

MA2017-10

**MARINE ACCIDENT
INVESTIGATION REPORT**

October 26, 2017



The objective of the investigation conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board is to determine the causes of an accident and damage incidental to such an accident, thereby preventing future accidents and reducing damage. It is not the purpose of the investigation to apportion blame or liability.

Kazuhiro Nakahashi
Chairman
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.

MARINE ACCIDENT INVESTIGATION REPORT

Vessel type and name: Oil/Chemical Tanker EIWA MARU 3
IMO number: 9073323
Gross tonnage: 740 tons

Accident type: Explosion
Date and time: Around 18:40, September 9, 2016 (local time, UTC +9 hours)
Location: Off to the south of Gobo City, Wakayama Prefecture
Around 163° true bearing, 9.1 nautical miles from the Kii Hinomisaki Lighthouse
(approximately 33°44.2'N, 135°06.9'E)

September 21 2014

Adopted by the Japan Transport Safety Board

Chairman	Kazuhiro Nakahashi
Member	Kuniaki Shoji
Member	Satoshi Kosuda
Member	Toshiyuki Ishikawa
Member	Mina Nemoto

SYNOPSIS

Summary of the Accident

At around 18:40 on September 9, 2016, while the oil/chemical tanker EIWA MARU 3 was sailing southeast off to the south of Gobo City, Wakayama Prefecture for Yokkaichi Port, Yokkaichi City, Mie Prefecture, with a master and other 9 crew members onboard, after unloading base oil, which is a base material of lubricants and other products, at Wakayama Shimotsu Port, Wakayama Prefecture, and with her crew cleaning her cargo tanks, an explosion occurred in her cargo tanks.

One crew member of EIWA MARU 3 was killed and two crew members suffered serious injuries. The tops and bulkheads of EIWA MARU 3's No. 2 and No. 3 cargo tanks were bent.

Probable Causes

It is probable that the accident occurred when, as the Vessel was proceeding southeast off to the south of Gobo City while conducting cleaning of the cargo tanks at night after unloading base oil in her No. 1 and No. 3 cargo tanks at Wakayama Shimotsu Port and leaving port, explosions occurred when, under conditions in which the Vessel began cleaning the cargo tanks using seawater with Butterworth cleaning machines and the cargo pumps and, in the course of the cleaning, base oil that remained in No. 2 cargo pump, bottoms of the No. 1 and No. 3 cargo tanks, and cargo-handling piping for the tanks was sprayed in the No. 3 cargo tank and became airborne up to the starboard No. 3 cargo tank ventilation duct, base oil in the duct and starboard No. 3 cargo tank vaporized and ignited

because the chief engineer conducted welding on the starboard No. 3 cargo tank ventilation duct.

It is somewhat likely that the chief engineer conducted the welding of the starboard No. 3 cargo tank ventilation duct as cleaning work was being done in tanks that had carried base oil with a high flash point because he thought there was no danger because the welded area was small and welding would be completed quickly.

It is probable that not flushing the cargo tanks, etc., prior to cleaning of the cargo tanks contributed to the circumstances in which base oil was sprayed in the No. 3 cargo tank and became airborne up to the starboard No. 3 cargo tank ventilation duct.

1 PROCESS AND PROGRESS OF THE INVESTIGATION

1.1 Summary of the Accident

At around 18:40 on September 9, 2016, while the oil/chemical tanker EIWA MARU 3 was sailing southeast off to the south of Gobo City, Wakayama Prefecture for Yokkaichi Port, Yokkaichi City, Mie Prefecture, with a master and other 9 crew members onboard, after unloading base oil, which is a base material of lubricants and other products, at Wakayama Shimotsu Port, Wakayama Prefecture, and with her crew cleaning her cargo tanks, an explosion occurred in her cargo tanks.

One crew member of EIWA MARU 3 was killed and two crew members suffered serious injuries. The tops and bulkheads of EIWA MARU 3's No. 2 and No. 3 cargo tanks were bent.

1.2 Outline of the Accident Investigation

1.2.1 Setup of the Investigation

The Japan Transport Safety Board (JTSB) appointed an investigator-in-charge and two other marine accident investigators to investigate this accident on June 10 and 20, 2016.

1.2.2 Collection of Evidence

September 11 to 16, 2016: On-site investigations and interviews

October 27, 28, 31, November 4, 24, December 16, 22, 2016, and February 7, 2017: Collection of questionnaire

November 7, 2016: Interviews and collection of questionnaire

1.2.3 Tests and Research by Other Institutes

With respect to this accident, the JTSB entrusted to the Nippon Kaiji Kentei Kyokai the investigations concerning the componential analysis of samples collected from the vessel.

1.2.4 Cooperation with the Investigation

The JTSB received advice and cooperation from researchers of the National Institute of Occupational Safety and Health, Japan of the Japan Organization of Occupational Health and Safety concerning the mechanisms behind the occurrence of explosions, and from researchers of the National Maritime Research Institute of the National Institute of Maritime, Port and Aviation Technology concerning the circumstances of the explosion as seen from the damage caused to the cargo tanks.

1.2.5 Comments from Parties Relevant to the Cause

Comments on the draft report were invited from the parties relevant to the cause of the accident.

1.2.6 Comments from the Flag State

Comments on the draft report were invited from the flag state of the EIWA MARU 3 (Republic of Korea).

2 FACTUAL INFORMATION

2.1 Events Leading to the Accident

2.1.1 The position according to the Automatic Identification System

According to the “records of the Automatic Identification System (AIS)^{*1} data (hereinafter referred to as “the AIS record”) of the “EIWA MARU 3” (hereinafter referred to as “the Vessel”) received by a data company in Japan,” the positions of the Vessel from 15:40:15 to 19:10:14 on September 9, 2016 were as shown in Table 2.1 below.

Table 2.1: AIS Record of the Vessel (Excerpt)

Time (HH:MM:SS)	Ship's position*		Course Over the Ground* (°)	Heading* (°)	Speed Over the Ground (knots [kn])
	Latitude (N) (° - ' - ")	Longitude (E) (° - ' - ")			
15:40:15	34-07-14.9	135-07-20.6	302.6	295	8.1
15:50:14	34-07-30.8	135-05-20.1	278.1	280	10.3
16:00:17	34-07-43.2	135-03-15.3	270.9	263	10.2
16:09:55	34-06-15.6	135-02-36.2	190.6	190	10.7
16:19:34	34-04-32.9	135-02-15.6	186.9	187	10.9
16:30:13	34-02-36.9	135-01-57.9	187.8	187	10.8
16:40:24	34-00-48.0	135-01-40.8	187.9	187	10.8
16:50:14	33-59-00.8	135-01-22.3	188.0	186	11.0
17:00:14	33-57-10.3	135-01-01.4	188.7	186	10.9
17:10:15	33-55-21.2	135-00-44.3	185.7	185	10.8
17:20:14	33-53-39.0	135-00-32.0	187.2	186	9.4
17:30:13	33-52-06.6	135-00-15.4	190.8	189	9.2
17:40:13	33-50-41.8	135-00-16.0	138.5	133	8.8
17:50:15	33-49-35.3	135-01-24.0	140.2	134	8.6
18:00:14	33-48-29.0	135-02-31.1	139.3	135	8.6
18:10:14	33-47-23.6	135-03-37.2	139.3	135	8.5
18:20:13	33-46-17.0	135-04-43.2	142.8	134	8.5
18:30:13	33-45-12.3	135-05-48.7	141.1	134	8.3
18:39:44	33-44-12.1	135-06-50.3	141.9	135	7.9
18:39:55	33-44-11.1	135-06-51.1	141.4	135	7.8
18:40:04	33-44-10.3	135-06-51.8	142.2	135	7.8
18:40:15	33-44-08.6	135-06-53.4	142.1	134	7.8
18:50:13	33-43-33.9	135-07-55.6	047.8	029	6.3
19:00:14	33-44-21.6	135-06-40.5	314.8	320	8.9
19:10:14	33-45-28.1	135-05-25.1	317.1	320	10.6

*: The vessel position indicates the position of the GPS antenna installed above the bridge, and the courses over the ground and headings indicated in true bearings (hereinafter the same).

^{*1} Automatic Identification System (AIS) is a device that each vessel uses to automatically transmit and receive information such as vessel identification code, ship type, name, position, course, speed, destination, and conditions of navigation and exchanges information with other vessels or land-based navigation aids.

2.1.2 Events Leading to the Accident according to the Statements of Crew members

According to the statements of Master of the Vessel (hereinafter referred to as “the Master”), chief officer (hereinafter referred to as “the Chief Officer”), third officer (hereinafter referred to as “the Third Officer”), boatswain, able seaman, first engineer (hereinafter referred to as “the First Engineer”), second engineer (hereinafter referred to as “the Second Engineer”); and logbook of the Vessel, the events leading to the accident were as follows.

- (1) Development of events from unloading at Ulsan Port, Republic of Korea, until departure from Onsan Port, Republic of Korea

On September 5, 2016 (local time), the Vessel, with the Master (national of the Republic of Korea) and nine other crew members (two nationals of the Republic of Korea, six nationals of the Republic of Indonesia, and one national of the People’s Republic of China) aboard, unloaded her entire cargo of tert-butyl alcohol (hereinafter referred to as “butyl alcohol”) from her No. 1 to No. 4 Cargo Tanks (hereinafter “cargo” shall be omitted for cargo tanks provided with numbers) at Ulsan Port and then departed for Onsan Port, after which cleaning was conducted in all cargo tanks.

The Vessel entered Onsan Port on September 7, was loaded with base oil, which is the base material of lubricants and other products, in her No. 1 and No. 3 Tanks, and departed for Wakayama Shimotsu Port, Wakayama Prefecture.

- (2) Development of events from entering Wakayama Shimotsu Port until the accident

At around 10:25 on September 9, 2016, the Vessel entered Wakayama Shimotsu Port and unloaded her entire cargo of base oil. At around 15:35, the Vessel departed in ballast condition for Yokkaichi Port, Yokkaichi City, Mie Prefecture.

With the Chief Officer leading the cleaning of the cargo tanks (hereinafter referred to as “tank cleaning”), the Vessel began gas-free operations*² to ventilate “the No. 1 and No. 3 Tanks and cargo pump and cargo-handling piping for the tanks” (hereinafter referred to as “the No. 1 and No. 3 System” at around 16:00.

Between around 17:20 and 17:30, as he was going to his cabin, the Master saw the chief engineer (hereinafter referred to as “the Chief Engineer”) carrying welding equipment. Because welding work requires procedures to receive permission from the management company and others, and because he thought it hazardous to conduct welding during tank cleaning, the Master instructed not to do any welding and heard the Chief Engineer respond that he would not do any welding.

At around 17:30, after the gas-free operations had been completed, the Vessel began “work to introduce steam into the cargo tanks to bring the ambient temperature to 60°C for the purpose of making it easier to clean off base oil adhered to the bulkheads” of the No. 1 and No. 3 Tanks (hereinafter referred to as “the steaming work”).

At around 18:00, the Second Engineer was instructed by the Chief Engineer to assist in welding and carried a drill for the purpose of drilling a hole in the welded area. However, as the Second Engineer thought that welding during the tank cleaning was hazardous, he suggested to the Chief Engineer that the welding should be done after the tank cleaning, but was told that the welded area was small and welding would be completed quickly, so no danger existed.

*² “Gas-free operation” refers to work to replace existing gas in an enclosed space with air so that the density of existing flammable gas will fall below a required density for a specific purpose; for example, to conduct work involving high heat, allow entry into the space, etc.

At around 18:20, the Vessel completed the steaming work and began cleaning the No. 1 and No. 3 Tanks with seawater for a scheduled time of approximately two hours and forty minutes.

At around 18:30, after the Chief Engineer opened a hole in a ventilation duct on the starboard No. 3 Tank (hereinafter referred to as “the Starboard No. 3 Ventilation Duct”) with a drill for the purpose of installing a pressure gauge on it, the Chief Engineer began “welding a pipe to the Starboard No. 3 Ventilation Duct” (hereinafter referred to as “the Welding of the Starboard No. 3 Ventilation Duct”) while squatting on his heels and holding a welding rod holder and with the Second Engineer standing next to the Chief Engineer and shining a flashlight. At around 18:40, with an able seaman and the First Engineer standing nearby, an explosion occurred in the cargo tank.

The Chief Engineer fell at the place of the Welding of the Starboard No. 3 Ventilation Duct, the Second Engineer was blown back and into the hand rail on the starboard side, and the able seaman standing to the forward side of the Chief Engineer was blown back and fell to the deck toward the bow.

The able seaman saw a column of flame coming from the area of a manhole hatch*³ (hereinafter referred to as “hatch”) behind the starboard No. 3 Tank and the First Engineer, after falling to the forward side, saw black smoke rising from the hatch of the starboard No 3 Tank. Additionally, the Chief Officer, who was on the aft portion of the poop deck, heard a loud sound.

Between approximately thirty seconds and one minute after the first explosion, there was a second explosion on the Vessel.

The First Engineer was blown toward the bow when he went aft to help the Chief Engineer and fell on the body of the able seaman, who had fallen on the forward side.

The First Engineer saw a column of flame come from the starboard No. 2 Tank hatch at the time of the second explosion, and the Chief Officer saw a column of flame and black smoke from the direction of the starboard No. 2 Tank hatch. Additionally, the Second Engineer felt a blast moving starboard aft.

(See Photo 2.1 and Figure 2.1)

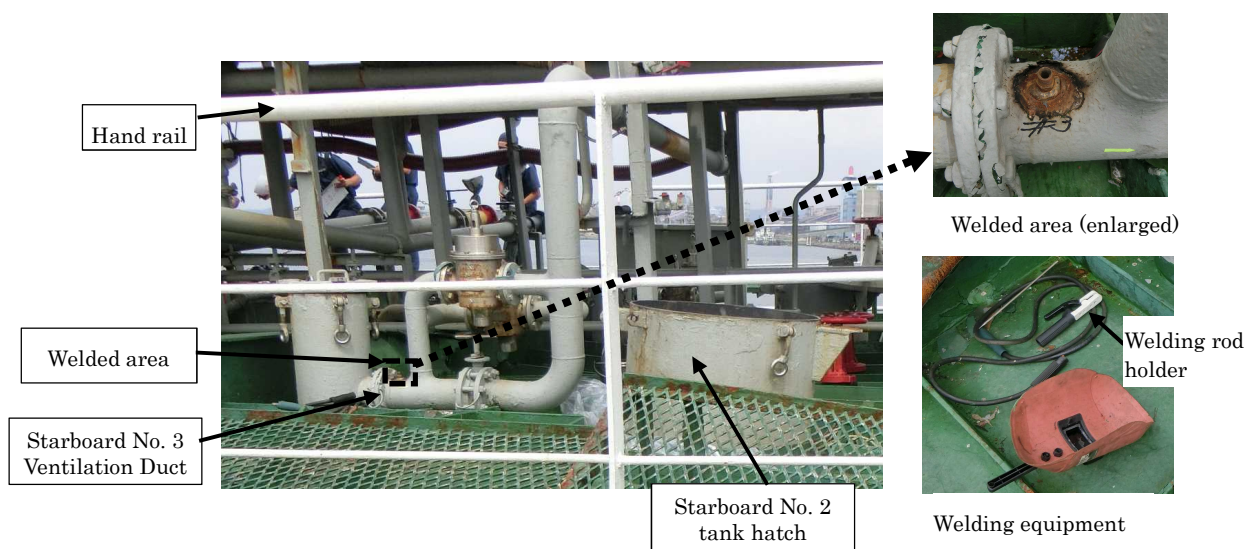


Photo 2.1 Area near the Place of the Welding of the Starboard No. 3 Ventilation Duct

*³ “Manhole hatch” refers to a hatch that is primarily used for human access to the inside of a cargo tank.

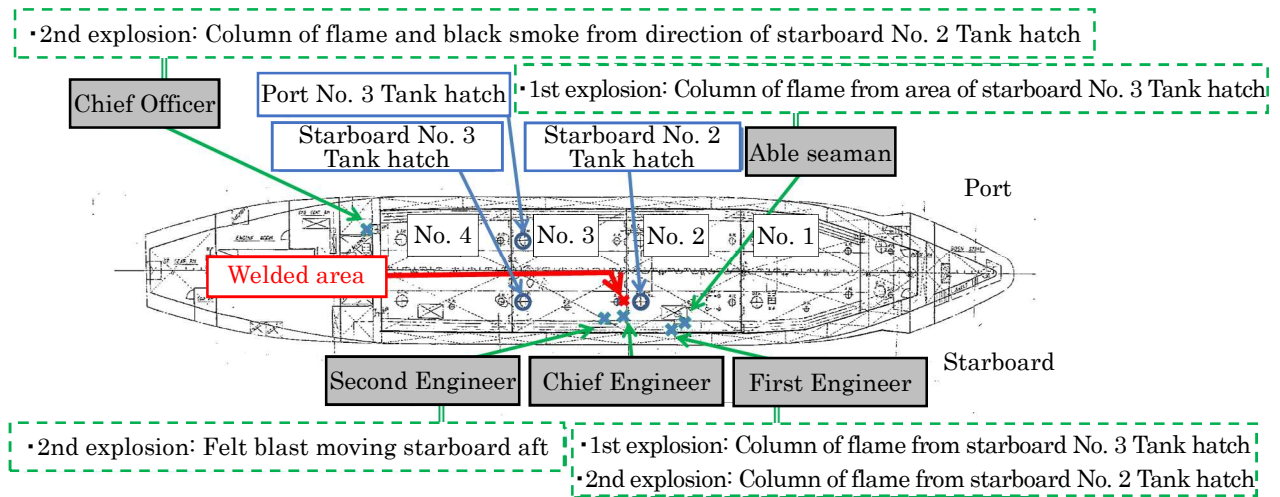


Figure 2.1 Arrangement of Crew Members near the Accident Location and Circumstances at the Time of the Accident

(3) Events following the accident

Because the Chief Engineer was on the deck and the Second Engineer could not walk, the First Engineer shouted for help and, together with the Chief Officer and the boatswain, who was near port No. 1 Tank, carried the Chief Engineer to the messroom and then carried the Second Engineer to the messroom. The able seaman walked to the aft portion of the poop deck.

The Master went to the bridge after hearing a loud sound in his cabin and understood there had been an explosion after seeing black smoke rising from the cargo tanks. At around 18:45, the Master notified the ship's agent of the accident and instructed the Chief Officer to begin firefighting operations.

The boatswain and the First Engineer connected a firehose to a fire hydrant on the deck in response to the Chief Officer's instructions and sprayed water through the hatches of the starboard No. 3 Tank and port No. 3 Tank, from which large quantities of black smoke were being emitted.

The Vessel reentered Wakayama Shimotsu Port, where the Chief Engineer, Second Engineer, and able seaman were carried to a wharf in Kainan City, Wakayama Prefecture, by a patrol vessel that had arrived to provide assistance after being alerted by the ship's agent, and then transported by ambulance to a hospital in Wakayama City, where the Chief Engineer was confirmed dead.

The date and time of occurrence of the accident was at around 18:40 on September 9, 2016, and the location was around 9.1 nautical miles (M) at 163° from the Kii Hinomisaki Lighthouse. (See Attached Figure 1 Navigation Route)

2.2 Injuries to Persons

According to the reply to the questionnaire of the hospital that received the crew members, the Chief Engineer's cause of death was a traumatic brain injury and traumatic subarachnoid hemorrhage. The Second Engineer required medical treatment of two months for a fracture of the left patella, and the able seaman suffered a subcutaneous hematoma of the right groin region and

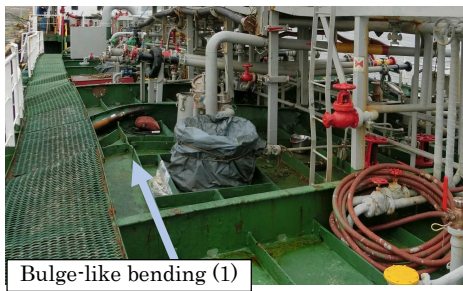
other injuries.

2.3 Damage to Vessel

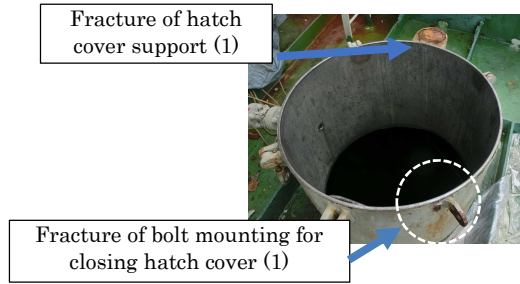
According to the on-site investigation and the responses to the questionnaire of the Wakayama City Fire Department and Keoyoung Shipping Co., Ltd., which is the ship's owner (hereinafter referred to as "Company A"), the damage to the Vessel's hull was as stated in items (1) to (5) below and the Vessel was scrapped on December 20, 2016.

- (1) The aft side of starboard No. 2 Tank and tops of starboard No. 3 Tank and port No. 3 Tank had bulge-like bending. Additionally, the hatch cover support and bolt mounting for closing the hatch cover of starboard No. 2 Tank and the hatch cover support for starboard No. 3 Tank were fractured.
- (2) The longitudinal bulkhead between the starboard No. 2 Tank and port No. 2 Tank (hereinafter referred to as the "No. 2 Centerline Bulkhead") was bent toward the starboard side on the upper part of the aft side.
- (3) The transverse bulkhead between the port No. 2 Tank and port No. 3 Tank (hereinafter referred to as the "Port 2-3 Transverse Bulkhead") bulge-like bending toward the forward side and fractured at the weld line (starboard side of the bottom edge).
- (4) The transverse bulkhead between the starboard No. 2 Tank and starboard No. 3 Tank (hereinafter referred to as the "Starboard 2-3 Transverse Bulkhead") inclined toward the forward side, bulge-like bending toward the forward side, and fractured at the weld line (upper and lower edges and port edge).
- (5) The longitudinal bulkhead between the starboard No. 3 Tank and port No. 3 Tank (hereinafter referred to as the "No. 3 Centerline Bulkhead") inclined toward the starboard side, bulge-like bending toward the starboard side, and fractured at the weld line (upper and lower edges and forward edge).

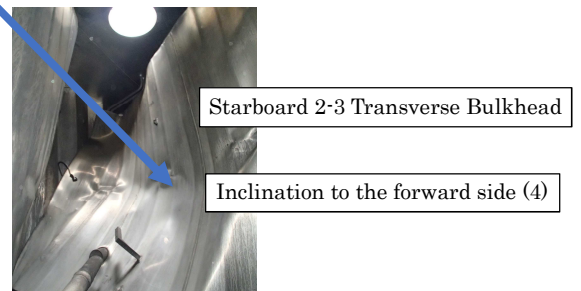
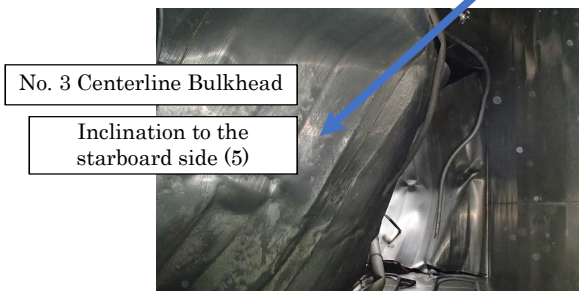
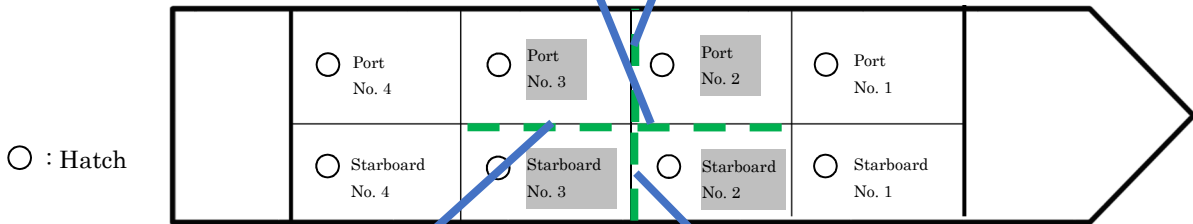
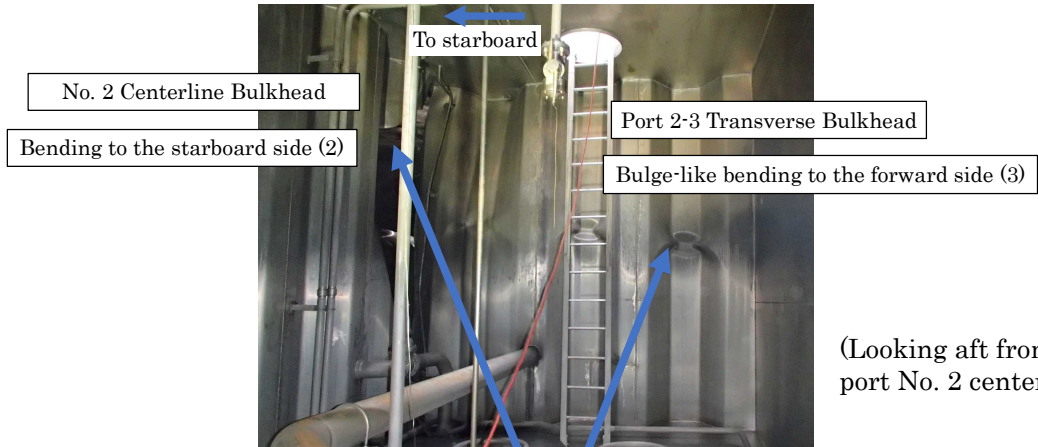
(See Photo 2.3)



(Damage to the starboard-side cargo tank top)



(Damage to the starboard No. 2 tank hatch)



(Looking forward from the back of starboard No. 3 tank) (Looking forward from the front of starboard No. 3 tank)

Note: The (1) to (5) appearing in the photos correspond to items 2.3 (1) to (5) .

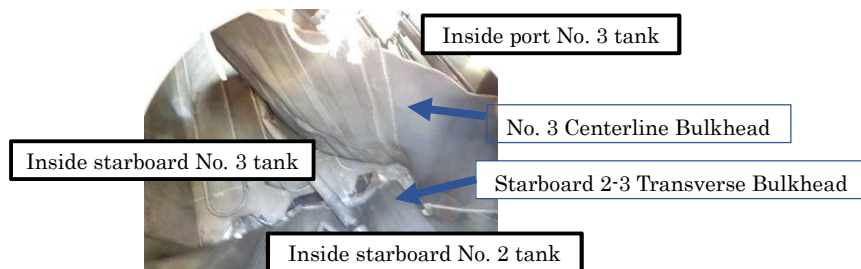


Photo 2.3 Damage to the Hull

2.4 Crew Information

(1) Gender, Age, and Certificate of Competence

The Master: Male, 61 years old

First Grade Navigation Officer (limited to merchant ships) certificate (issued by the Republic of Korea)

Date of Issue: June 10, 2016

(Valid until June 9, 2021)

The Chief Officer: Male, 69 years old, national of the Republic of Korea

Second Grade Navigation Officer (limited to merchant ships) certificate (issued by the Republic of Korea)

Date of Issue: May 24, 2016

(Valid until September 5, 2021)

The Chief Engineer: Male, 60 years old, national of the Republic of Korea

Second Grade Engineer (limited to output of less than 6,000 kW in the case of ocean-going vessels) certificate (issued by the Republic of Korea)

Date of Issue: April 16, 2015

(Valid until July 19, 2020)

The Second Engineer: Male, 30 years old, national of the Republic of Indonesia

Able Seaman: Male, 27 years old, national of the Republic of Indonesia

(2) Major Sea-going Experience

(i) The Master

According to the statement of the Master, he served primarily on chemical tankers for approximately thirty years since 1984 and came aboard the Vessel in May 2015. He was in good health at the time of the accident.

(ii) The Chief Officer

According to the statement of the Chief Officer, he served primarily on chemical tankers for approximately thirty years since 1986 and came aboard the Vessel in August 2016. He was in good health at the time of the accident.

(iii) The Chief Engineer

According to the replies to the questionnaire of Company A and the Master, the Chief Engineer had approximately 16 years of experience aboard chemical tankers and oil tankers and approximately ten years aboard general cargo ships and other vessels, during approximately two years and six years of that time he served as the chief engineer of a chemical tanker or oil tanker. He came aboard the Vessel in June 2016. He appeared to be in good health at the time of the accident.

(iv) The Second Engineer

According to the statement of the Second Engineer, he had served aboard oil tankers since 2010 and came aboard the Vessel in June 2016. He was in good health at the time of the accident.

(v) Able Seaman

According to the statement of the able seaman, he had served aboard oil tankers since 2010 and came aboard the Vessel in May 2016. He was in good health at the time of the accident.

2.5 Vessel Information

2.5.1 Particulars of Vessel

IMO number:	9073323
Port of registry:	Jeju (Republic of Korea)
Owner:	Company A (Republic of Korea)
Management company:	Company A
Class:	Korean Register of shipping
Gross tonnage:	740 tons
L×B×D:	63.82 m x 10.00 m x 4.50 m
Hull material:	Steel
Engine:	Diesel engine x 1
Output:	1,177 kW
Propulsion:	4-brade fixed pitch propeller x 1
Date of launch:	June 1993

2.5.2 Structure of the Vessel

According to the statements of the person in charge of the shipbuilder that designed the Vessel and of the Chief Officer and the reply to the questionnaire of Company A, the structure of the Vessel was as follows.

(1) Structure

The Vessel was a single-layer deck oil/chemical tanker with forecastle and poop. She had a boatswain's store, bow pump room, and other rooms in her forecastle, below which was a forepeak water tank (hereinafter referred to as "FPT"). On both sides were "cargo tank cleaning water and post-cleaning wastewater" (hereinafter referred to as "cleaning wastewater") tanks (hereinafter referred to as "CWT") and freshwater tanks (hereinafter referred to as "FWT"), aft of which were arranged cargo tanks numbered No. 1 to No. 4 in order from the bow on both sides, cargo pump rooms, engine room, and other rooms. On the poop was a bridge house comprised of three levels.

In the bridge house, a messroom was located on the poop deck, accommodations and other rooms were located on the boat deck, and the wheel house was located on the navigation bridge deck.

(See Figure 2.5-1)

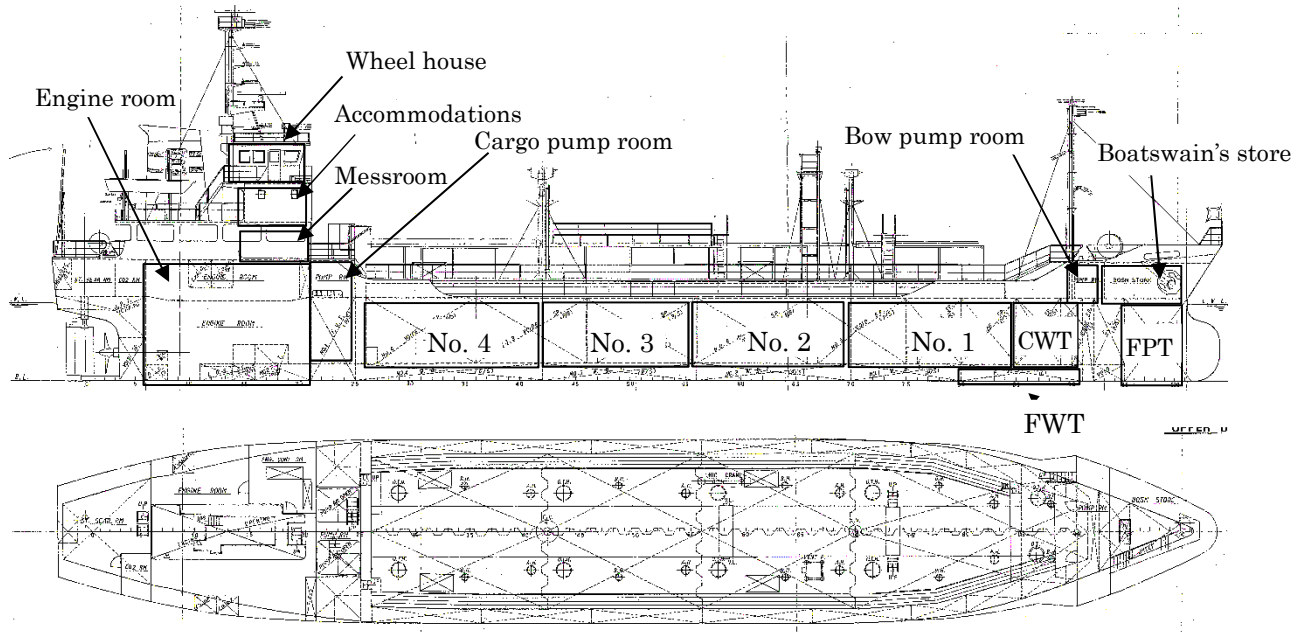


Figure 2.5-1 General Arrangement Plan

(2) Cargo tanks and cargo-handling piping

(i) The capacities of the cargo tanks were as shown in Table 2.5. The capacity of the CWT on each side was 21.726 m³. (See Figure 2.5-2)

Table 2.5 Capacities of the Cargo Tanks

Cargo tank name	Starboard side capacity (m ³)	Port side capacity (m ³)
No. 1 Tank	138.936	138.936
No. 2 Tank	155.639	155.639
No. 3 Tank	155.922	155.922
No. 4 Tank	169.428	169.428
Total	1,239.850	

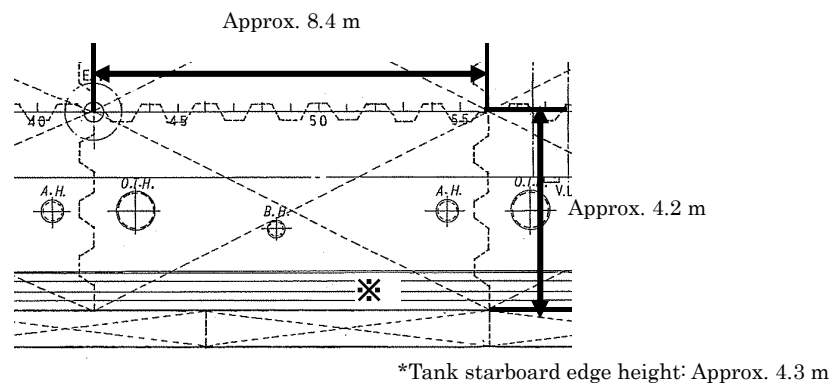


Figure 2.5-2 Main Measurements of Starboard No. 3 Tank

On each cargo tank were installed an air hatch (diameter of 0.30 m, height of 0.60 m) on the front and a hatch (diameter of 0.76 m, height of 0.60 m) on the back. A Butterworth

cleaning machine*⁴ was installed in the center within each cargo tank.

On and/or within the cargo tanks were cargo-handling piping, tank cleaning piping, ventilation ducts, and other installations. The ventilation ducts were connected to the air hatches. (See Photo 2.5)

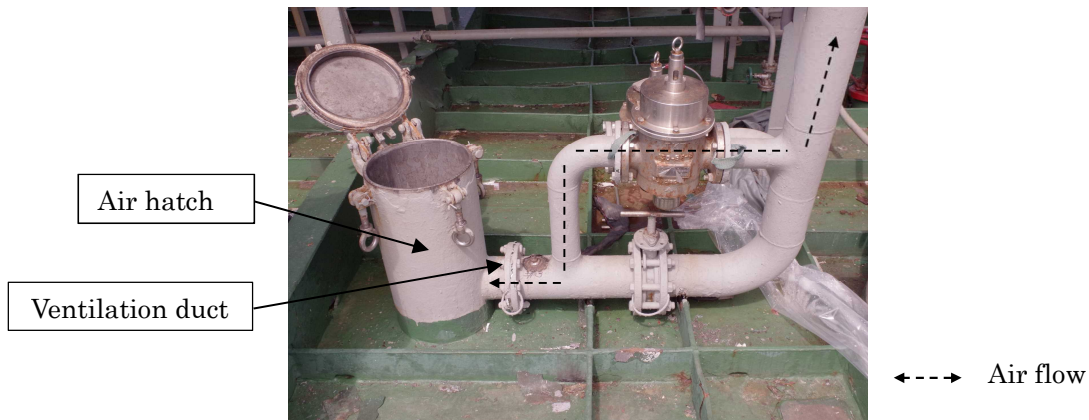
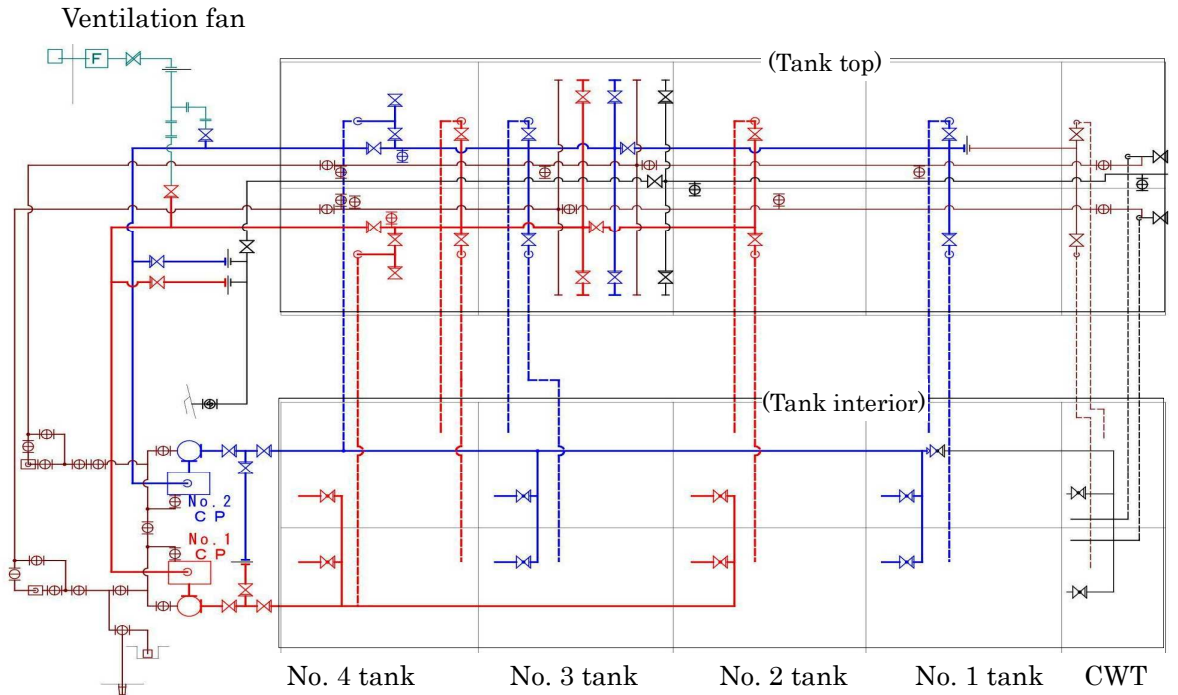


Photo 2.5 Air Hatch and Ventilation Duct

In the bow pump room were installed a cargo tank cleaning pump (hereinafter referred to as “TC Pump”) and other equipment, and in the cargo pump room were installed the No. 1 Cargo Pump for unloading the No. 2 and No. 4 Tanks (“No. 1 CP”), the No. 2 Cargo Pump for unloading the No. 1 and No. 3 Tanks (“No. 2 CP”), and other equipment. (See Figure 2.5-3, Figure 2.5-4, and Figure 2.5-5)

*⁴ A “Butterworth cleaning machine” is a device installed within a cargo tank that cleans the tank’s interior walls by rotating and evenly spraying high-pressure water.



Blue lines: Cargo-handling pipe system for No. 1 and No. 3 tanks
 Red lines: Cargo-handling pipe system for No. 2 and No. 4 tanks
 Brown lines: Pipe system for removal of residual fluid in the cargo pumps
 Black lines: Pipe system for removal of residual fluid in the CWT
 Note: The dotted line represents piping leading from the tank top to tank bottom.

Figure 2.5-3 Pipe Systems for Cargo Handling, etc.

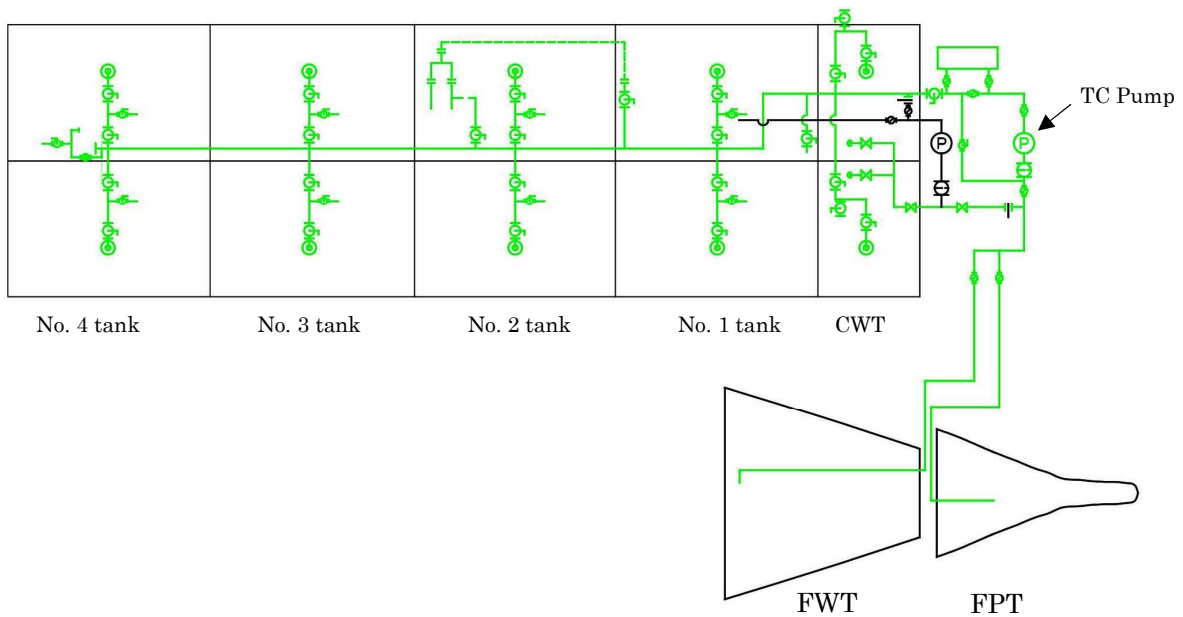
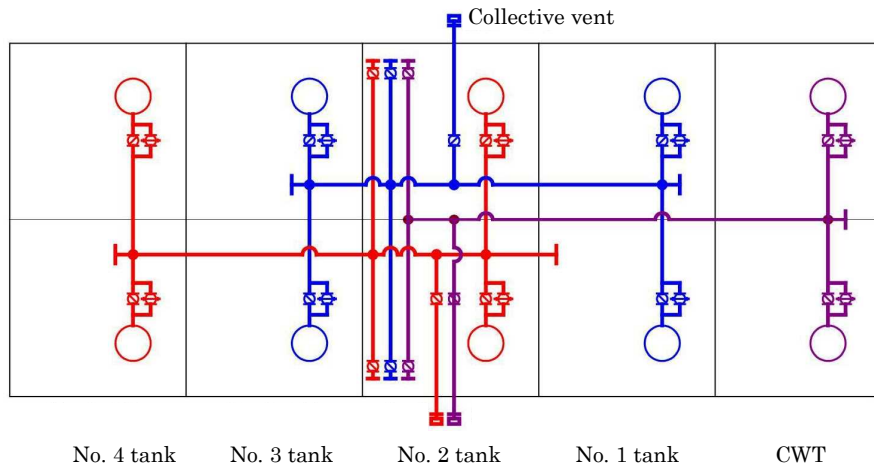


Figure 2.5-4 Tank Cleaning Water Pipe System



Blue lines: Ventilation duct system for No. 1 and No. 3 tanks
 Red lines: Ventilation duct system for No. 2 and No. 4 tanks
 Brown lines: CWT ventilation duct system

Figure 25-5 Ventilation Duct System

- (ii) The system was designed so that during the tank cleaning, water could be supplied from the CWT, FWT or FPT using the TC Pump. The water from the CWT could be heated by a heater in the tank to supply hot water. (See Figure 2.5-4 and Figure 2.5-6)

(When supplying water to the No. 1 or No 3 tank)

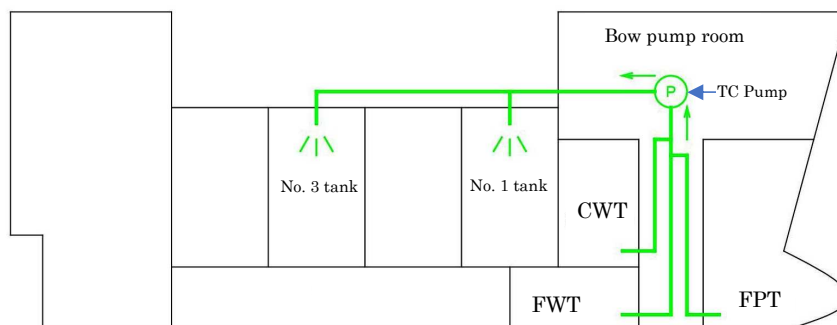


Figure 2.5-6 Water Supply Lines during Tank Cleaning

2.5.3 Information on the Materials, etc., of the Ventilation Ducts

According to the “*Sutenresu-ko Deta Bukku*” (stainless steel data book; edited by the Japan Stainless Steel Association, published in February 2000 by the Nihon Kogyo Shimbun Co., Ltd.), the melting point of the stainless steel used as material of the Starboard No. 3 Ventilation Duct (SUS304) is between 1,398 and 1,453°C.

2.6 Information on the Vessel’s Cargo prior to the Accident

- (1) According to the reply to the questionnaire of the shipper, in terms of its general characteristics, the base oil that was loaded on the Vessel is an aggregation of paraffin hydrocarbons with a carbon number around 13 to 25. It is refined from crude oil, is used as the base material of lubricants and other products, and is a liquid with a flash point*⁵

*⁵ “Flash point” refers to the lowest temperature at which a flammable substance (primarily a liquid) will produce vapors at a concentration necessary to ignite instantaneously when the substance is heated and flame is nearby.

of 150°C or higher.

- (2) According to the results of an analysis conducted by the manufacturer of the base oil that was loaded onto the Vessel, the flash point of the base oil is 164°C.

2.7 Other Information on the Vessel

- (1) According to the statement of the Chief Officer, the Vessel's draft at the time of the accident was about 0.70 m in the bow and about 3.90 m in the stern.
- (2) According to the statements of the Master and the Chief Officer and the response to the questionnaire of Company A, there was no malfunction or failure with the Vessel's hull, engine, or machineries with the exception of the TC Pump, which had been malfunctioning since the beginning of 2016.

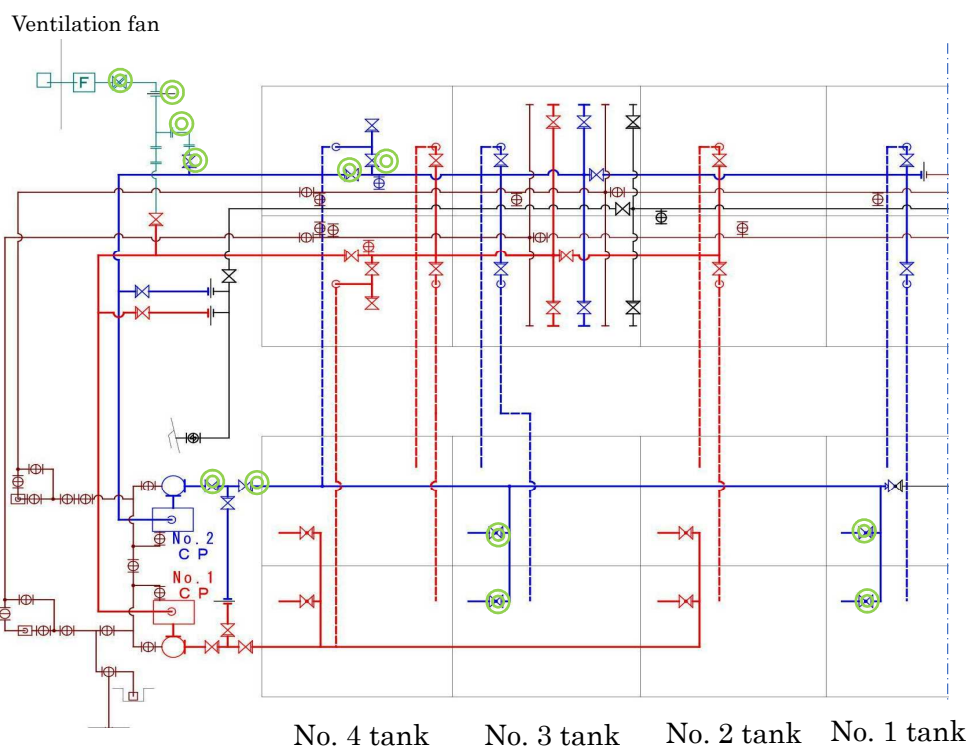
2.8 Information on the Tank Cleaning, etc.

2.8.1 Information on the Vessel

- (1) According to the on-site investigation and the statements of the Master, the Chief Officer, and the boatswain, the tank cleaning was as follows.

- 1) The executed and scheduled tank cleaning procedure at the time of the accident
 - a Gas-free operations

After unloading is completed, partition plates are removed and valves are opened as shown in Figure 2.8-1, ventilation is conducted with the ventilation fan for the purpose of ventilating the No. 1 and No. 3 System, and then it is confirmed that the alarm of the flammable gas detector is not sounding.



⊙ : Partition plates that are removed and valves that are opened prior to gas-free operations

Figure 2.8-1 Locations of valves, etc., that are opened prior to gas-free operations

- b The steaming work
- c Cleaning with seawater

Cleaning of cargo tanks with seawater (hereinafter referred to “seawater cleaning”) is conducted as described below.

- (a) Seawater of the general service line is introduced into the No. 1 and No 3 Tanks using the general service pump instead of the out-of-order TC Pump.
- (b) Cleaning is conducted by repeating a process whereby seawater accumulated in the No. 1 and No. 3 Tanks is sent to the Butterworth cleaning machines with the No. 2 Cargo Pump and sprayed on the inner walls of the tanks, and then the seawater that falls and accumulates in the tanks is again sent to the Butterworth cleaning machines by the same pump.

(See Figure 2.8-2)

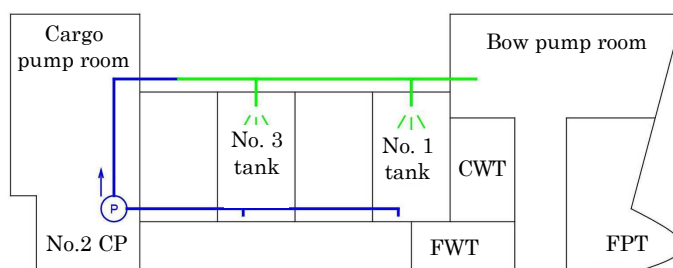


Figure 2.8-2 Seawater Cleaning at the Time of the Accident

- (c) Cleaning wastewater is sent to the CWT, which was used as the wastewater storage tank.
 - d Cleaning with freshwater
 - Cleaning of cargo tanks with freshwater (hereinafter referred to “freshwater cleaning”) is conducted as described below.
 - (a) Freshwater from the FWT is introduced into the No. 1 and No 3 Tanks using a portable pump instead of the TC Pump.
 - (b) Cleaning is conducted using the same steps described in c (b) and (c) above.
 - e Gas-free operations
 - Ventilation is conducted with the ventilation fan for the purposes of expelling newly occurring flammable gas in the No. 1 and No. 3 System and drying the system, and then it is confirmed that the alarm of the flammable gas detector is not sounding.
- 2) Circumstances of the hatches during the tank cleaning
- a The hatches on both sides of the No. 1 and No. 3 Tanks were open about 25% at around the time that the seawater cleaning was commenced. At the time of the accident, the port-side hatches had been completely opened to allow checking of the level of the seawater that was accumulating in the Tanks.
 - b The hatches on both sides of the No. 2 and No. 4 Tanks were closed at the time of the accident.
- 3) Other information
- a The mixture of cleaning wastewater that had accumulated in the No. 1 and No. 3 Tanks and seawater used in firefighting immediately after the accident was sent to the CWT after the accident.
 - b Company A’s manual on tank cleaning differentiated between cargo that is a chemical

product and cargo that is a petroleum product and established the following operations in each case.

(a) Chemical products

Perform washing (hereinafter referred to as “flushing”) of the insides of the cargo tank bottom, cargo pump, and cargo-handling piping (hereinafter referred to as the “cargo tanks, etc.”) without using the tank cleaning machine.

(b) Petroleum products

Conduct flushing of the cargo tank’s bottom.

- (2) According to the statement of a sampler, there was no odor but the odor of base oil in the No. 1 and No. 3 Tanks during sampling when the base oil was unloaded just prior to the accident.
- (3) According to the statement of the person in charge at the Wakayama City Fire Department, when he engaged in gas detection in the morning of September 11, flammable gas of 6% of the lower explosive limit (the concentration of a flammable gas when the lower explosive limit concentration of the flammable gas is 100%) was detected in the port No. 1 Tank and no gas was detected in the other cargo tanks.
- (4) According to the results of the investigation entrusted to the Nippon Kaiji Kentei Kyokai concerning the componential analysis of a sample collected from the surface area of the cleaning wastewater in the CWT following the accident, the sample contained base oil, seawater, xylene, toluene, and other components as shown in Table 2.8.

Table 2.8 Results of the Componential Analysis of the Sample

Component	% of weight
Base oil	48.0
Xylene* ¹	5.3
Toluene* ¹	4.3
Butyl alcohol* ¹ * ³	0.1
Water* ²	41.0
Salt* ²	1.3
Other* ³	0.1

*¹ Flash point and odor
 Xylene: 27°C, fragrant odor
 Toluene: 4°C, fragrant odor
 Butyl alcohol: 11°C, camphor odor

*² The concentration of salt in the water layer matched the concentration of salt in seawater.

*³ The hundredth place was rounded off.

2.8.2 Information of Shipping-Related Organizations

- (1) According to the “International Safety Guide for Oil Tankers and Terminals, Fifth Edition”^{*6} (edited by the International Chamber of Shipping, Oil Companies International Marine Forum, and International Association of Ports and Harbors; published by

^{*6} The “International Safety Guide for Oil Tankers and Terminals” is a standard book of reference for the safe operation of oil tankers and terminals that was prepared by international industrial organizations of ship owners, petroleum companies, and ports and harbors.

Witherby & Co., Ltd., 2006) (hereinafter referred to as “ISGOTT”), pertinent information is as follows.

- 1) When the environment is such that a volumetric concentration of oxygen of less than 8% cannot be confirmed in a cargo tank, flushing of the cargo tank, etc., must be conducted prior to tank cleaning.
 - 2) Spraying particles or droplets from a nozzle when introducing steam into a cargo tank or conducting tank cleaning with water will cause the particles, etc., to become charged. The risk of ignition of a flammable gas mixture exists if the charge accumulates and discharges.
- (2) According to the statement of a safety management official of a company that operates ocean-going and coastwise tankers with bases in Japan, the company conducts flushing of cargo tanks, etc., before tank cleaning when cleaning tanks after unloading petroleum products.

2.9 Weather and Sea Conditions

2.9.1 Weather Observations

- (1) Meteorological observations for September 9, 2016, at the Nanki-Shirahama Aviation Weather Station in Shirahama Town, Wakayama Prefecture, which is located approximately 13 M southeast from the accident site, were as provided in Table 2.9.

Table 2.9 Meteorological Observations

Time (Hour)	Precipitation (mm)	Temperature (°C)	Wind speed (m/s)	Wind direction
18	0.0	26.2	4.8	Northwest
19	0.0	25.5	3.7	Northwest

- (2) According to the “*Jitsugetsu Shutsubotsu Jikoku Keisan*” (sunrise/sunset and moonrise/moonset calculator) on the website of Japan Coast Guard’s Hydrographic and Oceanographic Department, the sun set near the accident site at 18:15 on the day of the accident.

2.9.2 Observations by Crew Members

According to the statement of the Third Officer, who was on navigational watch, the wind was blowing from the northeast at a wind force of three, the sea was calm, and the weather was clear at the time of the accident.

According to the logbook, the temperature on September 9, 2016, was 29°C at 16:00 and 26°C at 20:00.

2.10 Information on Vessel Operation Management

2.10.1 Operating Conditions

According to the statement of the Master and reply to the questionnaire of Company A, the Vessel’s operating conditions were as follows.

- (1) The Vessel primarily sailed between Japan and the Republic of Korea but also made irregular trips among the three countries of Japan, the Republic of Korea, and the People’s Republic of China.
- (2) The Vessel had sailed carrying base oil eight times between January 2016 and the

accident.

2.10.2 Information on Safety Management Pertaining to Work with High Heat on Deck

(1) Conditions on the Vessel

According to the statements of the Master and Second Engineer and reply to the questionnaire of Company A, the conditions of safety management pertaining to work with high heat on deck were as follows.

- 1) In around mid-August 2016, Company A instructed the Master and the Chief Engineer to install a pressure gauge for use when loading chemical products that require nitrogen sealing. The pressure gauge arrived at the Vessel when she was docked at Ulsan Port on September 5. The loading of a chemical product requiring nitrogen sealing was not scheduled until October 5.
- 2) Company A's manual concerning work with high heat on deck stated that documents noting the content of the work must be approved by the master and then submitted to Company A and receive Company A's permission.
- 3) When having a master, chief officer, or chief engineer board one of its owned vessels for the first time, or when having said crew member board one of its owned vessels after being on leave for several months, Company A instructed that a procedure for obtaining permission from Company A was required when conducting work with high heat on deck.
- 4) At the time of the accident, no documents noting the content of work with high heat had been submitted to the Master or Company A.

(2) Information of ISGOTT

According to ISGOTT, work with high heat in hazardous zones (for example, on a ship on which an explosive environment may exist) should be prohibited during cargo handling, tank cleaning, etc.

2.11 Information on the Explosions

- (1) An opinion concerning the mechanism of the explosions that was provided by researchers of the National Institute of Occupational Safety and Health, Japan of the Japan Organization of Occupational Health and Safety was as follows.

- 1) In the event that the explosion occurred when, under conditions in which oil with a flash point of 164°C formed tiny liquid drops (hereinafter referred to as "droplets") that became airborne with a roughly even distribution within the tank (length of approximately 8.4 m x width of approximately 4.2 m x height of approximately 4.3 m), and in which some of the droplets became dispersed even within the ventilation duct that was connected to the air hatch above the tank shown in Photo 2.5, welding was conducted on the ventilation pipe (temperature at the welded area: 1,400°C or higher), the two cases, a and b, presented below can be considered as mechanisms of the explosion.
 - a The airborne droplets contacted with an extremely hot area near the welded area and burned after vaporizing and igniting and then exploded as a result of (a) and (b) below.
 - (a) Nearby droplets burned after vaporizing and igniting from heat released by the burning.
 - (b) The burning of (a) above sequentially propagated.
 - b The airborne droplets vaporized after being heated in the ventilation duct and the accumulated flammable gas mixture contacted with an extremely hot area near the

welded area, ignited and burned, and then exploded as a result of (a) and (b) above.
(See Figure 2.12)

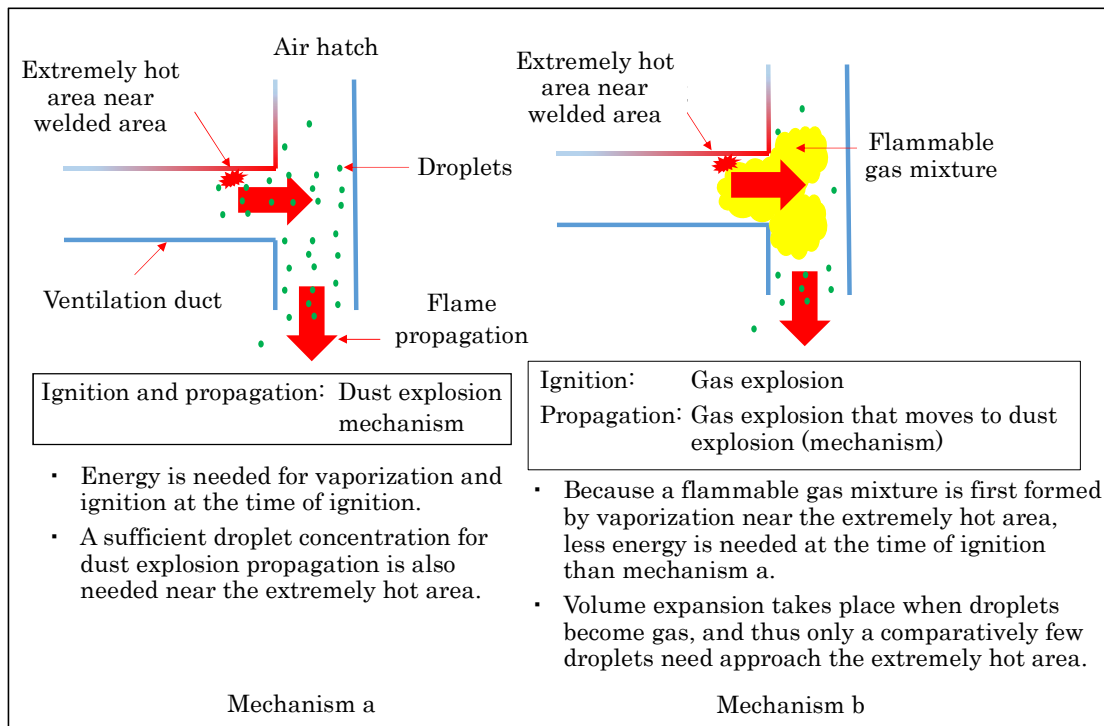


Figure 2.12 Explosion Mechanisms

- 2) In the case of an explosion in a tank, the tank's wall surfaces would become hot instantaneously (around the time the explosion ended) from the explosion's energy.
- 3) Regarding the question of whether it is possible an explosion would occur under conditions in which a certain amount of oil with a flash point of 164°C and air existed together in the tank and approximately thirty seconds to one minute had passed after the tank's walls were instantaneously heated, the National Institute of Occupational Safety and Health, Japan's opinion is as follows.
 - a An explosion is possible. In such a case, it is thought that the explosive mechanism would be in line with a and b below.
 - a Oil near a wall is heated and vaporizes and then forms a flammable gas mixture.
 - b If the temperature rises above the oil's flash point and there is a spark, the flammable gas mixture ignites and an explosion occurs.
- 4) If an explosion occurs in a tank and black smoke appears, it is thought possible that the combustion was incomplete and flame remains.
- 5) Regarding the possibility of ignition if, under the conditions of 1) above, flammable droplets with a flash point of 164°C were to contact near the welded area and static electricity were generated in the tank, ignition could happen easily in the area, as, even though the ignition point is unknown, the welded area has a temperature of more than 1,400°C. However, the possibility of ignition from static electricity is thought to depend on how much static electricity can be stored on those conditions.
- 6) Even if the hatch on top of the tank (diameter of 0.76 m, height of 0.60 m) is fully open when the in-tank explosion mentioned 1) above occurs, diffusion of the explosive pressure (drop in pressure caused by the explosion in line with increasing hole diameter) is

thought to be small, as the hatch's size vis-à-vis the tank's size is so small as to be equivalent to a situation in which no opening exists, and thus the explosion can cause damage to the tank's walls.

- (2) According to “*Anzen Kogaku Koza 2: Bakuhatsu*” (safety engineering course 2: explosions; edited by the Japan Society for Safety Engineering; published by Kaibundo in March 1983), a dust explosion is a phenomenon in which an explosion occurs when energy is provided by some kind of ignition source when particles of a flammable matter are airborne. The process of explosion is as follows.
 - 1) Heat energy is provided to the particle's surface and the surface temperature rises.
 - 2) The molecules of the particle's surface become a vapor that is released around the particle.
 - 3) The vapor of 2) above mixes with air and forms a flammable gas mixture that ignites and creates flame.
 - 4) The heat generated by the flame of 3) above promotes further molecular disintegration that results in the release of more and more flammable gas, which mixes with the air and propagates ignition.
- (3) An opinion concerning the circumstances of the explosion that was provided by researchers of the National Maritime Research Institute of the National Institute of Maritime, Port and Aviation Technology was as follows in 2) below, which was based on the conditions described in 1) below.
 - 1) Two explosions occurred and caused the damage described in 2.3.
 - 2) Given a to c below, it is thought that the first of the two explosions occurred in the port No. 3 Tank and it is thought possible that the explosion in the port No. 3 Tank was the largest explosion.
 - a The No. 3 Centerline Bulkhead was bent and inclined toward the starboard side, and the Port 2-3 Transverse Bulkhead was bent toward the bow.
 - b No deformation of the bulkheads that showed indications of an explosion in the port No. 4 Tank was observed.
 - c The No. 3 Centerline Bulkhead had the greatest inclination and other deformations among the cargo tanks.

3 ANALYSIS

3.1 Situation of the Accident

3.1.1 Course of the Events

According to 2.1.1, 2.1.2(2) and 2.8.1(1)1), it is probable that the following events occurred.

- (1) After unloading her entire cargo of base oil in her No. 1 and No. 3 Tanks, the Vessel departed Wakayama Shimotsu Port in ballast condition for Yokkaichi Port at around 15:35 and proceeded southeast to the south of Gobo City.
- (2) Between around 16:00 and 17:30, the Vessel conducted gas-free operations to ventilate the No. 1 and No. 3 systems; between around 17:30 and 18:20, the Vessel began the steaming work of the No. 1 and No. 3 Tanks; and at around 18:20, the Vessel began supplied water to the tanks and then subsequently began seawater cleaning with the Butterworth cleaning machines using the No. 2 Cargo Pump.
- (3) At around 18:30, the Chief Engineer began welding on the Starboard No. 3 Ventilation Duct, and at around 18:40 an explosion occurred on the Vessel.

3.1.2 Circumstances of Explosions

From 2.1.2, it is probable that two explosions occurred within the Vessel's cargo tanks as follows.

- (1) Approximately ten minutes after welding of the Starboard No. 3 Ventilation Duct began, the first explosion occurred and a column of flame rose from the starboard No. 3 Tank hatch.
- (2) Between approximately thirty seconds and one minute after the first explosion, a second explosion occurred and a column of flame rose from the starboard No. 2 Tank hatch.
- (3) After the second explosion, black smoke rose from the hatches of the starboard No. 2 Tank, starboard No. 3 Tank, and port No. 3 Tank.

3.1.3 Location of the Accident Occurrence

From 2.1.1, 2.1.2(2) and 3.1.1(3), it is probable that the location of occurrence of the accident was around 163°, 9.1 M from the Kii Hinomisaki Lighthouse.

3.1.4 Injuries to Persons

From 2.2, it is probable that the situation was as follows.

- (1) The Chief Engineer died from a traumatic brain injury and traumatic subarachnoid hemorrhage.
- (2) The Second Engineer suffered a major injury in the form of a fractured left patella and the able seaman received minor injuries that included a bruise on his right abdominal area.

3.1.5 Damage to Vessels

From 2.3, it is probable that the situation was as follows.

- (1) No explosions occurred in the No. 1 and No. 4 Tanks.
- (2) The Port and Starboard 2-3 Transverse Bulkheads on both sides and No. 3 Centerline Bulkhead suffered bending and other damage as shown in Figure. 3.1.
- (3) As a result of the damage mentioned in (2) above, the spaces above the starboard No. 2 Tank, starboard No. 3 Tank, and port No. 3 Tank became connected.

(See Figure 3.1)

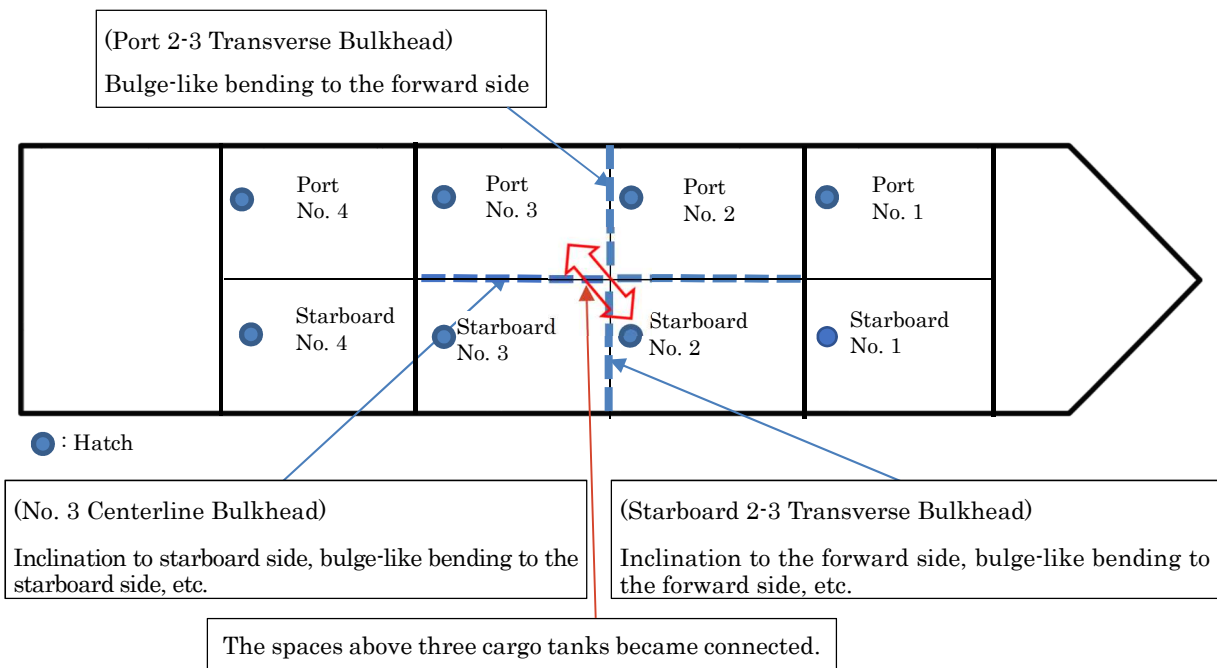


Figure 3.1 Damage to the Cargo Tank Bulkheads

3.2 Causal Factors of the Accident

3.2.1 Situation of Crew Members and the Vessel

(1) Crew Members

From 2.4, it is probable that the Master, Chief Officer, and Chief Engineer possessed a legally valid certificate of competence and had many years of experience aboard oil tankers and chemical tankers.

(2) The Vessel

From 2.7 (2), it is probable that, with the exception of the TC Pump, which was out of order, there was no malfunction or failure with the hull, engine, or machineries of the Vessel.

3.2.2 Weather and Sea Conditions

From 2.9, it is probable that, at the time of the accident, the wind was blowing from the northeast at a wind force of three, the sea was calm, the weather was clear, and the temperature was between 26°C and 29°C.

3.2.3 Analysis of Combusted Material

(1) From 2.1.2 (1), 2.6, 2.8.1 (4), and 3.1.1, it is probable that the following three flammable materials were combusted materials at the time of the explosion.

- 1) Butyl alcohol (flash point of 11°C) that was unloaded prior to the loading of base oil
- 2) Flammable material in the cleaning wastewater in the CWT (The component of the cleaning wastewater with the lowest flash point was toluene with a flash point of 4°C.)
- 3) Base oil that was loaded into the No. 1 and No. 3 Tanks (flash point of 164°C)

(2) From 2.1.2, 2.5.2 (2) 1), and 2.8.1, the possibility that the flammable materials mentioned in (1) 1) to 3) above were in the cargo tanks was as follows.

- 1) Butyl alcohol

From the following items a to c, it is probable that butyl alcohol was not in the cargo tanks.

- a The No. 1 to No. 4 Tanks were cleaned following unloading.
- b There was no odor but the odor of base oil in the No. 1 and No. 3 Tanks during sampling when the base oil was unloaded just prior to the accident.
- c Flammable gas was not detected in the No. 2 and No. 4 Tanks after the accident.

2) Flammable material in the wastewater in the CWT

Given that the piping between the CWT and cargo tanks were partitioned by multiple valves and from 1) b and c above, it is probable that flammable material in the wastewater in the CWT did not flow into the cargo tanks.

3) Base oil

- a Given that seawater cleaning had only just begun at the time of the accident, it is probable that base oil was adhered to the surface of the walls of the No. 1 and No. 3 tanks.
 - b Given that seawater cleaning had begun using the No. 2 Cargo Pump without flushing the “No. 2 Cargo Pump, bottoms of the No. 1 and No. 3 Tanks, and cargo-handling piping for the tanks” (hereinafter referred to as the “No. 2 Cargo Pump System”), it is probable that base oil remaining the system was sprayed in the No. 1 and No. 3 Tanks by the Butterworth cleaning machines and that droplets of the base oil became airborne up to interior of the ventilation duct.
- (3) From (1) and (2) above, it is probable that the combusted material at the time of the explosion was base oil in the No. 1 and No. 3 Tanks.

3.2.4 Analysis of the Ignition Source and Explosion Locations

(1) Ignition source

From 2.1.2 (2), 2.5.3, 2.6, 2.8.1 (1) 1), 2.8.2 (1) 2), 2.10.1 (2), 2.11 (1) 5), 3.1.5 (1), and 3.2.3, it is probable that the ignition source was as follows.

1) Given that the temperature of the welded area of the Starboard No. 3 Ventilation Duct was at least 1,400°C, ignition would occur if base oil came in contact with the area near the welded area.

2) The possibility that static electricity had been generated existed given that steaming work and seawater cleaning had been conducted in the No. 1 and No. 3 Tanks. However, from a to c below, there was no ignition caused by static electricity.

- a It is probable that no explosion occurred in the No. 1 Tank.
- b Given that it is probable that the circumstances of the static electricity and base oil in the No. 3 Tank were the same as in the No. 1 Tank, in which no explosion occurred, it is probable that the probability of ignition by static electricity is similarly low in the No. 3 Tank.
- c In the past eight times that tank cleaning was conducted after a load of base oil, it is probable that, as with the time of the accident, static electricity was generated by the steaming work and seawater cleaning and that base oil existed; however, no explosion occurred within the cargo tanks at those times.

3) From 1) and 2) above, the ignition source of the first explosion was near the welded area of the Starboard No. 3 Ventilation Duct.

(2) Explosion locations

From 2.11 (3), 3.1.2, 3.2.3 (3), and (1) 3) above, it is probable that the first explosion occurred in the starboard No. 3 Tank and the second explosion occurred in the port No. 3 Tank.

(See Figure 3.2-1)

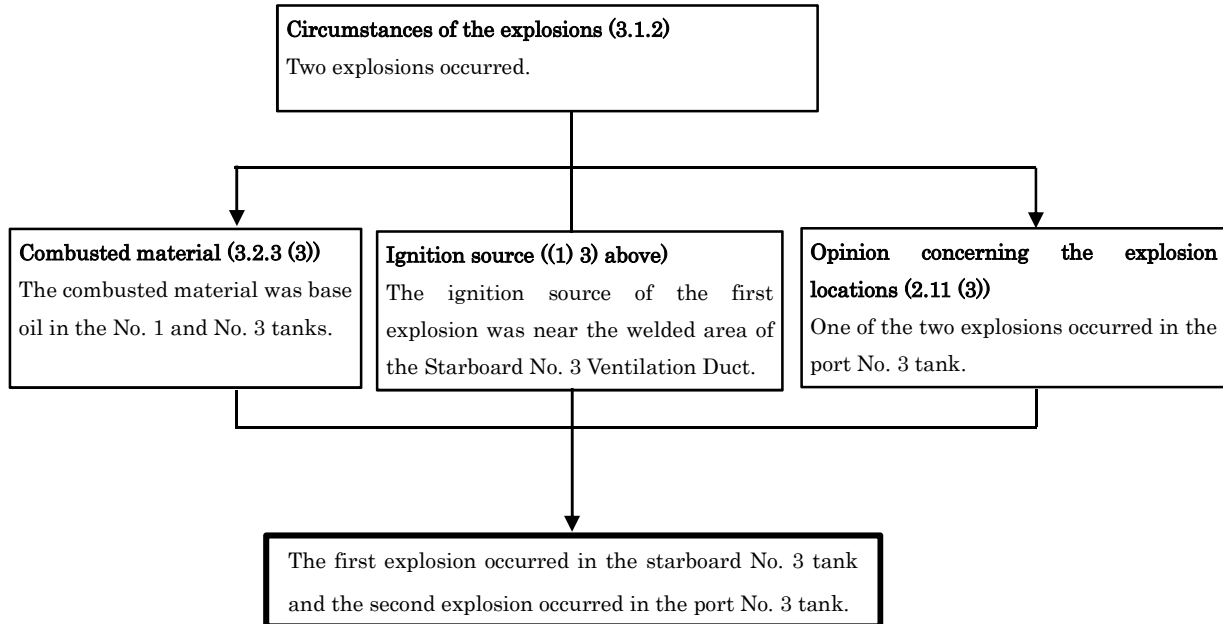


Figure 3.2-1 Explosion Locations

3.2.5 Analysis of the Mechanisms of the Explosions

From 2.3, 2.5.2 (2) 1), 2.5.3, 2.6, 2.11 (1), 3.1.1 (3), 3.2.3 (2) 3) and (3), and 3.2.4, it is probable that the mechanisms of the two explosions were as provided in (1) and (2) below in the case of the first explosion and in (3) below in the case of the second explosion.

(1) Mechanism 1

- 1) Airborne droplets of base oil contacted with an extremely hot area near the welded area, vaporized, ignited, and then exploded.
- 2) Nearby droplets burned after vaporizing and igniting from heat released by the burning, and the burning propagated as a result.

(2) Mechanism 2

- 1) Airborne droplets of base oil vaporized after being heated in the Starboard No. 3 Ventilation Duct and the accumulated flammable gas mixture contacted with an extremely hot area near the welded area, ignited, and burned.
- 2) Same as (1) 2) above.

(3) Mechanism 3

- 1) The No. 3 Centerline Bulkhead was heated by the first explosion, and then base oil near the bulkhead in the port No. 3 Tank vaporized and formed a flammable gas mixture that accumulated.
- 2) Accumulated flammable gas mixture passed through a hole in the No. 3 Centerline Bulkhead, came into contact with remaining flame in the starboard No. 3 Tank, and ignited.

3.2.6 Analysis of the Explosion Process

From 3.1.1, 3.1.2, 3.1.5, and 3.2.3 to 3.2.5, it is probable that the explosion process was as follows.

- (1) After unloading of the base oil, base oil remaining in the No. 2 Cargo Pump System was sprayed in the No. 3 Tank by the cargo pump and Butterfield cleaning machine, droplets of base oil that became airborne spread to the inside of the Starboard No. 3 Ventilation Duct, the droplets became vaporized by the heat of the welding and ignited, burning in the tank propagated, and the first explosion occurred.
- (2) As a result of the explosion of (1) above, the No. 3 Centerline Bulkhead was heated as the flame in the starboard No. 3 Tank spread.
- (3) As a result of the heating of the No. 3 Centerline Bulkhead; base oil near the bulkhead in the port No. 3 Tank vaporized, accumulated, and then ignited after passing through a hole in the bulkhead and contacting with flame remaining in the starboard No. 3 Tank; and the second explosion occurred.
- (4) Flame passing along the space above the interiors of the cargo tanks that had become connected from the port No. 3 Tank to the starboard No. 2 Tank as a result of the explosion of (3) above spread to the area of the starboard No. 2 Tank hatch.

(See Figure 3.2-2)

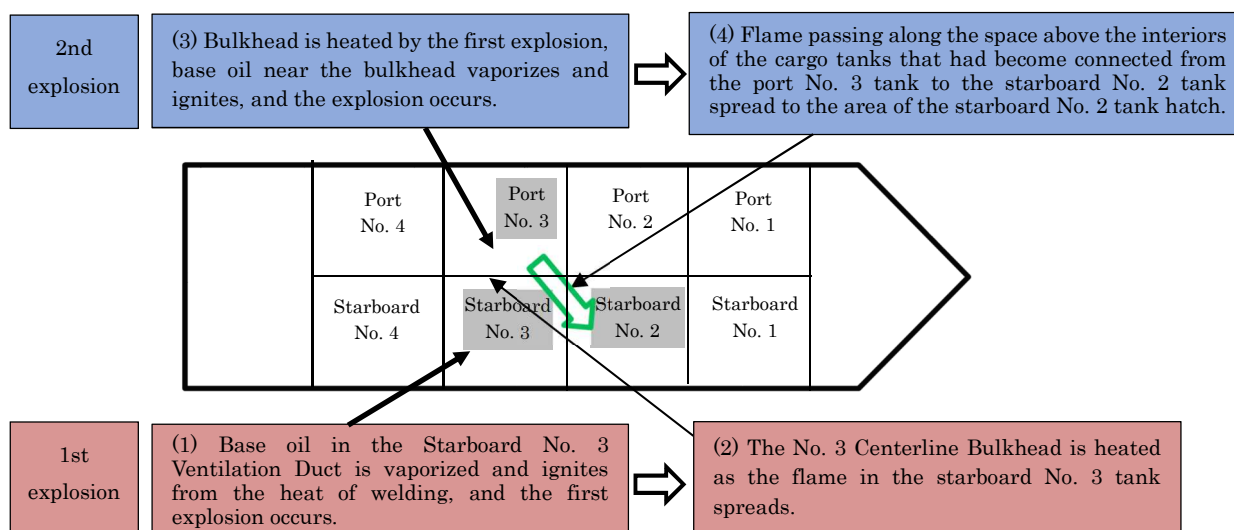


Figure 3.2-2 Explosion Process

3.2.7 Analysis of Safety Management Pertaining to Work with High Heat on Deck

From 2.1.2 (2), 2.6, 2.8.1 (1), 2.8.2, and 2.10.2 (1), the analysis is as follows.

(1) Work with high heat

- 1) It is probable that when the Master, Chief Officer, and Chief Engineer boarded the Vessel for the first time, or when said crew members boarded the Vessel after being on leave for several months, they were instructed that a procedure for obtaining permission was required when conducting work with high heat on deck; however, no such procedure for permission had been executed at the time of the accident.
- 2) It is somewhat likely that the Chief Engineer conducted welding on the Starboard No. 3 Ventilation Duct as cleaning work was being done in tanks that had carried base oil with

a high flash point because he thought there was no danger because the welded area was small and welding would be completed quickly.

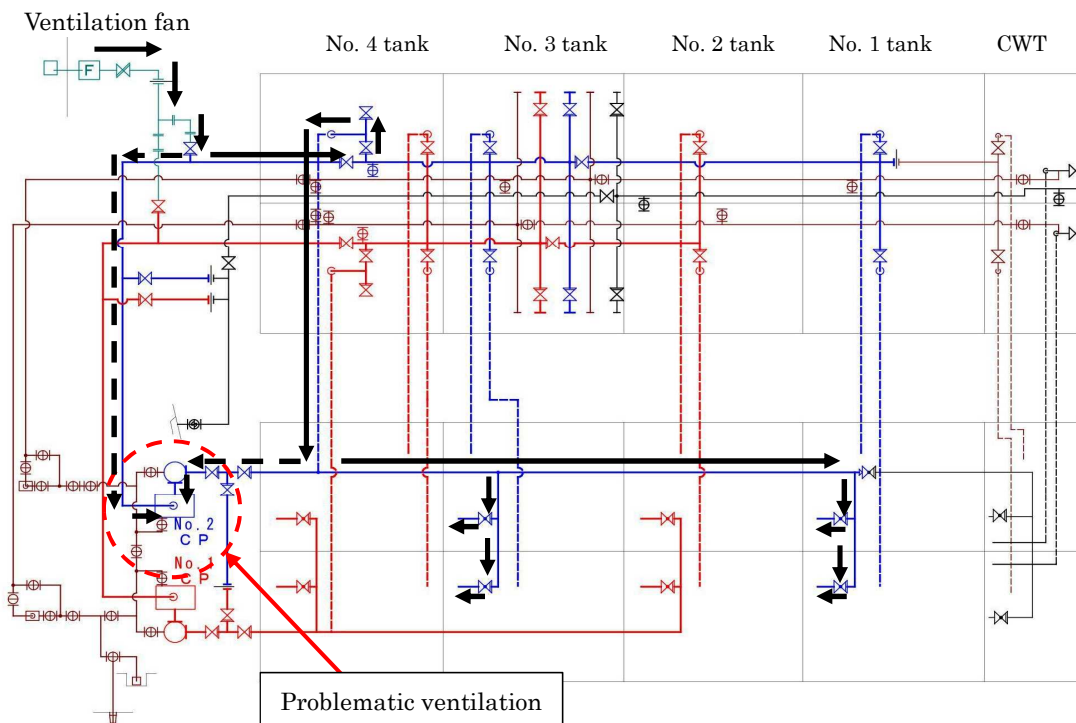
(2) Tank cleaning

1) Tank cleaning conducted after unloading of a petroleum product

It is certain that Company A's manual on tank cleaning did not specify that flushing of cargo tanks, etc., must be conducted prior to tank cleaning.

2) Gas-free operations

Given that, as shown in Figure 3.2-3, circumstances on the Vessel were such that removing flammable gas by sending air to the cargo pump was problematic when conducting gas-free operations, it is probable that it was necessary to conduct said operations after preparing a vent line through which the cargo pump was ventilated.



Note: The arrows in the figure indicate the flow of air.

Figure 3.2-3 Vent Lines during Gas-Free Operations

3.2.8 Analysis of the Accident Occurrence

From 3.1.1, 3.1.2, 3.2.3 (2) 3), 3.2.6, and 3.2.7, the situation was as follows.

- (1) It is probable that, after unloading her entire cargo of base oil in her No. 1 and No. 3 Tanks and then departing Wakayama Shimotsu Port in ballast condition for Yokkaichi port, the Vessel conducted gas-free operations to ventilate the No. 1 and No. 3 systems and steaming work.
- (2) It is probable that, while proceeding southeast off to the south of Gobo City as she conducted tank cleaning, the Vessel began seawater cleaning with Butterworth cleaning machines using the cargo pumps, and that, in the course of the cleaning, base oil that remained in the No. 2 Cargo Pump System was sprayed in the No. 3 Tank by the cargo

pump and Butterworth cleaning machine and became airborne up to the Starboard No. 3 Ventilation Duct.

Moreover, it is probable that not conducting flushing of the cargo tanks, etc., prior to tank cleaning contributed to the situation in which the base oil that remained in the No. 2 Cargo Pump System was sprayed in the No. 3 Tank and became airborne up to the Starboard No. 3 Ventilation Duct.

- (3) Given that the Chief Engineer welded on the Starboard No. 3 Ventilation Duct, it is probable that the first explosion occurred base oil in the ventilation duct and the starboard No. 3 Tank vaporized and ignited. It is somewhat likely that, as cleaning work was being done in tanks that had carried base oil with a high flash point, the Chief Engineer conducted welding at that time because he thought there was no danger because the welded area was small and welding would be completed quickly.
- (4) It is probable that the second explosion occurred when, between approximately thirty seconds and one minute after the first explosion, base oil in the port No. 3 Tank vaporized near No. 3 Centerline Bulkhead, which had become heated, and ignited.

4 CONCLUSIONS

4.1 Probable Causes

It is probable that the accident occurred when, as the Vessel was proceeding southeast off to the south of Gobo City while conducting tank cleaning at night after unloading base oil in her No. 1 and No. 3 Tanks at Wakayama Shimotsu Port and leaving port, explosions occurred when, under conditions in which the Vessel began seawater cleaning with Butterworth cleaning machines using the cargo pumps and, in the course of the cleaning, base oil that remained in the No. 2 Cargo Pump System was sprayed in the No. 3 Tank and became airborne up to the Starboard No. 3 Ventilation Duct, base oil in the duct and starboard No. 3 Tank vaporized and ignited because the Chief Engineer conducted welding on the Starboard No. 3 Ventilation Duct.

It is somewhat likely that the Chief Engineer conducted the Welding of the Starboard No. 3 Ventilation Duct as cleaning work was being done in tanks that had carried base oil with a high flash point because he thought there was no danger because the welded area was small and welding would be completed quickly.

It is probable that not flushing the cargo tanks, etc., prior to tank cleaning contributed to the circumstances in which base oil was sprayed in the No. 3 Tank and became airborne up to the Starboard No. 3 Ventilation Duct.

4.2 Other Identified Safety Issues

It is probable that circumstances on the Vessel made it necessary to conduct gas-free operations after preparing a vent line through which the cargo pump would be ventilated to remove as much flammable gas as possible from the cargo pump.

5 SAFETY ACTIONS

It is probable that the explosions occurred because the Welding of the Starboard No. 3 Ventilation Duct was conducted under conditions in which base oil remaining in the No. 2 Cargo Pump System was sprayed in the No. 1 and No. 3 Tanks during tank cleaning at night.

It is probable that not flushing the cargo tanks, etc., prior to tank cleaning contributed to the circumstances in which base oil was sprayed in the No. 3 Tank and became airborne up to the Starboard No. 3 Ventilation Duct.

Additionally, it is probable that work to remove as much flammable gas as possible from the cargo pumps was necessary during gas-free operations on the Vessel.

Accordingly, it is probable that implementation of the following measures is necessary to prevent occurrence of a similar accident and reduce the risk of explosion.

- (1) Company A should revise its work procedures to ensure that work with high heat on deck is conducted on the management of the company and the master.
- (2) Tanker owners should make the flushing of cargo tanks, etc., prior to tank cleaning part of the work procedure when cleaning tanks after unloading petroleum products.
- (3) Tanker owners should instruct crew members to conduct gas-free operations after preparing ventilation lines through which cargo pumps will be ventilated.

5.1 Safety Actions Taken

The safety actions taken by Company A are as follows.

- (1) Company A newly revised its manual for work stoppage procedures in the following ways on September 28, 2016.
 - 1) When a crew member becomes cognizant of an unsafe condition, act, error, or omission or a lack understanding that could result in an undesired result, the crew member must take measures to stop work together with the master and safety officer if time is available or independently if time is unavailable.
 - 2) In the event that a difference of opinion occurs concerning the appropriateness of a work stoppage or a solution to the work stoppage, the master shall make the final decision and record this decision.
- (2) Company A revised and made the following addition to its manual concerning work with high heat on October 17, 2016.

Welding tools and oxygen and acetylene tanks must be locked and sealed in a storeroom under the management of the master so that they cannot be used without the master's permission, and when they are used, the master must unlock the tanks, record the use, and report the use to the ship management company.

5.2 Safety Actions Required

It is probable that the tanker owner must implement the following actions.

- (1) Make the flushing of cargo tanks, etc., prior to tank cleaning part of the work procedure when cleaning tanks after unloading petroleum products.
- (2) Instruct crew members to conduct gas-free operations after preparing ventilation lines through which cargo pumps will be ventilated.

Attached Figure 1 Navigation Route

