

MA2019-3

**MARINE ACCIDENT
INVESTIGATION REPORT**

March 28, 2019



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: Chemical Tanker GOLDEN SUNNY HANA

IMO number: 9808857

Gross tonnage: 2,990 tons

Accident type: Explosion (Cargo oil tank)

Date and time: Around 10:05, April 8, 2018 (local time, UTC+9 hours)

Location: Off to the southeast of Kunisaki Port, Kunisaki City, Oita Prefecture

Around 111° true bearing, 5.0 nautical miles from the South Breakwater Lighthouse of Kunisaki Port

(approximately 33°32.2'N, 131°50.0'E)

March 6, 2019

Adopted by the Japan Transport Safety Board

Chairman Kazuhiro Nakahashi

Member Yuji Sato

Member Kenkichi Tamura

Member Toshiyuki Ishikawa

Member Makiko Okamoto

SYNOPSIS

< Summary of the Accident >

At around 10:05 on April 8, 2018, as the chemical tanker GOLDEN SUNNY HANA, with a master and 14 crew members on board, was proceeding southeast off to the southeast of Kunisaki Port, Oita Prefecture, while conducting cleaning work in a cargo oil tank, an explosion occurred in the cargo oil tank.

Two of GOLDEN SUNNY HANA's ordinary seamen were injured and her cargo oil tanks had holes and other damage.

< Probable Causes >

It is probable that the accident occurred when, as the Vessel was conducting the Circulation Work in the No. 2 port cargo oil tank and the No. 2 starboard cargo oil tank during cargo oil tank cleaning work while off to the southeast of Kunisaki Port, Oita Prefecture, an explosion occurred in the No. 2 port cargo oil tank because steam was injected into the No. 2 port cargo oil tank under conditions in which a combustible gas mixture of vaporized pyrolysis gasoline and air in the explosive range was present.

It is probable that the presence of the combustible gas mixture of vaporized pyrolysis gasoline and air in the No. 2 port cargo oil tank was not noticed because the gas concentration in the No. 2 port cargo oil tank was not measured prior to cleaning of the cargo oil tanks.

It is somewhat likely that the combustible gas mixture was within the explosive range because

flushing of the cargo lines and cargo oil tank bottoms was conducted under conditions in which ventilation and other measures were not implemented even though the gas concentration measurement taken after unloading was within the explosive range and approximately 30 liters of pyrolysis gasoline subsequently remained in both the No. 2 port cargo oil tank and the No. 2 starboard cargo oil tank, and the vaporized pyrolysis gasoline was not expelled outside, its gas concentration increased further with the passage of time, and it became mixed with air.

It is probable that steam was injected into the No. 2 port cargo oil tank with the intention of raising the temperature of the seawater used in the work of repeatedly pumping up liquid collected on the cargo oil tank's bottom with a pump installed in the cargo oil tank and then spraying the liquid with the Cleaning Machine .

< Safety Recommendations >

It is probable that an explosion occurred in the No. 2 port cargo oil tank when the chemical tanker GOLDEN SUNNY HANA was conducting circulation work in the No. 2 port cargo oil tank and the No. 2 starboard cargo oil tank during cargo oil tank cleaning work while off to the southeast of Kunisaki Port, Oita Prefecture.

It is somewhat likely that the explosion occurred in the No. 2 port cargo oil tank because, under conditions in which a combustible gas mixture of vaporized pyrolysis gasoline and air in the explosive range was present in the No. 2 port cargo oil tank and measurements of gas concentration and ventilation with ventilation equipment were not being conducted, electrically-charged steam was injected into the No. 2 port cargo oil tank and discharged, a spark was generated, and ignited the combustible gas mixture.

In view of the result of this accident investigation, the Japan Transport Safety Board recommends that HNCC Co., Ltd., which is the owner of GOLDEN SUNNY HANA, take the following measures for the purpose of preventing the occurrence of a similar accident:

HNCC Co., Ltd., should instruct crew members on chemical tankers on which combustible gas mixtures are present in cargo oil tanks to consistently execute the following.

- (1) Sufficiently provide ventilation with ventilation equipment after the flushing of cargo lines and cargo oil tank bottoms.
- (2) Measure gas concentration before cleaning work and during cleaning work, cease work immediately when a measurement is in the explosive range, and continue work after providing ventilation with ventilation equipment or introducing inert gas and then confirming safety.
- (3) Consider the danger of static electricity present in cargo oil tanks and do not inject steam if safety cannot be confirmed.

1 PROCESS AND PROGRESS OF THE INVESTIGATION

1.1 Summary of the Accident

At around 10:05 on April 8, 2018, as the chemical tanker GOLDEN SUNNY HANA, with a master and 14 crew members on board, was proceeding southeast off to the southeast of Kunisaki Port, Oita Prefecture, while conducting cleaning work in a cargo oil tank, an explosion occurred in the cargo oil tank.

Two of GOLDEN SUNNY HANA's ordinary seamen were injured and her cargo oil tanks had holes and other damage.

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 (Moji Office) and one other local accident investigator to investigate this accident on April 10, 2018.

It should be noted that the JTSB subsequently replaced with a marine accident investigator (Secretariat of the Japan Transport Safety Board) and one other marine accident investigator.

1.2.2 Collection of Evidence

April 10, May 31 and July 31,
2018:

Collection of questionnaires

April 12 and 13, 2018:

On-site investigations, interviews and collection of
questionnaires

April 19, 2018:

Interviews

1.2.3 Cooperation with the Investigation

Advice and cooperation concerning the mechanism of the explosion were provided by the Senior Research Staff of the National Research Institute of Fire and Disaster, Fire and Disaster Management Agency.

1.2.4 Comments from Parties Relevant to the Cause

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

1.2.5 Comments from the Flag State etc.

Comments on the report were invited from the flag state and substantially interested state of GOLDEN SUNNY HANA.

2 FACTUAL INFORMATION

2.1 Events Leading to the Accident

According to the statements of the master, navigation officer (hereinafter referred to as “Navigation Officer A”), boatswain, and three ordinary seaman (hereinafter referred to as “Ordinary Seaman A,” “Ordinary Seaman B,” and “Ordinary Seaman C”) of GOLDEN SUNNY HANA (Except Chapter 6, hereinafter referred to as “the Vessel”) and the reply to the questionnaire by the Vessel’s owner (HNCC Co., Ltd.; hereinafter referred to as “Company A”), the events leading up to the accident were as follows.

At around 23:00 on April 4, 2018, the Vessel, with the master (national of the Republic of Korea), Navigation Officer A (national of the Republic of Korea), Ordinary Seaman A (national of the Republic of Indonesia), and twelve other crew members (nine nationals of the Republic of Korea and three nationals of the Republic of Indonesia) aboard, left Pyeongtaek Port, Republic of Korea, for Yeosu Port, Republic of Korea, with approximately 2,000 tons of pyrolysis gasoline*¹ (Except Chapter 6, hereinafter referred to as “pygas”), a liquid cargo, in No. 1 cargo oil tank, No. 2 port cargo oil tank, No. 2 starboard cargo oil tank, No. 4 port cargo oil tank, No. 4 starboard cargo oil tank, No. 5 port cargo oil tank, and No. 5 starboard cargo oil tank (hereinafter “cargo oil” shall be omitted for cargo oil tanks having a number).

The Vessel entered Yeosu Port at around 12:25 on April 6, completed unloading her entire cargo of pygas at around 09:10 on April 7, and left port in ballast condition for Chiba Port, Chiba Prefecture at around 15:55 on the same day.

After flushing*² the cargo lines and tank bottoms, the Vessel decided to conduct “cleaning of the cargo oil tanks” (hereinafter referred to as “the Cleaning Work”) in preparation for cargo loading at Chiba Port without ventilating the cargo oil tanks using ventilation equipment. She began cleaning No. 2 port tank (Except Chapter 6, hereinafter referred to as “the Tank”) and the No. 2 starboard tank with normal temperature seawater using Butterworth cleaning machines*³ (hereinafter singularly referred to as “the Cleaning Machine”) from around 18:00 and then conducted the Cleaning Work with seawater heated to approximately 75°C before closing the hatch covers and halting work at around 02:25 on April 8.

The Vessel decided to resume the Cleaning Work using the Cleaning Machine at around 08:00. Navigation Officer A, the boatswain, Ordinary Seaman A, Ordinary Seaman B, and Ordinary Seaman C took their positions on the forward deck; the seawater to be used in the Cleaning Work was heated to approximately 60°C in preparation for work; and then approximately 2.6 tons of heated seawater and approximately 180 liters of cleaning agent were sent into the Tank and equal amounts of both were sent into No. 2 starboard tank.

The Vessel sent heated seawater and cleaning agent into the Tank and the No. 2 starboard tank and then, for the purpose of starting the “work of repeatedly pumping up liquid collected on the tank’s bottom with a pump installed in the tank and then spraying the liquid with the Cleaning Machine” (hereinafter referred to as “the Circulation Work”), Navigation Officer A started said pump at around 10:00.

*¹ “Pyrolysis gasoline” is a low-boiling-point gasoline that can be obtained from thermal decomposition and catalytic cracking of high-boiling-point fractions from crude oil. It is an extracting raw material for benzene, toluene, and xylene. It is also called thermal cracking gasoline.

*² “Flushing” refers to the removal of grime in pipes and tank bottoms with a liquid or other substance.

*³ 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 or oil during tank cleaning work.

Navigation Officer A decided to inject steam into the Tank and the No. 2 starboard tank for the purpose of raising the seawater's temperature. When, at around 10:05, he instructed Ordinary Seaman C to open the No. 2 starboard tank's steam valve and Ordinary Seaman A to open the Tank's steam valve and Ordinary Seaman A and Ordinary Seaman C opened their respective steam valves, an explosion occurred in the Tank.

The boatswain and Ordinary Seaman C saw Ordinary Seaman A and Ordinary Seaman B, who were injured by the blast, and rescued them.

The master, who was in his cabin, noticed the hull's shaking and went to the bridge, where he recognized that there was an explosion in the cargo oil tanks. He stopped the main engine with an order to another navigation officer and, at around 10:15, reported the accident to Japan Coast Guard.

Ordinary Seaman A and Ordinary Seaman B were rescued by a patrol ship that had arrived to provide assistance and were transported by ambulance to a hospital.

The Vessel subsequently navigated under her own power and anchored in a quarantine anchorage outside of Oita Port, Oita Prefecture, at around 14:55.

The date and time of occurrence of the accident were at around 10:05 on April 8, 2018, and the location was around 111° (true bearing; hereinafter the same), 5.0 nautical miles (M) from the South Breakwater Lighthouse of Kunisaki Port.

(See Annex Figure 1 Estimated Navigation Routes)

2.2 Injuries to Persons

(1) Ordinary Seaman A

According to the medical certificate, Ordinary Seaman A received second-degree burns to his head, face, right hand joints, left buttock, left thigh, right thigh, left leg joints, and right lower leg.

(2) Ordinary Seaman B

According to the statement of Ordinary Seaman B, he received slight burns to his face.

2.3 Damage to Vessel

According to the on-site investigations, statement of Navigation Officer A and the reply to the questionnaire of Company A and the Classification Society (KOREAN REGISTER OF SHIPPING), the situation was as follows.

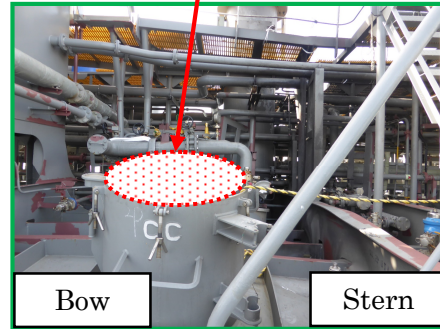
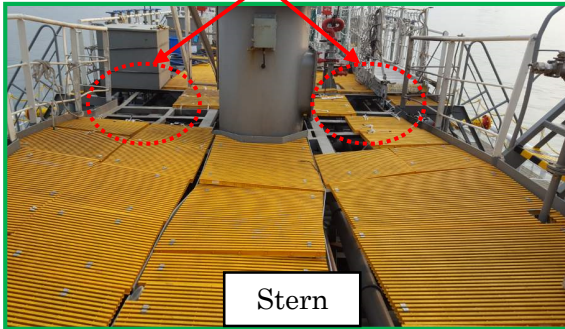
- (1) There were deformations together with cracks running longitudinally and transversely on the trunk deck as well as cracks and holes near the No. 1 tank, the Tank, and the No. 2 starboard tank.
- (2) There were cracks and deformations in the forward transverse bulkhead of the Tank, cracks in the upper and lower portions of the longitudinal bulkhead between the Tank and the No. 2 starboard tank as well as a roughly 100-mm deformation running toward the starboard side, and holes and deformations in the floor at the lower part of the forward transverse bulkhead. The hatch cover fell into the sea.
- (3) The hatch covers of No. 1 tank and the No. 2 starboard tank fell into the sea.
- (4) There were cracks and deformations in the forward transverse bulkheads of No. 3 port tank and No. 3 starboard tank and holes and deformations in the floor at the lower part of the

forward transverse bulkhead.

(See Figure 1)

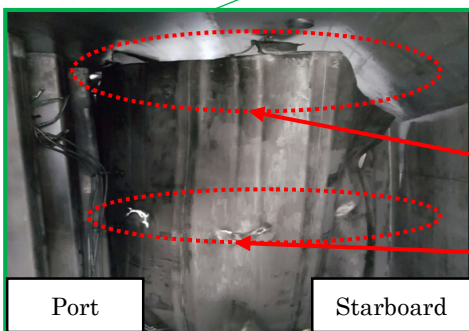
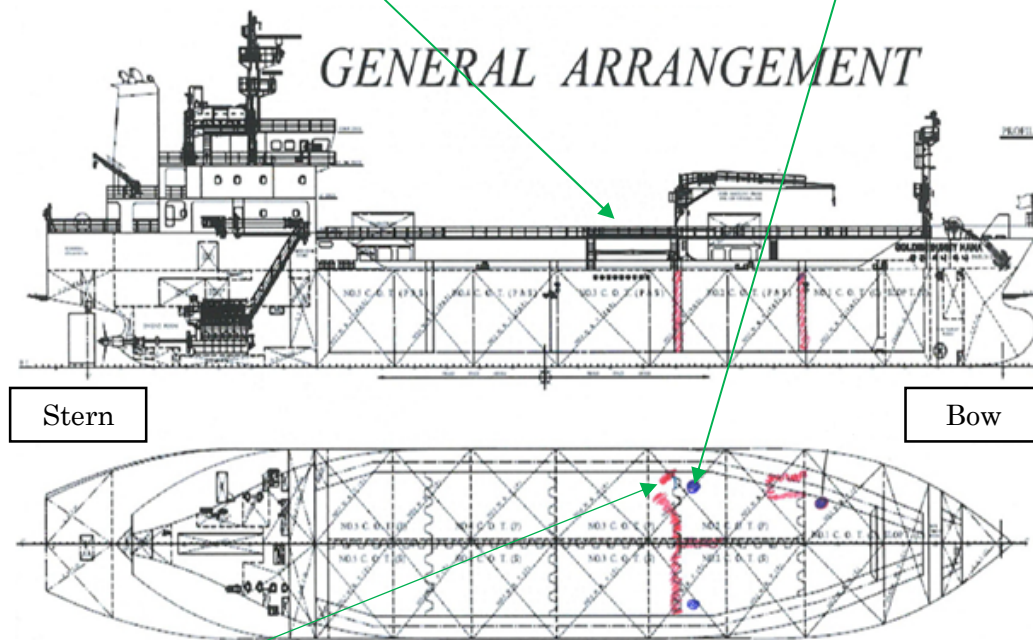
Damage to the passageways on the trunk deck
(The Tank and the No. 2 starboard tank are below the damaged locations.)

Place where the hatch cover had been



Damage looking from the top of No. 3 tank toward the bow

Damage to the Tank
(The hatch cover fell into the sea.)



— Damaged bulkhead
● Fallen hatch cover

Holes and deformations

Cracks

Damage to No. 3 port tank's forward transverse bulkhead

Figure 1 Damage Diagram

- (5) The No. 1 port ballast tank, No. 2 port ballast tank, No. 2 starboard ballast tank, No. 3 port ballast tank, and No. 3 starboard ballast tank had holes, cracks, and dents to their upper portions, and ballast water flowed into the No. 1 tank, the Tank, No. 2 starboard tank, No. 3 port tank, and No. 3 starboard tank.

2.4 Crew Information

(1) Gender, Age, and Certificate of Competence

Master: Male, 66 years old, national of the Republic of Korea

First grade navigation officer (limited to merchant ships) certificate (issued by the Republic of Korea)

Date of Issue: May 8, 2014

(Valid until June 23, 2019)

Navigation Officer A: Male, 51 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: December 18, 2017

(Valid until January 7, 2023)

Boatswain: Male, 60 years old, national of the Republic of Korea

Ordinary Seaman A: Male, 28 years old, national of the Republic of Indonesia

Ordinary Seaman B: Male, 44 years old, national of the Republic of Indonesia

Ordinary Seaman C: Male, 32 years old, national of the Republic of Indonesia

(2) Sea-going Experience, etc.

According to the statements of the master, Navigation Officer A, the boatswain, Ordinary Seaman A, Ordinary Seaman B and Ordinary Seaman C, the situation was as follows.

1) The master

The master became a crew member around 1976 and served aboard the Vessel as her master on December 17, 2017. He was in good health at the time of the accident.

2) Navigation Officer A

Navigation Officer A became a crew member around 1986 and came aboard the Vessel as a second officer in December 2017. He was promoted to chief officer in February 2018. He was in good health at the time of the accident.

3) The boatswain

The boatswain had approximately 20 years of experience at sea. He was in good health at the time of the accident.

4) Ordinary Seaman A

Ordinary Seaman A had approximately seven years of experience at sea, of which approximately two years came aboard chemical tankers. He came aboard the Vessel on January 10, 2018. He was in good health at the time of the accident.

5) Ordinary Seaman B

Ordinary Seaman B came aboard the Vessel on March 22, 2018. He was in good health at the time of the accident.

5) Ordinary Seaman C

Ordinary Seaman C came aboard the Vessel on January 10, 2018. He was in good health at the time of the accident.

2.5 Vessel Information

2.5.1 Particulars of Vessel

IMO number: 9808857

Port of registry: Jeju (Republic of Korea)

Owner: Company A (Republic of Korea)

Classification Society: KOREAN REGISTER OF SHIPPING

Gross tonnage: 2,990 tons

L×B×D: 91.40m×14.40m×7.80m

Hull material: Steel

Engine: Diesel engine × 1

Output: 2,427 kW

Date of launch: July 28, 2017

(See Photo 1)



Photo 1 The Vessel

2.5.2 Hull of the Vessel

The Vessel is a single-layer oil/chemical tanker with forecastle and poop. Forward transverse bulkheads were located in the corrugated No. 1 tank and in port-starboard pairings of No. 2 tank, No. 3 tank, No. 4 tank, and No. 5 tank in order from the bow. Hatches were provided for each tank on the trunk deck.

According to the reply to the questionnaire by Company A, the capacity of each tank was as shown in Table 1. Stainless steel was used in inner walls. No coating of paint or other material was used. In addition, approximately 30 liters of cargo oil remained in the tanks even after unloading with cargo pumps.

There were no malfunctions or areas undergoing repair in the hull's facilities at the time of the accident.

Table 1. Capacity of Each Tank

Cargo tank name	Starboard side capacity (m ³)	Port side capacity (m ³)
No. 1 tank	452.380	
No. 2 tank	471.870	471.390
No. 3 tank	491.060	490.040
No. 4 tank	490.180	491.770
No. 5 tank	397.120	396.880
Total	4152.690	

2.5.3 Information concerning the Cleaning Work

According to the statement of Navigation Officer A, the situation was as follows.

- (1) The Vessel conducted cleaning work by referring to *Dr. Verwey's Tank Cleaning Guide, Ninth Edition*, which is a commercially available manual for tank cleaning work. The details were as follows.
 - 1) Butterworth cleaning using seawater of between 50°C and 55°C for one hour
 - 2) Butterworth cleaning using seawater of between 70°C and 80°C for 1.5 hours
 - 3) Circulation work using seawater or freshwater of between 50°C and 70°C and cleaning agent for one hour
- (2) Navigation Officer A conducted work based on the manual as described in (1) and was appropriately adjusting the seawater's temperature within the provided ranges.

2.5.4 Information concerning the Circulation Work

According to the statements of Navigation Officer A and Ordinary Seaman A and the reply to the questionnaire of Company A, the Circulation Work was as follows.

(1) The Cleaning Machines

One Cleaning Machine each was installed on the trunk deck for the Tank and the No. 2 starboard tank.

(2) Seawater

Seawater used in circulation work was pumped up by a tank cleaning pump installed in the bow thruster room from a seawater intake in the room and then heated to approximately 60°C in the heater room and sent into the Tank and the No. 2 starboard tank. At the time of the accident, the volume of seawater sent into the Tank and the No. 2 starboard tank was approximately 2.6 tons for each.

(3) Cleaning agent

The cleaning agent was incombustible and was used for the purpose of tank cleaning. At the time of the accident, it was stored on deck in a plastic drum and was sent directly from the drum into the Tank and the No. 2 starboard tank with a mobile air pump. (See Figure 2)

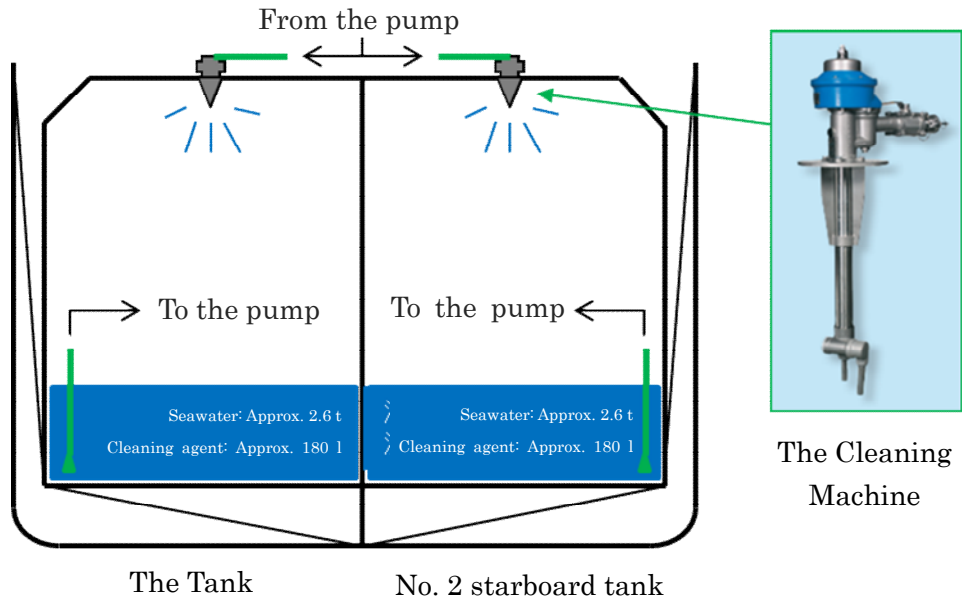


Figure 2 Circulation Work Diagram

2.5.5 Information concerning the Pygas

According to the statement of Navigation Officer A and reply to the questionnaire of Company A, the situation was as follows.

- (1) Pygas is a thermal cracking gasoline that includes toluene, benzene, and xylene. Its safety datasheet indicates that it has a flashpoint of 11°C or more and explosive range*⁴ of 1.3 to 7.5%. It is extremely combustible in either liquid or gaseous form. Other characteristics of pygas noted in the safety datasheet are provided in the following table.

Item	Unit	Value
Self-ignition temperature	°C	348
Concentration (15°C) (liquid)	kg/m ³	840-870
Specific gravity when vaporized (air ratio)*		3.9

* This indicates that, when air of the same volume is considered to be “1,” the mass of vaporized pygas is 3.9 times heavier than air.

- (2) The gas concentration of the Tank was measured after unloading at Yeosu Port. The result was 1.4 to 1.7% and therefore within the explosive range.
- (3) When the temperature of liquid pygas exceeds 11°C, the possibility that the pygas will evaporate quickly and combust explosively exists and the danger of fire rises.

2.5.6 Information concerning the Air

At around 02:25 on April 8, the hatch covers of the Tank and the No. 2 starboard tank were closed when the Cleaning Work was halted. However, at around 08:00, the hatch covers were opened when preparatory work began and thus air was being naturally supplied to the tanks.

*⁴ “Explosive range” refers to the range in which an explosion will occur if an ignition source (energy) is present within a certain mixture of gas remaining in the tank to air.

2.5.7 Electrification of the Tanks

According to advice by the Senior Research Staff of the Fire and Disaster Management Agency's National Research Institute of Fire and Disaster, reference literature*⁵ and the statement of Navigation Officer A, the situation was as follows.

- (1) Electrification can occur when water is sprayed in a tank or the surface of a liquid becomes agitated.
- (2) When there is electrically-charged mist created by the splashing of cleaning water filling a tank, a mass of charged cleaning water crossing through it can generate discharge sparks between protruding components within the tank.
- (3) Static electricity is generated when liquid is sprayed from a nozzle when cleaning a tank, and it has been confirmed in actual ship tests that generated electrically-charged mist drifts to a significant degree within the tank's air. This becomes even more pronounced with a temperature of between 19°C and 55°C in the case of cleaning with circulated water.

Additionally, in the cases of clean seawater and dirty seawater that contains oil, electrical field strength is larger for the latter. Moreover, the electrical field strength rises if cleaning agent is mixed in.

- (4) At the time of the accident, cleaning work involving the spraying of seawater heated to approximately 60°C and cleaning agent was being conducted using the Cleaning Machine in the Tank and the No. 2 starboard tank.

2.5.8 Information concerning Steam Injection

According to the statement of Navigation Officer A, reply to the questionnaire of Company A and reference literature*⁶, the situation was as follows.

- (1) At around 10:05, Navigation Officer A instructed Ordinary Seaman C to open the steam valve of the No. 2 starboard tank and Ordinary Seaman A to open the steam valve of the Tank for the purpose of raising the seawater's temperature.
- (2) The time between the opening of the steam valves and the accident was approximately three to five seconds.
- (3) The steam that was injected into the Tank and the No. 2 starboard tank had a temperature of approximately 120°C and pressure of approximately 0.7 MPa.
- (4) When steam is injected into a tank, a significant amount of electrically-charged steam is released into the air and becomes suspended in the air inside the tank, creating a space charge. When the density of this space charge is great, the danger exists that a lightning phenomenon-like charge will generate an electrical discharge toward protrusions inside the tank. To prevent the danger of a space charge within the tank, the steam's pressure must be reduced to no more than approximately 0.5 MPa.

2.5.9 Information concerning the Ignition and Explosion by Electrification

According to the statements of the master, Navigation Officer A, reply to the questionnaire

*⁵ *Tanka Anzen Tantosha Kyohon* (manual for persons in charge of tanker safety) (edited by the Association for Promoting Safety and Sanitation for Seafarers; Seizando-Shoten Publishing Co., Ltd.; published 1985)

*⁶ *Naiko Tanka Anzen Shishin (Kaiteiban)* (safety guidelines for coastal tankers [revised edition]) (Japan Coastal Tanker Association; edited by Naikokaiun Anzen Yudaku Kogai Boshi Kyokai [association for coastal navigation safety and prevention of oil pollution]; Seizando-Shoten Publishing Co., Ltd.; published 1985)

of Company A and reference literature^{*7}, the situation was as follows.

- (1) At the time of the accident, the master and Navigation Officer A felt the hull sway just once and observed smoke coming from a tank in the direction of the port bow; however, they did not see a fire.
- (2) Black soot was observed on the inside of the Tank's hatch in an investigation conducted after the accident.
- (3) At the time of the accident, there was no fire on the deck, and the crew members involved with the circulation work were using explosion-proof equipment and taking care not to drop tools.
- (4) For an explosion caused by electrification to occur, the petroleum gas and air mixture ratio must be within the upper and lower limits for an explosion and electrical discharge energy must be added.
- (5) An electrical discharge occurs when the electrical charge accumulates and the electrical field strength increases, and a sufficiently large potential difference is applied between items serving as electrodes.

2.5.10 Precautions Important Points in Company A's Tank Cleaning Procedure

According to the reply to the questionnaire of Company A, precautions were as follows.

- (1) The selection of the tank cleaning method depends on the type of residue to be removed, and the cleaning procedure must be determined with consideration for the physical and scientific characteristics of the cargo.
- (2) When conducting cleaning work, it must be confirmed prior to work that precautions concerning gas-free operations are being observed.
- (3) The cleaning work procedure must be decided with consideration for the cargo that was loaded previously, residue within the tanks, the time required for cleaning work, the possibility of heating, the number of available cleaning machines, the locations and number of hatches, pump capacity, the number of workers, and other items; the procedure must be approved by the master.
- (4) When planning cleaning work by a cleaning machine or steam, the concentration of combustible gas within the tank must be measured prior to starting work.
- (5) Tank bottoms and pipes where gas-free operations will take place must be flushed with seawater to prevent the generation of gas from residue oil of liquid cargo. This should be done by sending enough seawater into the tank to completely cover the bottom and then removing the seawater into a slop tank using a cargo pump. Introducing seawater from pipes that may spark an explosion from static electricity, such as a cleaning machine, is strictly prohibited.

2.5.11 Information concerning an Investigation into the Accident's Cause conducted by Company A

According to the reply to the questionnaire of Company A, the situation was as follows.

- (1) The Vessel did not measure the gas concentration within the cargo oil tanks prior to the Cleaning Work.
- (2) The Vessel was not providing ventilation with ventilation equipment and vaporized pygas

^{*7} *Tanka no Kasai to sono Taisaku* (tanker fires and countermeasures) (K. Imai; Seizando-Shoten Publishing Co., Ltd.; published 1966)

was present within the tanks at the time of the accident.

- (3) The steam valves of the Tank and the No. 2 starboard tank were opened immediately before the explosion.
- (4) The Vessel was using explosion-proof products for transceivers and other tools.

2.5.12 Information concerning Company A's Cleaning of Cargo Oil Tanks

According to the portion of Company A's Safety Management System^{*8} concerning cleaning work, cleaning was to be conducted as follows.

- (1) The Vessel was to measure the gas concentration in the cargo oil tanks prior to cleaning work and, if the measured value exceeded 10% of the lower explosive limit concentration, she was to provide ventilation until the value fell.
- (2) The Vessel was to provide tank ventilation with ventilation equipment after flushing.
- (3) The portion of the Safety Management System concerning cleaning work did not mention precautions or other items concerning the injection of steam.

2.6 Weather and Sea Conditions

2.6.1 Weather Observations

Meteorological observations at the Musashi Regional Meteorological Observation Station, which is located approximately 6.0 M southwest from the accident site, were as follows.

10:00 Wind direction: West-northwest; Wind Speed: 5.5 m/s; Temperature: 11.2°C

2.6.2 Observations of Crew Members

According to the statement of the master, at the time of the accident, the weather was clear, the sea was calm, visibility was good, and the temperature was 13°C.

^{*8} "Safety Management System" refers to a safety management system that is in conformity with the International Management Code for the Safe Operation of Ships and for Pollution Prevention.

3 ANALYSIS

3.1 Situation of the Accident Occurrence

3.1.1 Course of the Events

According to 2.1, it is probable that the situation was as follows.

- (1) The Vessel completed unloading her entire cargo of pygas at Yeosu Port at around 09:10 on April 7 and left Yeosu Port at around 15:55.
- (2) The gas concentration of the Tank was measured after unloading at Yeosu Port, and the result was between approximately 1.4 and approximately 1.7%.
- (3) In preparation for loading at Chiba Port, the Vessel conducted cleaning work in the Tank and the No. 2 starboard tank with normal temperature seawater using the Cleaning Machines from around 18:00, and then conducted cleaning work with seawater heated to approximately 75°C before closing the hatch covers and halting work at around 02:25 on April 8.
- (4) The Vessel decided to resume cleaning work at around 08:00. Navigation Officer A, the boatswain, Ordinary Seaman A, Ordinary Seaman B, and Ordinary Seaman C took their designated positions; the seawater to be used in the cleaning work was heated to approximately 60°C; and then approximately 2.6 tons of seawater and approximately 180 liters of cleaning agent were sent into the Tank and equal amounts of both were sent into No. 2 starboard tank.
- (5) Navigation Officer A started the tank cleaning pump at around 10:00 for the purpose of beginning circulation work in the Tank and the No. 2 starboard tank.
- (6) At around 10:05, Navigation Officer A instructed Ordinary Seaman C to open the No. 2 starboard tank's steam valve and Ordinary Seaman A to open the Tank's steam valve for the purpose of raising the seawater's temperature. When Ordinary Seaman A and Ordinary Seaman C opened their respective steam valves, an explosion occurred in the Tank.

3.1.2 Date, Time and Location of the Accident Occurrence

According to 2.1, it is probable that the date and time of occurrence of the accident was at around 10:05 on April 8, 2018, and the location was around 111° true bearing, 5.0 M from South Breakwater Lighthouse of Kunisaki Port.

3.1.3 Injuries to Persons

According to 2.1 and 2.2, Ordinary Seaman A was exposed to the blast and received second-degree burns to his head, face, right hand joints, left buttock, left thigh, right thigh, left leg joints, and right lower leg, and Ordinary Seaman B was exposed to the blast and received slight burns to his face.

3.1.4 Damage to Vessel

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

- (1) There were deformations together with cracks running longitudinally and transversely on the trunk deck as well as cracks and holes near the No. 1 tank, the Tank, and the No. 2 starboard tank.
- (2) There were cracks and deformations in the forward transverse bulkhead of the Tank,

cracks in the upper and lower portions of the longitudinal bulkhead between the Tank and the No. 2 starboard tank as well as a roughly 100-mm deformation running toward the starboard side, and holes and deformations in the floor at the lower part of the forward transverse bulkhead. The hatch cover fell into the sea.

- (3) The hatch covers of No. 1 tank and the No. 2 starboard tank fell into the sea.
- (4) There were cracks and deformations in the forward transverse bulkheads of No. 3 port tank and No. 3 starboard tank and holes and deformations in the floor at the lower part of the forward transverse bulkhead.
- (5) The No. 1 port ballast tank, No. 2 port ballast tank, No. 2 starboard ballast tank, No. 3 port ballast tank, and No. 3 starboard ballast tank had holes, cracks, and dents to their upper portions, and ballast water flowed into the No. 1 tank, the Tank, No. 2 starboard tank, No. 3 port tank, and No. 3 starboard tank.

3.2 Causal Factors of the Accident

3.2.1 Situation of Crew Members

According to 2.4, it is probable that the situation was as follows.

(1) The master

The master possessed a legally valid certificate of competence.

It is probable that the master became a crew member around 1976, that he came aboard the Vessel as her master on December 17, 2017, and that was in good health at the time of the accident.

(2) Navigation Officer A

Navigation Officer A possessed legally valid certificate of competence.

It is probable that Navigation Officer A became a crew member around 1986, that he came aboard the Vessel as a second officer in December 2017, that he was promoted to chief officer in February 2018, and that was in good health at the time of the accident.

(3) The boatswain

It is probable that the boatswain had approximately 20 years of experience at sea, and that he was in good health at the time of the accident.

(4) Ordinary Seaman A

It is probable that Ordinary Seaman A had approximately seven years of experience at sea, of which approximately two years came aboard chemical tankers, that he came aboard the Vessel on January 10, 2018, and that was in good health at the time of the accident.

(5) Ordinary Seaman B

It is probable that Ordinary Seaman B came aboard the Vessel on March 22, 2018, and that he was in good health at the time of the accident.

(6) Ordinary Seaman C

It is probable that Ordinary Seaman C came aboard the Vessel on January 10, 2018, and that was in good health at the time of the accident.

3.2.2 Weather and Sea Conditions

According to 2.6, it is probable that at the time of the accident, the weather was clear, the wind direction was from the northwest, the wind force was 4, the temperature was 11.2°C and the sea was calm.

3.2.3 Analysis of Cleaning Work at the Time of the Accident

According to 2.1, 2.5.3 to 2.5.12 and 3.2.3, it is probable that the situation was as follows.

- (1) It is probable that, although the Vessel had completed unloading her entire cargo of liquid pygas at Yeosu Port and all of her tanks were in an empty state, approximately 30 liters of liquid pygas remained, respectively, in both the Tank and the No. 2 starboard tank, and the gas concentration of vaporized pygas was approximately 1.4% to approximately 1.7% and therefore already within the explosive range.
- (2) Although the Vessel conducted flushing of the cargo lines and tank bottoms, it is probable that, because the details of the flushing are unclear, approximately 30 liters of liquid pygas was present in the tanks, and that, because ventilation by ventilation equipment was not being provided, vaporized pygas, which was heavier than the air, was not expelled from the tanks and remained inside the tanks.
- (3) It is somewhat likely that, because vaporized pygas became mixed with air in the tank and air supplied naturally from the hatch, which was opened approximately two hours before the Accident, a combustible gas mixture was present in the Tank and the No. 2 starboard tank.
- (4) It is probable that, when the Vessel conducted cleaning work in the Tank and the No. 2 starboard tank, it was not noticed that the combustible gas mixture was within the explosive range because gas concentration was not measured.
- (5) It is probable that approximately 2.6 tons of heated seawater of approximately 60°C and 180 liters of cleaning agent were sent into the Tank and the same amounts of both were sent into the No. 2 starboard tank for the purpose of conducting cleaning work in the tanks.
- (6) It is probable that the entire quantity of 30 liters of liquid pygas that remained in the tanks vaporized as a result of the Cleaning Work, and it is probable that the concentration was as follows and that, because the concentration value rose above the value that was measured after unloading when the Circulation Work took place, the concentration value rose from a value near the lower limit of the explosive range.

V_T 471.390 m³: The Tank's capacity (No. 2 port tank)

V_{T30} 471.360 m³: The Tank's capacity when 30 liters of pygas are considered

V_{TSW} 468.673 m³: The Tank's capacity when approximately 2.6 tons of seawater with a concentration of 1.025 g/cm³ and approximately 180 liters of cleaning agent are considered

$$V_{T30} = V_T - 30 \times 10^{-3} = 471.360$$

$$V_{TSW} = V_T - (180 + 2600/1.025) \times 10^{-3} = 468.673$$

The vaporized pygas concentration C_b of the Tank that was measured after unloading was

$$C_b = 1.4\text{-}1.7\%$$

When vaporized pygas capacity is V_{Gb} (m³) and the volume of air in the tank is V_{ab} (m³),

$$C_b = \frac{V_{Gb}}{V_{Gb} + V_{ab}}, \quad V_{Gb} + V_{ab} = V_{T30}, \quad \text{therefore}$$

$$V_{Gb} = C_b \times V_{T30} = 6.599 \text{ to } 8.013 \text{ m}^3$$

Assuming the following for concentration, etc.,

$\rho_{air15} = 1220.4 \text{ g/m}^3$: Air density at 15°C (calculated by assuming air with a gas mixture of 21% oxygen and 79% nitrogen at 0°C and converting to 15°C)

$\rho_{pygg/air} = 3.9$: Air ratio mass of vaporized pygas

$\rho_{pygr} = 840 \text{ kg/m}^3$: Concentration of liquid pygas (@ 15°C)

Volume V_{G30g} (m^3) when 30 liters of liquid pygas vaporizes is
(Temperature-caused changes in concentration are not considered)

$$\begin{aligned} V_{G30g} &= 30\text{l} \times \rho_{pygr} / (\rho_{pygg/air} \times \rho_{air}) \\ &= 30 \times 10^{-3} \times 840 \times 10^3 / (3.9 \times 1220.4) \\ &= 25200/4759.73 \\ &= 5.294 \text{ (m}^3\text{)} \end{aligned}$$

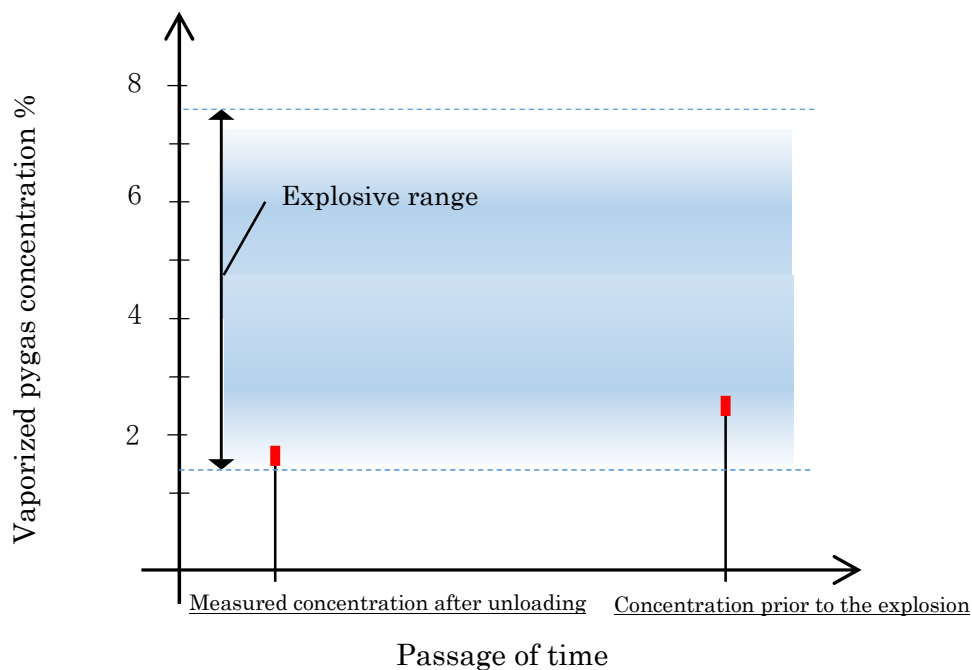
Vaporized pygas volume when 30 liters of liquid pygas are vaporized and added V_{Ga} (m^3) is

$$\begin{aligned} V_{Ga} &= V_{Gb} + V_{G30g} \\ &= 11.893 \text{ to } 13.308 \text{ (m}^3\text{)} \end{aligned}$$

Concentration C_a (%) when 30 liters of vaporized pygas are added is
(The amount of increased pygas is calculated as reduced air)

$$\begin{aligned} C_a &= C_b/V_{SW} \\ &= \frac{11.893 \text{ to } 13.308}{468.673} \\ &= 2.54 \text{ to } 2.84\% \end{aligned}$$

	Minimum value (%)	Maximum value (%)
After unloading	1.4	1.7
Before the explosion	2.54	2.84
Explosive range	1.3	7.5



(7) It is probable that, during circulation work in the Tank and the No. 2 starboard tank, Navigation Officer A ordered the injection of steam for the purpose of raising the temperature of seawater used in the work without knowledge of precautions concerning

injection of steam.

- (8) It is probable that the steam temperature (120°C) was lower than the self-ignition temperature of pygas (348°C).

3.2.4 Analysis of the Accident's Occurrence

According to 2.1, 2.5.3 to 2.5.11 and 3.2.3, it is probable that the situation was as follows.

- (1) Given that tank ventilation with ventilation equipment was not provided, it is probable that a combustible gas mixture at a concentration in the explosive range existed in the Tank.
- (2) Given that heated seawater with a temperature of 60°C was injected into the Tank, it is probable that the entire quantity of liquid pygas remaining in the tank vaporized, that its concentration increased after unloading, and that a combustible gas mixture with a concentration that was even higher than lower limit of the explosive range existed within the Tank.
- (3) Given that steam with a temperature of approximately 120 °C and pressure of approximately 0.7 MPa was injected into the Tank, it is somewhat likely that a condition in which highly charged steam existed as space charge in the Tank, and that a spark was generated when this charge directly discharged toward a protrusion in the tank.
- (4) It is somewhat likely that the combustible gas mixture in the tank ignited from the spark and exploded.

4 PROBABLE CAUSES

It is probable that the accident occurred when, as the Vessel was conducting the Circulation Work in the Tank and the No. 2 starboard tank during tank cleaning work while off to the southeast of Kunisaki Port, Oita Prefecture, an explosion occurred in the Tank because steam was injected into the Tank under conditions in which a combustible gas mixture of vaporized pygas and air in the explosive range was present.

It is probable that the presence of the combustible gas mixture of vaporized pygas and air in the Tank was not noticed because the gas concentration in the Tank was not measured prior to the Cleaning Work.

It is somewhat likely that the combustible gas mixture was within the explosive range because flushing of the cargo lines and tank bottoms was conducted under conditions in which ventilation and other measures were not implemented even though the gas concentration measurement taken after unloading was within the explosive range and approximately 30 liters of pygas subsequently remained in both the Tank and the No. 2 starboard tank, and the vaporized pygas was not expelled outside, its gas concentration increased further with the passage of time, and it became mixed with air.

It is probable that steam was injected into the Tank with the intention of raising the temperature of the seawater used in the Circulation Work.

5 SAFETY ACTIONS

It is probable that an explosion occurred in the Tank when the Vessel was conducting circulation work in the Tank and the No. 2 starboard tank during tank cleaning work while off to the southeast of Kunisaki Port, Oita Prefecture.

It is somewhat likely that the explosion occurred in the Tank because, under conditions in which a combustible gas mixture of vaporized pygas and air in the explosive range was present in the tank and measurements of gas concentration and ventilation with ventilation equipment were not being conducted, electrically-charged steam was injected into the Tank and energized, a spark was generated, and ignited the combustible gas mixture.

Accordingly, it is probable that the owner must implement the following measures for crew members on vessels that carry pygas in order to prevent occurrence of a similar accident.

- (1) Instruct crew members to sufficiently provide ventilation with ventilation equipment after the flushing of cargo lines and tank bottoms.
- (2) Instruct crew members to measure gas concentration before cleaning work and during cleaning work, to cease work immediately when a measurement is in the explosive range, and to continue work after providing ventilation with ventilation equipment or introducing inert gas, for example, and confirming safety.
- (3) Instruct crew members to consider the danger of static electricity present in tanks and to not inject steam if safety cannot be confirmed.

5.1 Safety Actions Taken by Company A

Company A implemented the following measures to prevent recurrence:

- (1) Added the following to the portion of its Safety Management System concerning cleaning work.

- 1) Fundamental rule of cleaning work

Follow methods and procedures provided in ISGOT^{*9} 11.3 when conducting cleaning work after unloading ignitable or explosive cargo.

- 2) Steam injection

Consider the danger of static electricity and do not inject steam into tanks when the danger exists.

Abide by following items when beginning tank cleaning work:

Close the hatch covers of all cargo oil tanks and ballast tanks.

Clean tanks and cleaning lines prior to cleaning to keep rust and other contaminants out of cargo oil tanks.

For tanks that carried a combustible product, conduct inerting^{*10} prior to cleaning. Check the oxygen level in the tank between the time before the start of cleaning and actual cleaning. If the cleaning time will be extended, conduct additional checks. Stop cleaning during the additional checks. Record all measurement results in detail.

When cleaning must be done under conditions in which inerting has not been conducted, follow all of the preventative measures listed in Chapter 7 of TSG^{*11} and Chapter 9 of ISGOTT. Said preventative measures shall include procedures to prohibit the use of tank

^{*9} ISGOTT: International Safety Guide for Oil Tankers and Terminals

^{*10} "Inerting" refers to the introduction of inert gas into a cargo oil tank for the purpose of preventing explosions.

^{*11} TSG: Tanker Safety Guide prepared by the International Chamber of Shipping

cleaning agent, the injection of steam, and the use of water exceeding 60°C and recycled cleaning water unless it is conformed that there is no gas in the tank. Measure the concentrations of combustible substances before cleaning a tank that has been inerted. In general, do not start cleaning when the gas concentration exceeds 20% LFL.^{*12} Take periodic gas measurements during cleaning. Cease cleaning if the gas concentration exceeds 50% LFL. When injecting steam, gas shall not be present in the tank and all measurement results shall be recorded in detail.

3) Cleaning work guide

For cargoes and special cargoes requiring a W.W.T. (Wall Wash Test; a confirmation of the thoroughness of tank cleaning), Company A shall receive advice from contracted cleaning technology advisors and provide tank cleaning methods to the Vessel.

4) Tank cleaning planning and reporting of results

Masters shall report the cargo oil they carried previously, the cargo oil they will carry next, their implementation of flushing of tank bottoms and inerting, the start and end times of cleaning, and the amount of cleaning agent used to Company A.

- (2) Provided special cleaning work training by persons designated under the ISM Code to all vessels.
- (3) Added a course on cleaning work to the pre-boarding training program.
- (4) Posted precautions for cleaning work in cargo control rooms.

^{*12} LFL: Lower Flammable Limit

6 SAFETY RECOMMENDATIONS

It is probable that an explosion occurred in the No. 2 port cargo oil tank when the chemical tanker GOLDEN SUNNY HANA was conducting circulation work in the No. 2 port cargo oil tank and the No. 2 starboard cargo oil tank during cargo oil tank cleaning work while off to the southeast of Kunisaki Port, Oita Prefecture.

It is somewhat likely that the explosion occurred in the No. 2 port cargo oil tank because, under conditions in which a combustible gas mixture of vaporized pyrolysis gasoline and air in the explosive range was present in the No. 2 port cargo oil tank and measurements of gas concentration and ventilation with ventilation equipment were not being conducted, electrically-charged steam was injected into the No. 2 port cargo oil tank and discharged, a spark was generated, and ignited the combustible gas mixture.

In view of the result of this accident investigation, the Japan Transport Safety Board recommends that HNCC Co., Ltd., which is the owner of GOLDEN SUNNY HANA, take the following measures for the purpose of preventing the occurrence of a similar accident:

HNCC Co., Ltd., should instruct crew members on chemical tankers on which combustible gas mixtures are present in cargo oil tanks to consistently execute the following.

- (1) Sufficiently provide ventilation with ventilation equipment after the flushing of cargo lines and cargo oil tank bottoms.
- (2) Measure gas concentration before cleaning work and during cleaning work, cease work immediately when a measurement is in the explosive range, and continue work after providing ventilation with ventilation equipment or introducing inert gas and then confirming safety.
- (3) Consider the danger of static electricity present in cargo oil tanks and do not inject steam if safety cannot be confirmed.

Annex Figure 1 Estimated Navigation Route

