck lights, which were located throughout the cargo deck area. The fixtures were explosion-proof and approved for hazardous locations, but may have sustained damage in the heavy weather encountered while crossing the Atlantic, particularly the fixtures located forward. Although these fixtures are higher than one to two meters above the deck, the estimated height of the flash, they cannot be discounted as a possible ignition source since Chief Officer Das observed the momentary flash from a distance of 3.6 nautical miles.

Electrician Bactat stated that he did not routinely inspect the lighting fixtures on deck, relying on the deck crew to report any problems with the fixtures.[70] He stated that the crew did not report any problems with the light fixtures during cargo operations in New York. Third Officer Ortilano stated that the deck officers did not routinely inspect the fixtures before cargo operations and would only report a problem if a light was not working.

[69] Unlike petroleum tankers chemical ships do not use non-sparking tools because some of these tools can cause reactions with some chemicals.

[70] A review of records revealed one explosion proof fixture mounted on the forecastle bulkhead had been replaced because the enclosure was wasted.

Electrician Bactat also reported that he had worked on an exterior light fixture outside of the accommodations on the main deck on 28 February 2004. The socket of the fixture required replacement. He secured the power, tagged out the circuit and disassembled the fixture, but did not finish the work since he had been awake since 0200 and left the work for the next day. This fixture could not be the ignition source since it was de-energized and was located aft.

Another possible ignition source was a spark from the funnel, which last underwent repairs in 2002. Such sparks are not uncommon, and under the right conditions a hot particle of soot could have found its way to a pocket of vapor on deck. The vessel was proceeding on a southerly course and winds were out of the northwest at less than 15 knots. Under these conditions, and with 22 cargo tanks venting directly to the deck level, the conditions were ripe for the accumulation of flammable vapor in pockets among the many obstructions on deck. If a hot particle found its way to one of these vapor pockets it could trigger a flash and fire as described by Chief Officer Das. However, the vessel was underway at about 14.5 knots, and any soot or hot particles would most likely trail aft and fall harmlessly into the water. It is not likely the 15-knot northwest wind would have overcome the tendency of the exhaust to trail aft.

A spark from portable, battery operated equipment was also considered as a possible ignition source. The crew was returning to work near dusk and would likely be using flashlights. Other battery operated equipment, such as portable gas meters, would also be in use during a tank cleaning operation. If the crew changed batteries on deck in an area where vapors had accumulated, it is possible a spark could be generated. The likelihood of this occurring is considered slight. Battery operated portable equipment aboard the BOW MARINER was certified for use in hazardous locations, and changing of batteries normally occurred in the cargo control room, other work spaces or accommodations. The crew did not routinely carry replacement batteries with them on deck, and would have most likely taken the equipment to a safe location where spare batteries were stored. In addition, it is unlikely that such low voltage equipment would generate a flash sufficient to be seen from a distance of 3.6 nautical miles.

2.6 Structural Damage, Flooding and Sinking

The BOW MARINER suffered catastrophic structural damage throughout the cargo block in two main explosions, each of which was actually a rapid series of explosions representing individual tanks exploding in sequence. The first tank to explode could not be determined; nor could the sequence of tank explosions. According to the only witness the initial explosion occurred on the port side in the midbody. Underwater video revealed that nearly all of the wing tanks exploded, with most of the side shell missing in the cargo block on both sides. Damage control efforts were not possible and would not have delayed the ultimate sinking.

Survivors and witnesses reported the vessel listed almost immediately to starboard and down by the bow. This initial starboard list and head down trim is not conclusive that the first explosions occurred on the starboard side forward. All of the explosions occurred in less than two minutes, and it is just as likely that the initial list and trim were the result of more extensive initial damage in that area as any other cause. Survivors stated the ship later shifted suddenly to port and settled on an even keel. This occurred when the stern of the ship was rising, indicating this shift may have occurred when the bow of the 570 foot ship hit the bottom, about 250 feet below sea level. The ship was in this position when the first Coast Guard aircraft, an HC-130, arrived at about 1915 and began filming with an infrared video camera. It is not known how long it took for the ship to reach this position, but based on the statements of survivors it was certainly less than one hour. The sinking of the BOW MARINER was filmed on the infrared video at precisely 1937.

Review of the underwater video revealed extensive damage to the cargo block area, with much of the side shell missing and large sections of deck plating damaged. There were fractures forward and aft that were not consistent with damage from an explosion, which likely occurred when the bow struck bottom and later when the entire ship came to rest in an upright position.

At the time of the explosions cargo tanks 2C, 3C, 4C, 6C, 7C and 9CP were loaded with ethanol. The underwater video revealed these tanks, with the exception of number 2C, did not explode. Damage to the deck over cargo tank 2C appears consistent with an explosion, which should not have occurred given the tank was loaded. However, it is possible that the force of the explosion of adjacent cargo tanks may have been sufficient to cause the damage observed.

2.7 Training, Indoctrination and Drills

The six survivors reported vastly different memories of fire and boat drills conducted, ranging from weekly to only once in six months. Only one crewmember could recall specific details of a fire and boat drill that occurred in January while the vessel was sailing from Taiwan to Singapore; however, this drill was not recorded in the Minutes of the January Safety Committee Meeting.

There were other indications that the records of training and drills, as recorded in the Minutes of the Safety Committee Meetings, were inaccurate. Many of the entries related to inspections were identical from month to month, including typographical errors, indicating portions of the Minutes were simply copied from month to month.
The Minutes were sent to Ceres officials ashore monthly, where they were reviewed. No single

person was assigned to review the Minutes, and under the existing review procedure a different person might review the Minutes from month to month. As a result, it is likely that each month's report was reviewed in a vacuum, without comparison to previous reports. It is unlikely this procedure would detect the problems noted in the Minutes reviewed for this investigation.

2.8 Shipboard Culture

The master, chief officer and chief engineer of the BOW MARINER were Greek and the remaining officers and crew were Filipino. The authority and responsibility of the senior shipboard management is spelled out in Section 6.1.3 of the SQMM, as well as Sections 2.2 (master), 2.3 (chief officer) and 2.4 (chief engineer) of the FOPM. Under the SQEMS the master has "total responsibility" for the operation, seaworthiness and safety of the vessel at all times. The chief officer is also designated as the safety officer, responsible for maintenance of equipment and training of personnel, in addition to his other duties. All three senior officers are charged with implementing the SQEMS.

Section 2.1.1 of the FOPM describes the master's authority as follows:

> The master has full authority over all persons (personnel and passengers) onboard his vessel. The Master's authority is not questioned and must be supported and maintained by onboard personnel. Orders must be carried out and obeyed as said, in letter and in spirit. Refusal to do so is grounds for prompt disciplinary action, including possible termination of employment.

Such absolute authority is not unusual aboard seagoing vessels. Indeed, many would argue such absolute authority is essential to maintaining good order and discipline. But on the BOW MARINER the distinctions between the Greek senior officers and Filipino crew were remarkable. Filipino officers did not take their meals in the officer's mess, were given almost no responsibility and were closely supervised in every task. The second assistant engineer, who was working aboard a Ceres vessel for the first time, was upset when he was chastised on his first day aboard because he inquired about his management and administrative duties. The chief engineer sternly told him that he would be given verbal job orders daily, was to do only as he was told and would have no administrative duties beyond making log entries. In contrast, Section 2.4.2 of the FOPM spells out significant duties for the second engineer - duties the chief engineer on the BOW MARINER was not prepared to entrust to his subordinate officers. This contrast between the content of the SQEMS and actual practice aboard the BOW MARINER was pervasive.

The lack of trust was apparent on deck as well. The surviving deck crew reported that the chief officer would not sleep, beyond short naps in a chair in the CCR, during cargo operations. They stated this practice was common aboard Ceres vessels. The chief officer performed all management and administrative duties himself, including the preparation of plans for cargo loading/unloading, ballast management, tank cleaning and gas freeing, training and drills. He did not delegate or attempt to train the junior officers to perform any of these tasks, either to reduce his own workload or provide for their professional growth. As a result the Filipino crew had little knowledge of the technical aspects of their job, so much so that they failed to question

unsafe actions or procedures. When questioned about what they would do if instructed to do something unsafe by one of the senior officers, each crewman replied that they would do as they were ordered. [One crewman said that the orders of the Greeks were "like words from God."] This lack of technical knowledge and fear of the senior officers explains why the crew did not question the master's unsafe order to open all of the empty tanks; they either did not know about the danger or were not inclined to question the master's order.

The fear of the Greek officers extended also to the galley. Messman Tagle reported that he did not like the Greek officers because they were verbally abusive to him and constantly threatened to send him home if he did not work harder or faster. Chief Cook Marentes was likewise afraid of losing his job. While these may have been the usual complaints of the lowest ranking crewmen aboard ship, there can be no question that such fear can lead to a shipboard culture where safety takes a backseat to preserving one's livelihood.

This attitude toward Filipino officers and crew was not limited to the BOW MARINER. As part of this investigation, the investigating officer visited a sister vessel, the BOW TRANSPORTER, in Singapore. During that visit many of the same attitudes were observed. The Filipinos were only permitted to speak to the investigating officer and Singapore officials in the presence of the senior officers, leading to obvious nervousness. Nevertheless, several crewmembers made statements confirming the same cultural divide existed aboard the BOW TRANSPORTER. The chief officer reported that he planned all of the cargo and tank cleaning operations, and also remained awake throughout all cargo operations. And engineers reported that they were not permitted to test the IGS in the absence of the chief engineer, a task any licensed officer on a tank ship should be able to perform.

Probably the most telling evidence of the lack of cohesiveness in the crew of the BOW MARINER was their response to the explosion. Although the official language of the crew was English, the Captain Kavouras and Chief Engineer Athansiou were conversing in Greek when they assembled with the crew aft of the accommodations. Messman Tagle, who was with this group, reported that he and the other crewmen were simply waiting for someone to tell them what to do. Those instructions never came. The final blow came when the Captain Kavouras ignored questions from Third Officer Ortilano about whether a distress signal had been sent. Instead of an organized, thoughtful response, the situation deteriorated to "every man for himself."

Ceres officials have defended the Captain Kavouras' actions and the crew's reaction after the explosion, citing emotional trauma triggered by the explosions, fire and immediate list. However, such trauma is expected and is precisely the reason that crews must be thoroughly trained and frequently drilled – so that they will react instinctively in an emergency just as they have been trained. The "trauma explanation" is also suspect given that far less experienced crewmembers controlled their emotions and reacted professionally. Captain Kavouras abandoned ship without sending a distress signal or conducting a muster, and left behind crewmembers he knew to be alive. Such conduct reflects his failure to conduct regular, realistic drills to prevent just such a reaction.

2.9 Commercial Pressures

The BOW MARINER arrived in New York two days behind schedule after a difficult crossing in poor weather. The bad weather caused the deferral of work on deck to prepare for a charterer's inspection scheduled for Houston, whereby all cargo tanks were required to be gas freed. It is not known if these delays and deferred work were a factor in decisions made by Captain Kavouras and/or Chief Officer Melles about the methods of gas freeing the tanks. Survivors reported that they did not work any more overtime than usual or sense any urgency from the senior officers. It is not known, then, why Captain Kavouras and Chief Officer Melles resorted to ill-advised and unsafe gas freeing methods that appeared to be intended to vastly speed the process.

One area where commercial pressures were clearly a factor was in the failure to inert the tanks. It is abundantly clear that, contrary to plain and unequivocal statements of company policy in the SQEMS, operation of the IGS aboard Ceres vessels built before 1 July 1986 was the exception and not the rule. Ceres sites several reasons for not inerting, including cargo contamination; damage to tank coatings; cost; and the vessel's date of build.

2.10 Other Recent Tank Ship Explosions

This report would not be complete without observing that the BOW MARINER casualty was the worst of four tank ship explosions that occurred worldwide between December 2003 and June 2004. The other casualties were:

> December 24, 2003 – The tanker SUN VENUS exploded while enroute Kobe, Japan from South Korea. The ship was cleaning tanks after discharging a cargo of benzene and ethyl alcohol. Two crewmen remain missing.
>
> January 2, 2004 – The tanker PANAMA SERENA exploded in Sardinia, Italy while discharging a cargo of benzene. Two crewmen remain missing.
>
> June 4, 2004 – The tanker NCC MEKKA, operated by Odfjell, exploded off the coast of Brazil while cleaning tanks. Two crewmen were killed.

In just six months there were four chemical tank ship explosions resulting in 27 deaths, severe environmental damage and significant economic damage, including the total loss of one ship. Three of the four casualties involved tank cleaning. This abysmal record and alarming trend deserves immediate and decisive action to identify common causes and implement corrective actions before more needless deaths occur.

3.0 Conclusions

1. The cause of this casualty was the ignition of a fuel/air mixture that was within its flammable limits, leading to a fire on deck.

2. The ignition source could not be determined. Sources that could not be ruled out include electrostatic discharge; mechanical sparks caused by metal-on-metal contact; faulty electrical equipment; hot soot or particles from the funnel; and sparks from changing the batteries of portable electrical equipment in a hazardous location.

3. Opening the 22 cargo tanks that previously held MTBE permitted flammable vapors that were heavier than air to accumulate on deck, and diluted the fuel-rich atmosphere in the cargo tanks with oxygen, bringing them into the flammable range.

4. The fire was followed by two significant explosions that occurred less than two minutes apart. The first occurred at 1806, and the second occurred before 1808. Each of the major explosions was actually a series of rapid explosions as each of the empty tanks exploded within seconds of one another.

5. The explosions caused catastrophic structural damage and led to immediate flooding of nearly the entire cargo block. The ship sank one hour and 32 minutes after the first explosion.

6. Contributing to this casualty was the failure of the operator, Ceres Hellenic Enterprises, Ltd., and the senior officers of the BOW MARINER, to properly implement the company and vessel SQEMS.

7. The cargo tanks were not inerted during the discharge of MTBE in New York, as required by the SQEMS. The tanks were not required to be inerted by U.S. law or international conventions because the BOW MARINER was constructed before 1 July 1986. If the tanks had remained closed, the explosion would not have occurred.

8. Captain Kavouras' order to open the 22 cargo tanks that had previously held MTBE was a stunningly significant breach of normal safe practices for a tank ship and defies explanation or excuse. Opening the tanks exposed the crew to toxic fumes, permitted flammable vapors that were heavier than air to accumulate on deck, and diluted the rich atmosphere in the cargo tanks with oxygen, bringing them into the flammable range.

9. The entry of the boatswain into the cargo tanks wearing a SCBA was dangerous and ill advised, but did not violate the Ceres' Confined Space Entry Policy in effect on 28 February 2004. That policy has since been revised to prohibit entry under the same circumstances.

10. The failure of Captain Kavouras to properly organize a response to the explosions contributed to the high loss of life. He abandoned ship without sending a distress signal, without attempting to contact a nearby ship, without conducting a proper muster or search for injured crewmen, and without attempting to launch primary lifesaving appliances.

11. Captain Kavouras and Chief Engineer Athanasiou abandoned ship within 10 minutes of the first explosion, leaving behind other crewmembers they knew to be alive. Their premature action exposed the crewmen who entered the water with them to the cold water far earlier than necessary, and contributed to the high loss of life.

12. The actions of Third Officer Lugen Ortilano, making his first trip as a licensed officer, were commendable and helped save the lives of himself and five others. The Coast Guard recognized him for his heroic efforts.

13. The lack of immersion suits contributed to the high loss of life. There was sufficient time for the survivors of the explosion, who were relatively uninjured, to don an immersion suit before entering the water. If the survivors had immersion suits the probability of rescue by one of the many responding vessels or aircraft, several of which were on scene in less than two hours, was very high.

14. The failure of Captain Kavouras to conduct regular and effective fire and boat drills contributed to the high loss of life. It is widely accepted that people react in emergencies precisely as they have trained. In this casualty, the officer on watch failed to sound the general alarm, failed to make an announcement and failed to send a distress signal. Several crewmen panicked and no one reported to their muster stations with the equipment they were assigned to bring. Those who gathered aft were disorganized, did not know what to do and were in desperate need of leadership that Captain Kavouras and Chief Engineer Athanasiou did not provide.

15. There is evidence that Ceres and the senior officers of the BOW MARINER failed to follow proper relief and indoctrination/familiarization training for critical crewmembers. Second Assistant Engineer Aguilar did not have the 72-hour minimum overlap required by the SQEMS for officers making their first voyage with Ceres. The 72-hour overlap requirement could have been met had Ceres signed off the departing second assistant engineer in Greece instead of Egypt. Other surviving officers reported they were not given time to complete the required familiarization checklist or read even a portion of the SQEMS. In fact, Second Assistant Engineer Aguilar stated he was specifically prohibited from performing many of the duties listed for his position in the SQEMS by Chief Engineer Athanasiou.

16. There is evidence of a lack of cohesiveness between the three senior Greek officers and the Filipino crew, but it could not be determined if this contributed to the casualty. Filipino officers did not eat their meals in the officer's mess, and were given only menial tasking. Several survivors reported that the Greeks treated them with disrespect and were

constantly threatening them with being fired. The survivors clearly feared the Greek officers, and each stated that they would obey any order from them, even if they knew the order to be unsafe. Able Seaman Ronquillo stated that orders from the Greeks were like "words from God."

17. The BOW MARINER spilled about 3,188,711 gallons of ethyl alcohol, 192,904 gallons of HFO, 48,266 gallons of LFO and an unknown quantity of slops into the U.S. EEZ.

18. There is no evidence that drugs or alcohol contributed to this casualty.

19. There is no evidence that fatigue contributed to this casualty; however, it is noted that the practice of the chief officer to remain awake for the entire cargo transfer operation would surely lead to extreme fatigue.

20. The regulations for investigation of marine casualties contained in 46 CFR Part 4 are out of date and conflict with revisions made to 46 U.S.C. 6101 made several years ago.

4.0 Recommendations

1. Recommend a copy of this report be provided to the following entities:
    1. The governments of Greece, the Philippines and Singapore.
    2. Odjfell Asia II PTE, Ltd.
    3. Ceres Hellenic Ship Enterprises, Ltd.
    4. The International Maritime Organization.
    5. INTERTANKO
    6. The International Chamber of Shipping
    7. The American Bureau of Shipping (ABS)
    8. Det Norske Veritas (DNV)

2. Recommend 46 CFR Part 4 be revised to reflect the addition of Subparagraph (d)(2) to 46 U.S.C. 6101 in 1992 and Subparagraph (g) to 46 U.S.C. 6101 in 2002.

3. Recommend 46 CFR Part 32.53, Inert Gas Systems, be revised to require the inerting of all cargo tanks carrying flammable cargoes aboard vessels equipped with Inert Gas Systems, regardless of the vessel's date of build.

4. Recommend that Ceres review their internal policies and procedures concerning workforce interaction and cooperation, including but not limited to delegation of appropriate duties to qualified officers.

5. Recommend the Commandant approach the International Maritime Organization, the International Chamber of Shipping and INTERTANKO about forming a study group to examine the causes of all tank vessel explosions in the last five years involving tank cleaning to search for common factors.

6. Recommend Commandant send a message to all marine safety field units emphasizing the importance of randomly verifying a tank vessel's compliance with its SMS for tank cleaning, confined space entry and tests and inspections of equipment.

//S//
J. R. Crooks, Jr.
Investigating Officer