

MA2017-12

**MARINE ACCIDENT
INVESTIGATION REPORT**

December 21, 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: Container Vessel MANHATTAN BRIDGE
Vessel number: 142550 (IMO number: 9689615)
Gross tonnage: 152,297 tons

Accident type: Explosion of the Auxiliary Boiler
Date and time: Around 23:04, January 19, 2017 (local time, UTC)
Location: Port of Felixstowe, United Kingdom of Great Britain and Northern Ireland
Around 012° true bearing, 2.0 nautical miles from the Dovercourt High Lighthouse
(approximately 51°57.8'N, 001°17.2E)

November 29, 2017

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 >

While the container vessel MANHATTAN BRIDGE was docking with a master, 25 crew members and a pilot onboard at the port of Felixstowe, United Kingdom of Great Britain and Northern Ireland, at around 23:04 on January 19, 2017 (local time), an explosion occurred in the furnace of the auxiliary boiler.

The duty oiler died, the second engineer suffered injuries and the burner unit of the auxiliary boiler damaged.

< Probable Causes >

It is probably that the accident occurred, in the night time, while MANHATTAN BRIDGE was docking at the port of Felixstowe, United Kingdom of Great Britain and Northern Ireland, an explosion occurred within the furnace of the auxiliary boiler.

It is considered somewhat likely that explosion occurred in the furnace is because under existence of carbon monoxide gases heated by incomplete combustion and flames in the furnace, the second engineer operated the forced draft fan and the secondary air was supplied. The explosion occurred by a rapid chemical reaction changing heated carbon monoxide gas. Or in the situation where marine gas oil existed as a highly concentrated flammable gas in the high temperature furnace, the forced draft fan was operated and secondary air was supplied, then the flammable gas was mixed with air, the concentration was between the upper limit and lower limit concerning the

explosion. As a result, the explosion occurred.

It is probably that the second engineer operated the forced draft fan for the purge in the furnace.

It is probably that the existence of the marine gas oil a highly concentrated flammable gas was as follows. Under slimy wax-like material stuck to strainer etc., which was clogged causing the marine gas oil pressure drop but the marine gas oil pressure did not drop to fuel oil low pressure alarm set point, the marine gas oil to the rotary cup burner flow reduced. The primary air and the secondary air was supplied as same volume as before marine gas oil clogging, the marine gas oil was blown away and the atomizing marine gas oil became unevenly stable. The flame was cooled by the excess air and flame pattern was broken causing the combustion status very bad and remaining unburnt marine gas oil in the furnace and unburnt marine gas oil vaporized.

It is probably that the carbon monoxide gases heated by incomplete combustion and flame existed in the furnace because the forced draft fan stopped by the Furnace (Flame-Eye) Abnormal alarm, the secondary air damper was closed, secondary air was not supplied, and combustion continued under insufficient air quantity.

It is probably that the strainer was clogged as follows. When MANHATTAN BRIDGE used the marine gas oil containing a large amount of paraffin wax and the Cold Filter Plugging Point of it was high, the temperature around the auxiliary boiler oil burning apparatus was below the cold filter plugging point of the marine gas oil and the paraffin wax precipitated in the strainer.

1 PROCESS AND PROGRESS OF THE INVESTIGATION

1.1 Summary of the Accident

While the container vessel MANHATTAN BRIDGE was docking with a master, 25 crew members and a pilot onboard at the port of Felixstowe, United Kingdom of Great Britain and Northern Ireland, at around 23:04 on January 19, 2017 (local time), an explosion occurred in the furnace of the auxiliary boiler.

The duty oiler died, the second engineer suffered injuries and the burner unit of the auxiliary boiler damaged.

1.2 Outline of the Accident Investigation

1.2.1 Setup of the Investigation

The Japan Transport Safety Board appointed an investigator-in-charge and one other marine accident investigator to investigate this accident on January 20, 2017.

1.2.2 Collection of Evidence

January 23~25, 27, February 2, 6, 8, 16, 22, June 1, 14, 16, 19, 28, July 31, 2017: Collection of questionnaire

February 19, 2017: On-site investigations, interviews and collection of questionnaire

February 20, April 21, July 18, August 4, 2017: interviews and collection of questionnaire

April 14, May 10, 30, 2017: interviews

June 6, 2017: On-site investigations

1.2.3 Cooperation with the Investigation

Investigative documents concerning the auxiliary boiler explosion on MANHATTAN BRIDGE were provided by the Marine Accident Investigation Branch of United Kingdom of Great Britain and Northern Ireland on June 6, 2017.

1.2.4 Test and Research by Other Institutes

To investigate this accident, the JTSA entrusted the fuel oil analysis company with the investigation of the Fuel Oil in use at the time of the explosion.

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 Substantially Interested State

Comments on the draft report were invited from the coastal state involved in the accident.

2 FACTUAL INFORMATION

2.1 Events Leading to the Accident

According to the statements of the chief engineer, the first engineer of the MANHATTAN BRIDGE (hereinafter referred to as “the Vessel”) and the person in charge of “K” LINE SHIP MANAGEMENT (SINGAPORE) PTE. LTD. (hereinafter referred to as “Company A”) which was the ship management company of the Vessel and the reply to the questionnaire by the master and the second engineer (hereinafter referred to as “Engineer A”), the events leading to the accident were as follows.

At around 14:35 on January 16, 2017 (local time; hereinafter the same), prior to entering the North Sea sulphur emission (Sox*¹) control area (ECA*²) regulated by MARPOL 73/78 Convention*³ annex VI, the Vessel, with the master, the chief engineer, the first engineer, the oiler (hereinafter referred to as “Oiler A”) and 22 crew members, changed the fuel oil supply to the main engine, auxiliary generator engines and auxiliary boiler from heavy fuel oil to marine gas oil (hereinafter referred to as “MGO”).

After finishing discharged and loaded the cargoes at port of Rotterdam in the Kingdom of the Netherlands, at 08:55 on January 19, 2017, the Vessel with the containers of 8,725 TEU*⁴ (approximately 90,790 t) sailed from the port of Rotterdam to the port of Felixstowe in Suffolk, United Kingdom of Great Britain and Northern Ireland (hereinafter referred to as “UK”).

While arriving at the port of Felixstowe, all engineers and duty oiler were assigned each entering harbor standby stations in engine department at 16:00.

The auxiliary boiler emergency trip alarm was activated at around 17:30 and the Engineer A opened the rotary cup burner*⁵ of ‘the auxiliary boiler oil burning apparatus’ (hereinafter referred to as “the Oil Burning Apparatus”) and cleaned the inside.

After that, the auxiliary boiler emergency trip alarm was activated three times upto 19:51. On every occasion, after checking the auxiliary boiler, the other Engineer had cancelled the auxiliary boiler alarm at the auxiliary boiler local control panel and re-started the auxiliary boiler.

At around 20:00, an oiler who assigned his entering harbor standby stations handed over his duties to the Oiler A of the next watch. Then, at around 20:10, the Vessel was proceeded to the container terminal of Felixstowe with a pilot. The Vessel arrived at the container terminal with the first line ashore at around 22:45. At 23:01, the engine control room alarm panel indicated an auxiliary boiler emergency trip alarm.

*¹ "SOx" refers to sulphur oxide, which is generated by burning fuel oil containing sulphur and becomes a causative substance of air pollution and acid rain.

*² "Emission Control Areas (ECA)" refers to emissions of SOx, NOx (nitrogen oxides) and PM (particulate matter) generated from vessels by Annex VI of MARPOL 73/78 Convention compared to normal waters. In north sea of Europe, it is applied when entering the east side of the west longitude line of the western part of the United Kingdom of Great Britain and Northern Ireland and west of the French Republic.

*³ "MARPOL 73/78 Convention" is called the Convention for the Prevention of Marine Pollution and aims to prevent marine pollution of the oceans and seas, including dumping, oil and air pollution. The objective of this convention is to preserve the marine environment in an attempt to completely eliminate pollution by oil and other harmful substances and to minimize accidental spillage of such substances.

*⁴ "TEU" stands for Twenty feet Equivalent Unit, which is a unit indicating the load capacity of a container vessel, and one TEU means one twenty feet container.

*⁵ "Rotary cup burner" means a burner of a type that atomizes fuel oil by centrifugal force and air flow caused by rotation of the rotary cup at the tip of the burner.

The Engineer A, watch-keeping the engine room machineries in engine control room, accepted the alarm and left the engine control room and for the auxiliary boiler side which was on the third deck port side of the engine room. Then he met the Oiler A in front of the Oil Burning Apparatus.

The Engineer A saw the red alarm warning light flashing at the auxiliary boiler local control panel and he reset the auxiliary boiler emergency trip to stop the warning alarm after confirming the indication of the “Furnace (Flame-Eye) Abnormal” (ember in furnaces occur except during combustion) on the auxiliary boiler local control panel. Then he switched the auxiliary boiler control mode from ‘Auto’ to ‘Manual’ to purge unburnt gases in the furnace, then the forced draft fan*⁶ (hereinafter referred to as “FD fan”) started running.

At around 23:04, an explosion occurred within the auxiliary boiler furnace while the Engineer A was in position at starboard-fore side of the Oil Burning Apparatus and the Oiler A was in position at front of the Oil Burning Apparatus. The burner unit door fell to starboard-fore side deck and the secondary air nozzle blew off to fore side by the force of the explosion.

When the engineers who were assigned their entering harbor standby stations heard the big sound and left the engine control room, they saw the Engineer A with his boiler suit on fire at starboard side and put out the fire on the Engineer A by the portable fire extinguisher. Then they saw the Oiler A lying on the deck in front of the auxiliary boiler with his boiler suit on fire. They put out the fire on the Oiler A by the portable fire extinguisher.

After put out the fire of Oiler A and the Engineer A’s boiler suits, the Oiler A was confirmed dead and the Engineer A was transported to a medical center.

The date and time of occurrence of the accident were at around 23:04 on January 19, 2017, and the location was at around 2.0 M at 012° true bearing from the Dovercourt High Lighthouse.

(See Attached Figure 1 Outline Map of the Location of the Accident Events.)

2.2 Death and Injury to Persons

(1) The Oiler A

According to the coroner’s certificate of the fact of death, the cause of death was multiple injuries

(2) The Engineer A

According to the medical certificate, the Engineer A suffered burns on the right hand and his right thigh.

2.3 Damage to Vessel

According to the on-site investigations, the statement of the person in charge of the Oil Burning Apparatus manufacturing company (hereinafter referred to as “company B”), and replies to the questionnaire by the company A, the burner unit door fell to the deck by the breakage of the burner unit door locking mechanism and its hinge, secondary air nozzle was blown off and bent, therefore a part of burnt boiler suit was sticking to the secondary air nozzle.

*⁶ "Forced Draft Fan" refers to a equipment for supplying combustion air into a furnace in a boiler.

Auxiliary boiler

Fallen the burner unit door



Photo 2.3-1 Burner unit door

Stuck a part of boiler suit



Photo 2.3-2 Secondary air nozzle damage condition

2.4 Crew Information

(1) Gender, Age, and Certificate of Competence

(i) Master

Male, 45 years old, national of the Republic of the Philippines

Endorsement attesting the recognition of certificate under STCW regulation I/10: Master (issued by Japan)

Date of Issue: February 26, 2016

(Valid until December 11, 2019)

(ii) Chief engineer

Male, 56 years old, national of the Republic of the Philippines

Endorsement attesting the recognition of certificate under STCW regulation I/10: Chief engineer (issued by Japan)

Date of Issue: December 16, 2015

(Valid until March 29, 2017)

(iii) Engineer A

Male, 47 years old, national of the Republic of the Philippines

Endorsement attesting the recognition of certificate under STCW regulation I/10: Second engineer (issued by Japan)

Date of Issue: August 18, 2016

(Valid until September 18, 2017)

(iv) Oiler A

Male, 35 years old, national of the Republic of the Philippines

(2) Sea-going Experience and Status of Health

According to the statement of the chief engineer and replies to the questionnaire by the Engineer A and the Company A, their sea-going experiences and status of health were as follows.

(i) Master

The master took a position as a seaman around January, 1995, and he went aboard on vessels managed by the Company A from September, 2000. Then he

served as a master on vessels managed by the Company A from around February, 2008

He was in good health condition at the time of the accident.

(ii) Chief engineer

The chief engineer took a position as a seaman around November, 1985, and he went aboard on vessels managed by the Company A from around May, 1998. Then he served as a chief engineer on vessels managed by the Company A from around November, 2007

He was in good health condition at the time of the accident.

(iii) Engineer A

The Engineer A took a position as a seaman around February, 1994, and he went aboard on vessels managed by the Company A from around April, 1997. Then after experiencing the post of an oiler, a third engineer on pure car carriers and container vessels, he took a position as second engineer from around October, 2011.

He went aboard on the Vessel A on August 22, 2016.

He was in good health condition at the time of the accident.

(iv) Oiler A

The Oiler A took a position as a seaman and went aboard on vessels managed by the Company A on around May, 2005, and after experiencing the post of a wiper on pure car carriers, he took a position as an oiler from around May, 2007.

He went aboard on the Vessel A on August 10, 2016.

He appeared to be in good health condition at the time of the accident.

2.5 Vessel Information

2.5.1 Particulars of Vessel

Vessel number:	142550
IMO number:	9689615
Port of registry:	Kobe, Hyogo
Owner:	East River Shipping GK/C/O.
Management company:	Company A
Class	Nippon Kaiji Kyokai (Class NK)
Gross tonnage:	152,297 tons
L×B×D:	365.94 m x 51.20 m x 25.83 m
Cargo capacity	13,900 TEU
Hull material:	Steel
Engine:	Diesel engine x 1
Output:	48,900 kW
Generator engine	Diesel engine, 3,650 kW x 4
Propulsion:	5-blade fixed pitch propeller x 1
Date of launch:	June 20, 2015

(See Photo 2.5-1, Attached Figure 2 General arrangement Plan)



Photo 2.5-1 Vessel A

2.5.2 Information concerning the auxiliary boiler etc.

(1) Arrangement of the equipment around the auxiliary boiler

The auxiliary boiler was located on the third deck starboard side in the engine room composed of five decks. In addition, the fuel oil tanks were on the port side of the auxiliary boiler, the auxiliary boiler local control panel was on the aft side of the auxiliary boiler, the waste oil incinerator and the exhaust pipe of the No.3 generator engine were on the fore side of the auxiliary boiler, and the Oil Burning Apparatus was attached to the front of the auxiliary boiler. (See Figure 2.5-1)

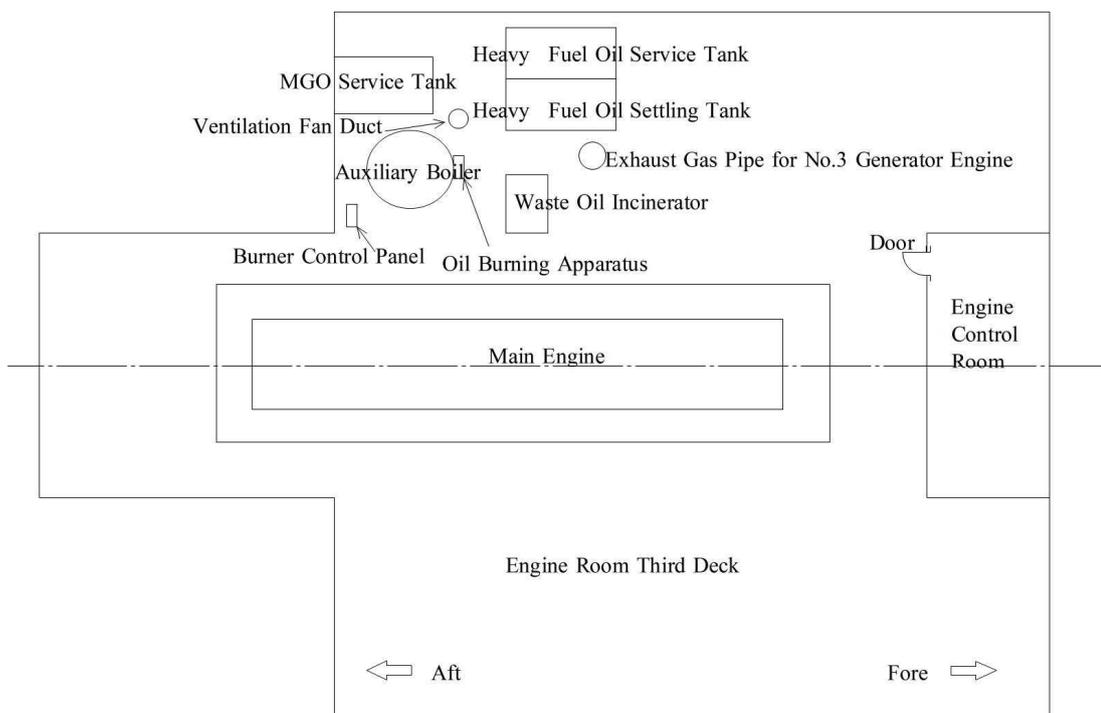


Figure 2.5-1 Engine room third deck

(2) Information of the Auxiliary Boiler

(i) Auxiliary Boiler

The auxiliary boiler was a vertical oil-fired boiler with an approved working pressure of up to 0.8 MPa and an evaporation rate of 4,000kg/hour. The auxiliary boiler fuel oil supply system enabled heavy fuel oil, MGO and fuel oil / water emulsion*7 to be burnt in the furnace. The auxiliary boiler had the rotary cup burner and the FD fan which supplied combustion air to the furnace. At the time of the accident, the auxiliary boiler used MGO for fuel oil. (See Photo 2.5-2)

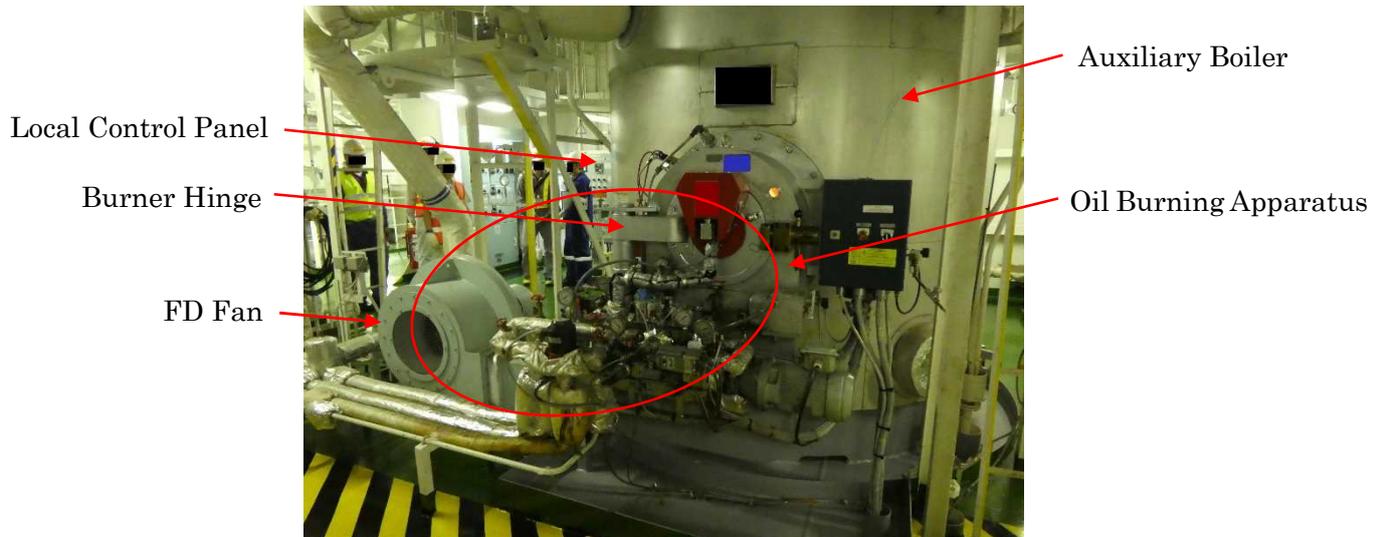


Photo 2.5-2 Auxiliary Boiler

(ii) Fuel Oil Piping

(a) Pilot Burner

MGO was supplied from the MGO service tank to the pilot burner via a pilot burner pump and pump strainer, a secondary in-line strainer, and a pilot burner solenoid valve.

(b) Rotary Cup Burner

When operating the rotary cup burner on either heavy fuel oil or MGO, the fuel oil was supplied from the respective service tank to the burner unit via a duplex strainer (hereinafter referred to as "the Strainer A"), a fuel oil pump, an oil heater, and the other strainer (hereinafter referred to as "the Strainer B"), two main solenoid valves, and a quick-closing valve.

The pressure of the fuel oil of the rotary cup burner piping was adjusted to be 0.3 MPa by the fuel oil pressure adjusting valve.

(See Figure 2.5-2)

*7 "Fuel Oil / Water Emulsion" refers to a fuel that is emulsified by mixing water with fuel, which is an effective fuel for reducing NOx and smoke.

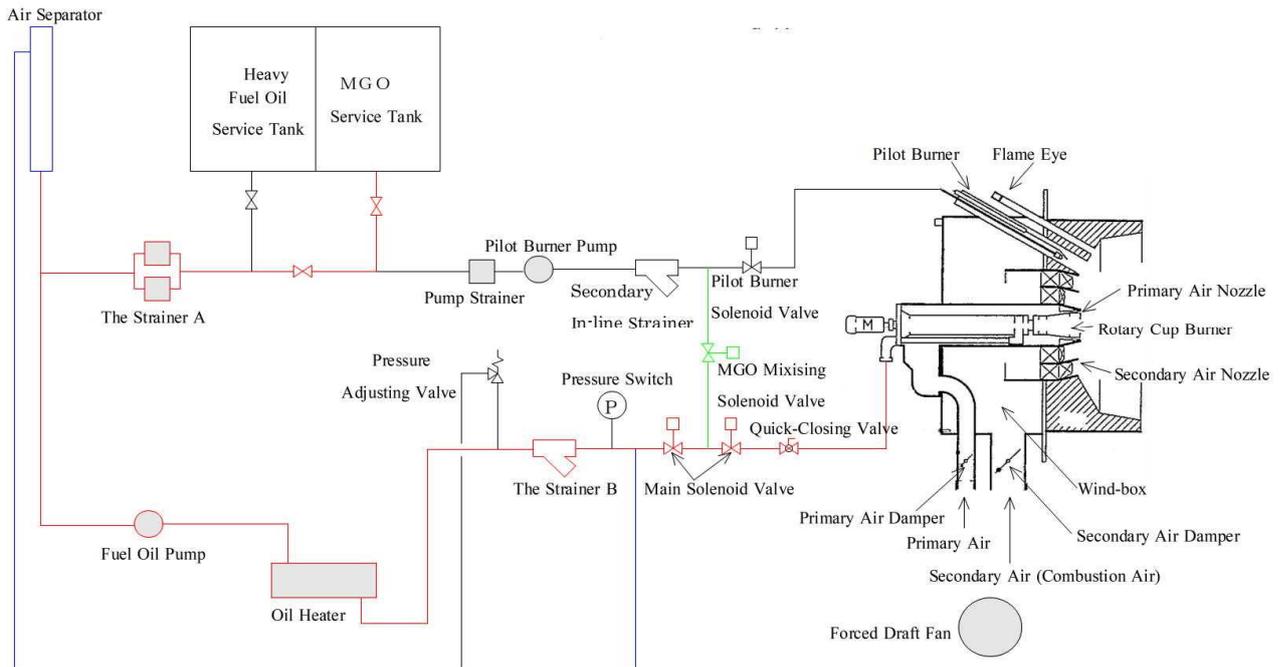


Figure 2.5-2 Fuel Oil Piping

(iii) Combustion in the auxiliary boiler

According to the statement of the person in charge at the Company B and replies to the questionnaire by the Company A and the Company B, the burner was operated essentially automatic by steam pressure. When steam pressure decreases lower than the “steam pressure low combustion start” set point (0.53 MPa), the control system initiates a “start sequence”. The pilot burner solenoid valve was opened, fuel oil was supplied to the pilot burner, and the pilot burner was fired. After a short delay, the main solenoid valve was opened and fuel oil with around 0.3 MPa was supplied to the rotary cup burner which was rotated at around maximum 6000rpm (revolution per minutes).

The fuel oil spread evenly across the inner surface of the taper by centrifugal force and was supplied to the furnace conically by the primary air through the primary air damper and the primary air nozzle surrounding the end of the cup. The combustion in the furnace was started by the fire of the pilot burner. Then, secondary air is supplied by a FD fan to the burner unit through the secondary air damper (hereinafter referred to as “the 2nd Damper”) and the secondary air nozzle. When steam pressure increases higher than the “steam pressure combustion stop” set point (0.65 MPa), the control system initiates a “stop sequence”.

The auxiliary boiler also equipped a flame eye sensor for automatic combustion control; if a flame eye sensor does not detect the flame, the supply of fuel oil is stopped.

(See Figure 2.5-3, Photo 2.5-3)

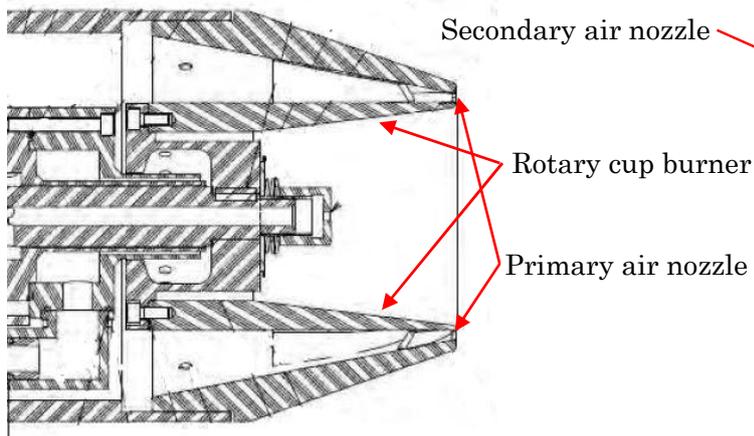


Figure 2.5-3 Rotary cup burner

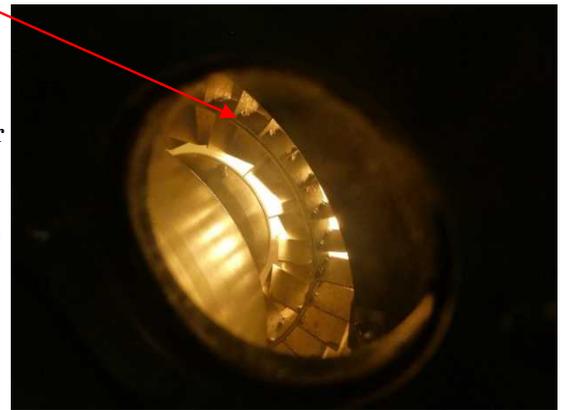


Photo 2.5-3 Combustion condition
(taken from the sight glass)

(iv) Boiler Water Piping

The Vessel was equipped with an auxiliary boiler and an exhaust gas economizer (EGE) as devices to generate steam.

The boiler water circulated through the EGE for the main engine and the EGE for the generator engine with a boiler water circulation pump for the purpose of recovering the heat possessed by the exhaust gas.

According to the reply to the questionnaire by Company A, in the Vessel, three of four generators were running at the time of the accident.

(See figure 2.5-4)

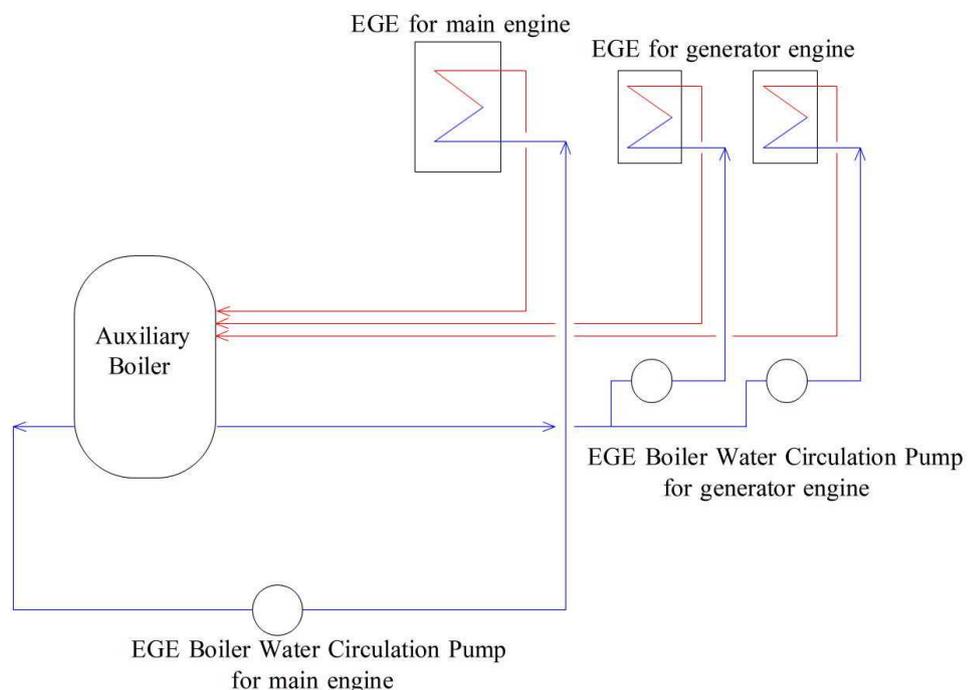


Figure 2.5-4 Boiler Water Piping for EGE

(v) Secondary Air Nozzle Equipped Condition

The secondary air nozzle was equipped to the auxiliary boiler with four screws (M6) so as to cover the burner. (See Figure 2.5-5, Photo 2.5-4)

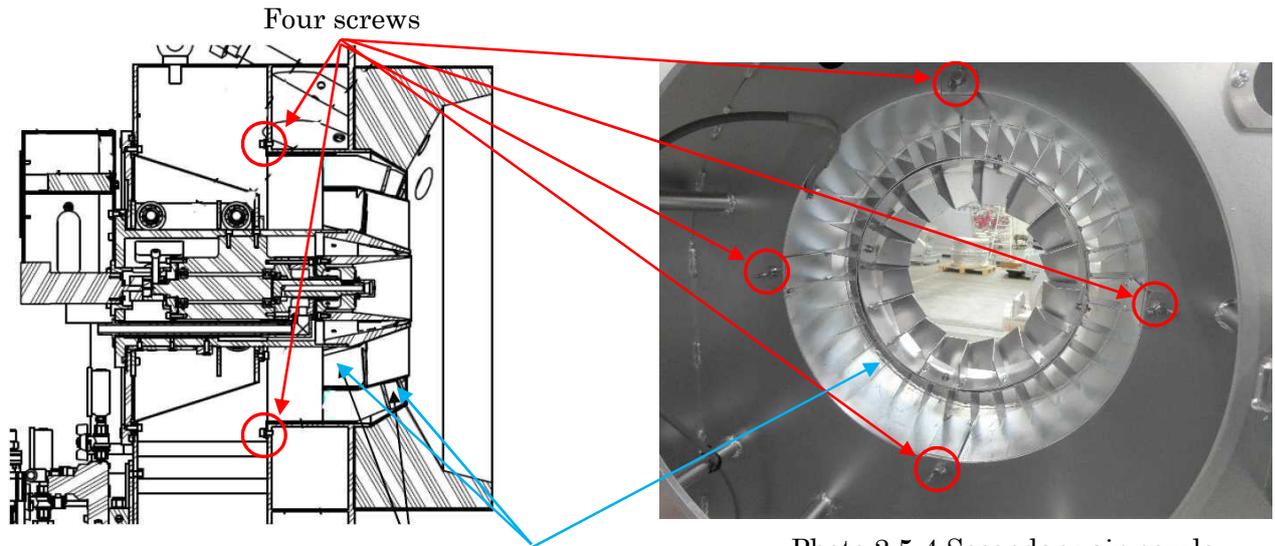


Figure 2.5-5 Cross section of Secondary air nozzle of Oil Burning Apparatus

Photo 2.5-4 Secondary air nozzle

(vi) The alarm of the Oil Burning Apparatus

According to the statements of the person in charge at the Company B and the reply to the questionnaire by the Company B, the alarm of the Oil Burning Apparatus was as follows.

Various safety devices are equipped as a safety system in the auxiliary boiler, some of which are designed to shut down fuel oil supply, and to stop a fuel oil pump and FD fan, etc.

As part of the alarm function equipped to the auxiliary boiler was as shown in the Table 2.5.

Table 2.5 Safety device

Kind of alarm	Status of Oil Burning Apparatus	System status
Furnace (Flame-Eye) Abnormal	Except during combustion and for 15 seconds after combustion finishes in pilot burner or rotary cup burner, condition of flame eye is monitored. When ember in furnaces occur, hard and soft ware order burner trip.	An auxiliary boiler emergency trip alarm sounds in the engine control room and fuel oil supply is shut down. An auxiliary boiler becomes the burner stop.
Ignition Failure	When flame eye does not detect flame after ignition over 15 seconds, hard and soft ware order burner trip.	
Flame Failure	In case flame eye is turned off when main solenoid valve is opened (during combustion), hard and soft ware order burner trip	
Burner Hinge Open	When burner hinge is opened (limit switch detects burner hinge	

	open) during combustion, hard and soft ware order burner trip.	
Wind-Box Temperature High	When thermostat in wind-box detects high temperature regardless of combustion, hard and soft ware order burner trip.	
Fuel Oil Pressure Low	When fuel oil pressure switch is turned off, control system sends out alarm signal to engine room.	

(3) Information of the Engine Room Ventilation Fan and the Outlet of the Duct of the Engine Room Ventilation Fan around the Auxiliary Boiler

According to the on-site investigations and the statement of the chief engineer, information of the engine room ventilation fan and the outlet of the duct of the engine room ventilation fan around the auxiliary boiler are as follows.

The Vessel was equipped with four engine room ventilation fans and outside air was supplied from the outlet of the engine room ventilation fans to the engine room at all time. The engine room ventilation fans adjusted air supply automatically according to the pressure in the engine room.

According to the statement of the person in charge at the Company B, when the person in charge at the Company B repaired the Oil Burning Apparatus at the port of Hamburg in Federal Republic of Germany, he felt cold air blowing around the Oil Burning Apparatus. As the outside air came from the outlet of the engine room ventilation fan at port side of the Oil Burning Apparatus, he closed its damper.

(See Photo 2.5-5)



Photo 2.5-5 Outlet of the engine room ventilation fan at port side of the Oil Burning Apparatus

2.6 Information of the Auxiliary Boiler Control Panel Alarms from 23:01 to 23:04

According to the statement of the chief engineer, the first engineer and the reply to the questionnaire by the Company A, the information of the auxiliary boiler control panel alarms from 23:01 to 23:04 were as follows.

Table 2.6 Information of the Auxiliary Boiler Control Panel Alarms from 23:01 to 23:04

Time	Engine control room alarm log	Auxiliary boiler local control panel alarm log	Status of the auxiliary boiler	Correspondence of the Engineer A
Around 23:01	Auxiliary boiler emergency trip	Furnace (Flame-Eye) Abnormal	Burner stopped FD fan stopped The 2nd Damper stopped Fuel oil pump stopped No flame in the furnace	Reset the auxiliary boiler at local control panel to clear the alarm
Around 23:01		Furnace (Flame-Eye) Abnormal	Burner stopped FD fan stopped The 2nd Damper stopped Fuel oil pump stopped No flame in the furnace No leakage of the fuel oil from the burner	Reset the auxiliary boiler at local control panel to clear the alarm
				Started the FD fan running for purge unburnt gases in the furnace
			Flame confirmed in the furnace	

				Tried to stop the FD fan in order to stop the supply of air after closing the Quick-Closing Valve to shut off the fuel oil. (An explosion occurred immediately after closing the Quick-Closing valve, so it was impossible to stop the FD fan.)
Around 23:04	Fire in Engine Room	Wind-box High Temperature Furnace (Flame-Eye) Abnormal Hinge Open	Explosion occurred in the furnace	

2.7 Information of the Condition of the Oil Burning Apparatus after Explosion

According to the statement of the person in charge at the Company B, the reply to the questionnaire by the Company B and the information from the Marine Accident Investigation Branch of United Kingdom of Great Britain and Northern Ireland (hereinafter referred to as “MAIB”), the operation test of the Oil Burning Apparatus was carried out after this accident, the results were as follows.

(1) Main Solenoid Valves

In the operation test of the solenoid valves of the fuel piping, it was recognized that one of the main solenoid valves, which was on the side of the rotary cup burner, was stuck in the open position, but another main solenoid valve was normal.

(2) Igniter with the pilot burner

As a result of the operation test of the igniter, the igniter did not spark, but replaced it with a spare igniter held by the vessel, and confirmed to spark.

(3) Rotary Cup Burner

As a result of the operation test of the rotary cup burner, the operation of the rotary cup burner was good.

According to the statement of the chief engineer and person in charge at the Company B, the reply to the questionnaire by the Company B, after this accident, the fuel piping was removed from the rotary cup burner, the fuel pump was operated, pressure was applied to the main solenoid valves, and the leak test was performed. No leak was detected from the main solenoid valve of which the operation was normal.

2.8 Information of the Maintenance History of the Auxiliary Boiler

According to the reply to the questionnaire by the Engineer A and the Company A, the maintenance history of the auxiliary boiler was as follows.

The Vessel regularly maintained the auxiliary boiler on the Planned Maintenance System (PMS) established by Company A, and the maintenance history between October and December 2016 was as follows

October 2016	Cleaned the Oil Burning Apparatus Water analysis Cleaned smoke tubes and furnace Carried out safety devices test
November 2016	Cleaned smoke tubes and furnace
December 2016	Cleaned smoke tubes and furnace Carried out safety devices test

The Vessel cleaned the fuel system strainer twice in one voyage, and just before this accident, she carried out the same cleaning on January 9, 2017.

2.9 Information of the Fuel Oil

2.9.1 Explosive Limit etc. of MGO

According to the Material Safety Data Sheet, Flash Point, Auto-ignition temperature and Explosive limit of MGO are as follows.

Flash Point	52°C Minimum
Auto-ignition temperature	257°C
Lower explosive limit	0.7%(V)
Upper explosive limit	5.0%(V)

2.9.2 Information of MGO in use at the time of the explosion

According to the statement of the chief engineer and the person in charge at the Company A, the reply to the questionnaire by the Company A, MGO in use at the time of the explosion (hereinafter referred to as "the MGO") had been supplied in the port of Rotterdam on 8 November 2016. During the bunkering process, a fuel sample was taken. The sample was then sent for analysis and the results were as follows.

Density @ 15°C	882.7 kg/m ³
Viscosity @ 40°C	5.8 mm ² /s
Viscosity @ 60°C	3.8 mm ² /s
Water	< 0.01 %v/v
Sulphur	0.10 %m/m
Pour Point	< -6 °C
Flash Point	> 70 °C

2.9.3 Information of Paraffin Wax in the MGO

(1) Trial Operation after repairing at the port of Hamburg

According to the statement of the chief engineer, the first engineer, the person in charge at the Company A and the person in charge at the Company B, the trial operation

after repairing at the port of Hamburg was as follows.

After the Oil Burning Apparatus repairing, the person in charge at the Company B tried to operate the burner with the MGO and operated the fuel oil pump at the port of Hamburg at around 22:00 January 24, 2017. It was failed by rapid drop of fuel oil pressure and reduction of fuel oil flow. Though at normal operation the fuel oil pressure should be 0.3 MPa, it was dropped just about to 0.15 MPa without warning alarm after about one minute operation.

He opened the strainer② for the confirmation of fuel oil condition, he found slimy wax-like material stuck to strainer②, which was almost clogged. After the strainer② cleaning, once again the fuel oil pump was operating and same clogging condition was occurred after one minute operation. (See Photo 2.9-1)



slimy wax-like material stuck

Photo 2.9-1 Clogging condition of strainer②

Opening the strainer②, he found same material stuck to strainer②. He opened the strainer① for the confirmation of fuel oil condition, he found same material stuck to strainer①. (See Photo 2.9-2)



slimy wax-like material stuck

Photo 2.9-2 Clogging condition of strainer①

He thought that sludge was accumulated on the bottom of MGO service tank and the oil was drained*8 but the situation was not improved. Finally, crew put the fuel additive

*8 "Oil is drained" refers to discharging moisture etc. in the FO tank.

(Cold flow improvers) and he adjusted the Pressure Adjusting Valve. Then the MGO start to be circulated. Fuel oil pressure maintained about 0.3 MPa and fuel oil flow became stable.

The Company A provided the Cold flow improvers to the management vessels (including the Vessel) sailing in the north sea of Europe and the waters of North America. At the conference with the Company A, it was said that the Cold flow improvers should be applied in MGO tank from November to April. But the chief engineer did not add the Cold flow improvers to MGOs in the past, nor was it used on the Vessel.

(2) Air temperature etc. at the time of trial operation of auxiliary boiler at the port of Hamburg

According to the reply to the questionnaire by the Company A and the Company B, air temperature at the time of trial operation of auxiliary boiler at the port of Hamburg was about 0°C and the temperature inside the wind-box where the air was supplied through the 2nd Damper by the FD fan was about 8.8°C

(3) Properties of Paraffin Wax

According to the reply to the questionnaire by the fuel oil analyze company, paraffin wax was linear hydrocarbons refined from crude oil, and generally contained 20 or more carbon as a main component. It precipitated at low temperatures, and became waxy, strainers were clog with it. (See Figure 2.9-1)

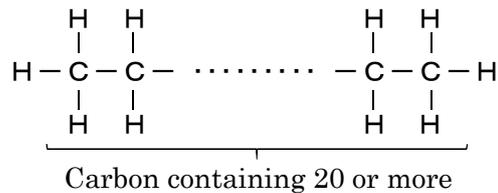


Figure 2.9-1 Paraffin wax composition diagram

(3) The MGO analysis by JTSB

JTSB inspectors took the MGO samples. These were sent to the fuel oil analyze company and were analyzed Cloud Point*⁹ (CP), Cold Filter Plugging Point*¹⁰ (CFPP), Pour Point*¹¹ (PP) and Gas Chromatography-Mass Spectrometry analysis*¹² (GC-MS analysis). In addition, these were analyzed the Cloud Point, Cold Filter Plugging Point and Pour Point when adding the Cold flow improvers which was held by the Vessel to MGO. The test results were shown as Table 2.9 and Figure 2.9-2.

Table 2.9 Test Results

	The MGO	The MGO with Cold flow improvers added

*⁹ "Cloud point" refers to the temperature at which the sample oil at the bottom of the test tube becomes hazy or begins to fog due to precipitation of paraffin wax when the sample oil is cooled without stirring.

*¹⁰ "Cold Filter Plugging point" refers to the temperature at the time when the filtration time of 20 ml of the sample oil exceeds 60 seconds, or the temperature at which the sample oil does not pass through the filter when filtering by suction through the specified wire mesh while cooling the sample oil.

*¹¹ "Pour point" refers to the lowest temperature at which the sample oil flows when the sample oil is cooled without stirring.

*¹² " Gas Chromatography-Mass Spectrometry analysis " refers to an analysis in which gases emitted from a sample oil are separated for each component and the type of the separated components is determined.

Cloud Point	19 °C	18 °C
Cold Filter Plugging Point	12 °C	5 °C
Pour Point	-10 °C	-10 °C

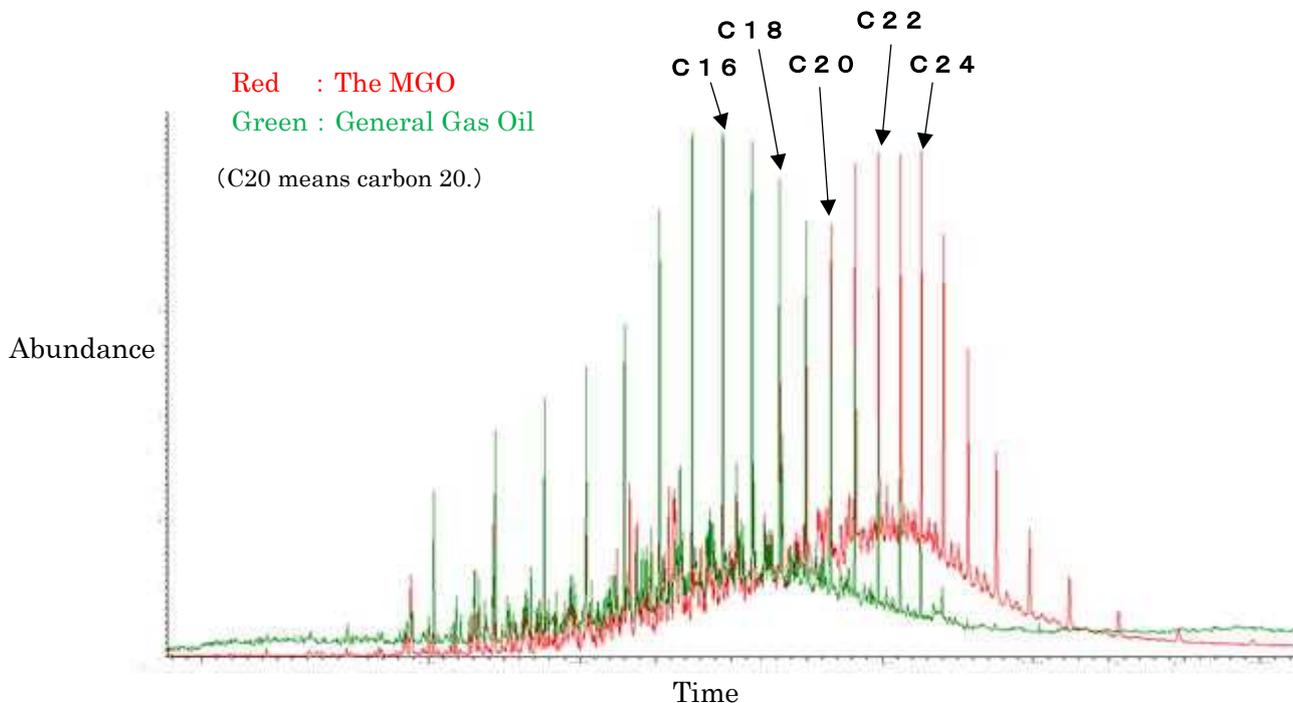


Figure 2.9-2 GC-MS analysis

(3) The MGO analysis by MAIB

According to the information from the MAIB, MAIB inspectors took fuel samples from the auxiliary boiler fuel supply line. These were sent to the analysis facility. The results were as follows.

Cold Filter Plugging Point 14°C
Pour Point -9°C

Due to dark appearance of the oil, Cloud Point result was unobtainable.

2.10 Information on Safety Management of the Company A

According to the reply to the questionnaire by the Company A, Safety Management of the Company A was as follows.

2.10.1 Safety Management System

(1) Document of Compliance

Document of Compliance was issued to the Company A under the review of the Safety Management System by NIPPON KAIJI KYOKAI and its outline was as follows.

Type of ship Other cargo ship
Date of issue 15th July 2015
Expiration date 19th January 2020
Latest annual verification 16th February 2016

(2) Safety Management Certificate

Safety Management Certificate was issued to the Vessel A under the review of the Safety Management System by NIPPON KAIJI KYOKAI and its outline was as follows.

Type of ship	Other cargo ship
Date of issue	9th March 2016
Expiration date	8th March 2021

2.10.2 Guidelines on Maintenance and Inspection of Equipment

Company A prepared the guidelines concerning the operation (i.e. maintenance and inspection. etc.) of equipment installed in vessels such as main engine, boiler, generator engine, etc., and instructed the management vessels to conduct maintenance according to the guidelines.

2.10.3 Equipment in Charge of the Engine Crew

The Company A has set up duty equipment in charge for each engineer, and has instructed each engineer to develop a maintenance plan and implement a maintenance .According to the List of Duties for Crew, the duty equipment and duties were as follows.

(1) The Engineer A

- (i) Generator engine and generator
- (ii) Auxiliary boiler and related equipment
- (iii) EGE
- (iv) Main air compressor, Auxiliary air compressor, emergency air compressor and control air compressor
- (v) Air vessel and appurtenance
- (vi) Fresh water generator
- (vii) Fuel oil transfer system, etc.

(1) The Oiler A

- (i) Engine watch-keeping at sea and in port, supporting the engineer for care and maintenance of instruments
- (ii) Bunkering operation
- (iii) Operation to incinerate waste oil and combustible refuse, cleaning operation of the engine room in general, etc.

2.10.4 Duties of the auxiliary boiler and related equipment in Crew Control and Training Manual

In the Crew Control and Training Manual, the content of the duty work, that the Engineer A should perform about the auxiliary boiler of the responsible equipment, was described as follows for the work of

- (1) To peruse the operation manual of each equipment, operate, inspect, and provide care and maintenance in accordance with this.
- (2) To conduct boiler water tests periodically, blow off boiler water*¹³, and introduce a boiler compound in order to maintain a specified level

*¹³ " Blow Off Boiler Water " refers to discharging a part of boiler water for the purpose of adjusting the concentration of boiler water.

- (3) To clean the burner and the inside of the furnace periodically.
- (4) To pay attention to smoke from the funnel,; and adjust the fuel oil pressure and quantity, and air supply as appropriate in order to maintain normal combustion.
- (5) To check periodically to see if various safety devices properly function.
- (6) To blow soot*¹⁴ periodically.

2.10.5 Maintenance of the auxiliary boiler

The Company A determines PMS for each equipment. On the Vessel, the auxiliary boiler was undertaken systematically according to PMS and the following work was done as the main maintenance

- (1) To clean the smoke tubes
- (2) To inspect and clean the rotary cup burner and the pilot burner
- (3) To replace and clean the fuel oil strainer
- (4) To conduct boiler water tests, blow off boiler water
- (5) To check the safety devices

2.11 Information of Presumption of the Cause of the Auxiliary Boiler Explosion by the Company B

According to the statement of the person in charge at the Company B and the reply to the questionnaire by the Company B, the presumption of the cause of the auxiliary boiler explosion by the Company B was as follows.

2.11.1 Mechanism at the time of the explosion

Generally, following two causes are considered for a boiler explosion.

- (1) Ignition action without ventilation of flammable gas filled in a confined space.
- (2) Backdraft occurred by a rapid chemical reaction changing carbon monoxide gas*¹⁵ in the furnace.

In other word, carbon monoxide gas filled in a confined space after abnormal fire and declining abnormal fire, was combined with large volume of oxygen, and carbon dioxide and heat occurred rapidly.

It should not be a case of above (1) because no ignition action was reported from the Vessel's engineer.

The Company B considered (2) as a factor that the auxiliary boiler exploded. Based on it, the mechanism at the time of explosion can be assumed as follows.

Emergency alarm happened due to Furnace (Flame-Eye) Abnormal alarm on 23:01 and the burner stopped on the Oil Burning Apparatus. First reset at the auxiliary boiler control panel was done by the Vessel's engineer in charge. Flame-eye missed flame for an instant and reset could be done.

Then as soon as the flame was detected again, "Furnace (Flame-Eye) Abnormal" alarmed. Second reset was done confirming the furnace condition by the Vessel's engineer in charge.

*¹⁴"Soot blow" refers to the removal of soot which adhered to the heat exchanger surface of a boiler, EGE etc. by steam, air etc.

*¹⁵"Carbon monoxide gas" refers to a highly flammable gas which is generated when incomplete combustion occurs in the state of oxygen shortage, and the explosion lower limit is 12.5% (V), the explosion upper limit is 74.55% (V).

The vessel's engineer operated FD fan to 'Manual' for purge in the furnace. After that the explosion occurred.

2.11.2 The Reason of "Furnace (Flame-Eye) Abnormal" Alarmed

One Main Solenoid Valve (rotary cup burner side) was stuck at open condition, another Main Solenoid Valve was normal under the investigation of the Oil Burning Apparatus after the accident. The person in charge at the Company B started the fuel oil pump for the leaking test and confirmed no leakage from the normal Main Solenoid Valve. Therefore, the possibility of the MGO leakage from the Main Solenoid Valve was excluded for this case.

After the Oil Burning Apparatus repair, the person in charge at the Company B tried to operate the burner with the MGO and operated the fuel oil pump at the port of Hamburg. But it was failed by rapid drop of fuel oil pressure and reduction of fuel oil flow. While at normal operation the fuel oil pressure should be 0.3 MPa, it was dropped just about to 0.15 MPa after about one minute operation. The strainer for the confirmation of oil condition was opened and was found slimy wax-like material stuck to strainer, which was almost clogged. The Cold flow improvers was added to the MGO. Then the MGO start circulating. Fuel oil pressure maintained about 0.3 MPa and the fuel oil flow became stable.

As above, the reason of Furnace (Flame-Eye) Abnormal was as follows.

- (1) The paraffin wax precipitated in the strainer and slimy wax-like material stuck to strainer at the time using the MGO, which is clogged causing the MGO flow reduction.
- (2) Under the MGO flow reduction, the primary air and the secondary air were supplied as same volume as before MGO clogging. The MGO was blown away and the atomized MGO became unevenly stable. The flame was cooled by the excess air and flame pattern was broken causing the combustion status very bad remaining unburnt MGO in the furnace. From these things, in the auxiliary boiler, the unburnt MGO remaining in the furnace was evaporated even after the automatic burning operation was completed and atomizing of MGO from the rotary cup burner ceased. Therefore flammable gas and flame remained in the furnace.

2.12 Weather and Sea Condition

2.12.1 Observations by Crew Members

According to the Vessel's logbook, the situation on January 19, 2017 was as follows.

20:00 Weather : Cloudy Wind direction : East Wind force : 4

24:00 Weather : Cloudy Wind direction : East Wind force : 4

According to the reply to the questionnaire by the Company A, air temperature and sea water temperature on 19 January 2017 were as follows.

15:00 Air temperature : 6°C Sea water temperature : 9°C

22:45 Air temperature : 6°C Sea water temperature : 4°C

2.12.2 Information from MAIB

According to the information from MAIB, at the time of the accident, the weather was cloudy, the wind direction was NNE, the wind speed was 3~4m/s, the air temperature was 4°C and the visibility was good.

3 ANALYSIS

3.1 Situation of the Accident

3.1.1 Course of the Events

As described in 2.1~2.3, it is probable that the following events occurred.

- (1) At around 14:35 on January 16, 2017, prior to the Vessel entering ECA, the Vessel changed the fuel oil supply from heavy fuel oil to the MGO.
- (2) While arriving at the port of Felixstowe, at around 16:00, all engineers and duty oiler assigned each entering harbor standby stations in engine department.
- (3) The auxiliary boiler emergency trip alarm was initiated four times from 17:30 to 19:51. When the auxiliary boiler emergency trip alarm was initiated at around 17:30, the Engineer A opened the rotary cup burner of the auxiliary boiler oil burning apparatus and cleaned the inside. For other three alarms, the other Engineer had cancelled the auxiliary boiler alarm at the auxiliary boiler local control panel and re-started the auxiliary boiler.
- (4) At 23:01, the engine control room alarm panel indicated an auxiliary boiler emergency trip alarm. The Engineer A switched the auxiliary boiler control from 'Auto' to 'Manual' to purge unburnt gases at the auxiliary boiler local control panel, then the FD fan started running. While the Engineer A was in position in starboard-fore side of the Oil Burning Apparatus and the Oiler A who was assigned his entering harbor standby station at 20:00 was in position in front of the Oil Burning Apparatus to wait for instruction from the Engineer A, the Engineer A confirmed a flame in the furnace and tried to stop the FD fan after closing the Quick-Closing Valve. However it was impossible to stop the FD fan and an explosion within the auxiliary boiler furnace occurred at around 23:04.
- (5) The Oiler A was confirmed dead and the Engineer A was transported to a medical center by a burn. The Oil Burning Apparatus was damaged.

3.1.2 Location of the Accident Occurrence

As described in 2.1, it is probable that the location of the accident occurrence was at around 2.0 M at 012° true bearing from the Dovercourt High Lighthouse.

3.1.3 Damage to the Vessel

As described in 2.3, it is probable that the burner unit door of the auxiliary boiler fell to the deck, secondary air nozzle was blown off and bent.

3.1.4 Death and Injury to Persons

As described in 2.1~2.3, it is probable that the Oiler A died of multiple injuries as it was hit by the secondary air nozzle blown off by the blast and the Engineer A burned in the right hand and right thigh because of the blast.

3.2 Causal Factors of the Accident

3.2.1 Situation of Crew Members

As described in 2.4, the situations of the crew members were as follows:

The Master, the chief engineer and the Engineer A possessed a legally valid endorsement attesting the recognition of certificate under STCW regulation 1/10.

It is probable that the Master, the chief engineer and the Engineer A were in good health at the time of the accident.

It is considered somewhat likely that the Oiler A was in good health at the time of the accident.

3.2.2 Weather Conditions

As described in 2.12, it is probable that the weather conditions at the time of the accident were as follows.

The weather was cloudy, the wind was from the NNE~east, the wind force was 4, the air temperature was 4~6°C and visibility was good.

3.2.3 Properties of MGO

As described in 2.9, it is probably that the properties of MGO were as follows.

Auto-ignition temperature of MGO was 257°C and explosive limit of it was 0.7 to 5.0%. At the time of the accident, the MGO contained a lot of paraffin wax and the Cold Filter Plugging Point was 12 to 14°C. The Cold Filter Plugging Point at the time of adding the Cold flow improvers held by the Vessel was about 5°C.

3.2.4 Analysis of Temperature around the Oil Burning Apparatus at the time of the accident

As described in 2.5.2, 2.9.3(2), 2.12 and 3.2.2, it is considered somewhat likely that the temperature around the Oil Burning Apparatus at the time of the accident was as follows.

Air temperature at the time of trial operation of auxiliary boiler at the port of Hamburg was about 0°C and the temperature inside the wind-box where the air was supplied by the FD fan was about 8.8°C.

Air temperature at the time of the accident at the port of Felixstowe was 4 to 6°C and outside air was blowing downward through the engine room ventilation fan's outlet which was mounted on the ceiling on the port side of the Oil Burning Apparatus.

From these things, the temperature around the Oil Burning Apparatus was estimated to be about 12 to 15 °C, which was the temperature below the Cold Filter Plugging Point of the MGO

3.2.5 Analysis of the MGO remained in the furnace

As described in 2.5.2(2), 2.5.2(3), 2.7, 2.9, 2.11 and 3.2.4, analysis of the MGO remained in the furnace was as follows.

(1) The situation during the combustion of the auxiliary boiler

(i) Clogging of strainer① and strainer②

It is probably that when the Vessel used the MGO containing a large amount of paraffin wax, the temperature around the Oil Burning Apparatus fell to the Cold Filter Plugging Point of the MGO and the paraffin wax precipitated in the strainer① and/or the strainer②. Then the strainer① and/or the strainer② clogged.

(ii) Malfunction of the Pressure Adjusting Valve

In the trial operation after repairing at the port of Hamburg, the Cold flow improver was added and further the Pressure Adjusting Valve was adjusted, then the fuel oil pressure did not drop. So while using the MGO, it is considered somewhat likely that slimy wax-like material stuck to strainer, Pressure Adjusting Valve malfunctioned due to the influence of the precipitated paraffin wax, the MGO pressure dropped and the MGO to the rotary cup burner flow reduced.

(iii) The MGO atomizing from the rotary cup burner

It is considered somewhat likely that under the primary air and the secondary air is supplied as same volume as before MGO clogging, slimy wax-like material stuck to the strainer of MGO line or Pressure Adjusting Valve malfunctioned due to the influence of the precipitated paraffin wax, which is clogged causing the MGO to the rotary cup burner flow reduction and unevenly stable of the MGO atomizing.

(iv) Combustion condition of rotary cup burner

It is considered somewhat likely that in the Vessel, slimy wax-like material stuck to strainer etc. at the time of using the MGO, which is clogged causing the MGO pressure drop. However, as the MGO pressure did not drop to fuel oil low pressure alarm set point, automatic combustion continued to burn. The MGO was blown away and the atomizing MGO became unevenly stable. The flame was cooled by the excess air and flame pattern was broken causing the combustion status very bad and remaining unburnt MGO in the furnace.

(2) The situation after automatically stopped of the combustion of the auxiliary boiler

(i) Analysis on existence of MGO leakage from the Main Solenoid Valve

It is probably that one Main Solenoid Valve (rotary cup burner side) was stuck at open condition, another Main Solenoid Valve was normal under the investigation of the Oil Burning Apparatus after the accident. The person in charge at the Company B started the fuel oil pump for the leaking test and confirmed no leakage from the normal Main Solenoid Valve. Therefore, the possibility of the MGO leakage from the Main Solenoid Valve was excluded for this case.

(ii) Occurrence situation of the alarm of Furnace (Flame-Eye) Abnormal

The alarm of Furnace (Flame-Eye) Abnormal is activated when flame eye detects flame except during combustion and for 15 seconds after combustion finished in pilot burner or rotary cup burner.

It is considered somewhat likely that the alarm of Furnace (Flame-Eye) Abnormal that was activated at 23:01 was as follows.

After the combustion of the rotary cup burner stopped automatically, although the MGO was not supplied to the rotary cup burner, unburned MGO remaining in the furnace during automatic combustion continued to burn. From these things, when 15 seconds or more passed after automatically stopped of the combustion, the flame eye detected a flame in the furnace and the alarm was activated.

3.2.6 Analysis on the auxiliary boiler reset work of the Engineer A

As described in 2.5 and 2.6, it is probably that the auxiliary boiler reset work of the Engineer A was as follows.

(1) The alarm of auxiliary boiler emergency trip was activated due to Furnace (Flame-Eye) Abnormal alarm on 23:01. First reset at the auxiliary boiler control panel was done by the Engineer A. After that, Furnace (Flame-Eye) Abnormal alarm was activated again. From this, flame eye missed flame for an instant and reset could be done. Then as soon as the flame was detected again, "Furnace (Flame-Eye) Abnormal" alarmed.

(2) As second Furnace (Flame-Eye) Abnormal alarm was activated, the Engineer A inspected the Oil Burning Apparatus, and found burner stopped, FD fan stopped, the 2nd Damper stopped fuel oil pump stopped, no flame in the furnace and no leakage of fuel oil from the burner.

(3) Since the FD fan stopped, the 2nd Damper was closed and secondary air was not supplied, the Engineer A started the FD fan for purge in the furnace.

(4) The Engineer A inspected the inside of the furnace after starting the FD fan, found a flame in the furnace and immediately closed the Quick-Closing valve, but an explosion occurred immediately after.

3.2.7 Analysis on the occurrence of explosion in the furnace

As described in 2.6, 2.9, 2.11 and 3.2.5, it is considered somewhat likely that the occurrence of explosion in the furnace was as follows.

After automatic combustion of the rotary cup burner was stopped, unburned MGO remaining in the furnace during automatic combustion vaporized, became a flammable gas and continued to burn. Then Furnace (Flame-Eye) Abnormal alarm was activated, FD fan stopped, the 2nd Damper was closed and combustion air was not supplied. As a result, the flame which became incompletely combustion and flammable carbon monoxide gas or flammable gas of the MGO became present in the furnace.

In the auxiliary boiler, for the purpose of the purge in the furnace, the FD fan was operated and the secondary air was supplied and the explosion occurred by a rapid chemical reaction changing heated carbon monoxide gas.

Or in the situation where MGO existed as a highly concentrated flammable gas in the high temperature furnace, the FD fan was operated and secondary air was supplied, then the flammable gas was mixed with air, the concentration was between the upper limit and lower limit concerning the explosion. As a result, the explosion occurred.

3.2.8 Analysis of the Accident Occurrence

As described in 2.1, 2.5.2(2), 2.9 and 3.2.3 to 3.2.7, the analysis of the accident was as follows:

(1) It is probably that prior to the Vessel entering ECA, the Vessel changed the fuel oil supply from heavy fuel oil to the MGO which contained a lot of paraffin wax and the Cold Filter Plugging Point of it was high.

(2) It is considered somewhat likely that when the Vessel used the MGO containing a large amount of paraffin wax, the temperature around the Oil Burning Apparatus was below the Cold Filter Plugging Point of the MGO and the paraffin wax precipitated in the strainer during automatic combustion.

(3) It is probably that in the Vessel, slimy wax-like material stuck to strainer or Pressure

Adjusting Valve malfunctioned due to the influence of the precipitated paraffin wax at the time of using the MGO, which is clogged causing the MGO pressure drop. However, as the MGO pressure did not drop to fuel oil low pressure alarm set point, automatic combustion continued to burn.

(4) It is considered somewhat likely that under the primary air and the secondary air was supplied as same volume as before MGO clogging, the MGO pressure dropped and the MGO to the rotary cup burner flow reduced. Then the MGO was blown away and the atomizing MGO became unevenly stable. The flame was cooled by the excess air and flame pattern was broken causing the combustion status very bad remaining unburnt MGO in the furnace.

(5) It is probably that after the steam pressure reached the set pressure and the combustion of the rotary cup burner stopped automatically, unburned MGO remaining in the furnace during automatic combustion continued to burn, the flame eye detected a flame in the furnace, the alarm was activated. Then the Engineer A and the Oiler A carried out reset work of the auxiliary boiler.

(6) It is probably that first reset at the auxiliary boiler control panel was done by the Engineer A. After that, flame eye missed flame for an instant and reset could be done. Then as soon as the flame was detected fire again in the furnace, second Furnace (Flame-Eye) Abnormal alarm was activated. The Engineer A inspected the Oil Burning Apparatus, and found burner stopped, FD fan stopped, the 2nd Damper stopped fuel oil pump stopped, no flame in the furnace and no leakage of fuel oil from the burner.

(7) It is probably that since the FD fan stopped, the 2nd Damper was closed, secondary air was not supplied, the flame which became incompletely combustion, flammable carbon monoxide gas and flammable gas of the MGO became present in the furnace, therefore FD fan was started for purge in the furnace.

(8) It is considered somewhat likely that the Engineer A inspected the inside of the furnace after starting the FD fan, and found a flame in the furnace. After the Engineer A immediately closed the Quick-Closing valve, he tried to stop the FD fan. But the FD fan did not stop. The secondary air was supplied and the explosion occurred by a rapid chemical reaction changing heated carbon monoxide gas. Or in the situation where the MGO existed as a highly concentrated flammable gas in the high temperature furnace, the FD fan was operated and secondary air was supplied, then the flammable gas was mixed with air, the concentration was between the upper limit and lower limit concerning the explosion. As a result, the explosion occurred

(9) It is probably that in the Vessel, the burner unit door fell to the deck by the breakage of the burner unit door locking mechanism and its hinge, secondary air nozzle was blown off and bent

(10) The Oiler A died as it was hit by the secondary air nozzle blown off by the blast, and the Engineer A burned because of the blast.

4 PROBABLE CAUSES

It is probably that the accident occurred, in the night time, while the Vessel was docking at the port of Felixstowe, UK, an explosion occurred within the furnace of the auxiliary boiler.

It is considered somewhat likely that explosion occurred in the furnace is because under existence of carbon monoxide gases heated by incomplete combustion and flames in the furnace, the Engineer A operated the FD fan and the secondary air was supplied. The explosion occurred by a rapid chemical reaction changing heated carbon monoxide gas. Or in the situation where MGO existed as a highly concentrated flammable gas in the high temperature furnace, the FD fan was operated and secondary air was supplied, then the flammable gas was mixed with air, the concentration was between the upper limit and lower limit concerning the explosion. As a result, the explosion occurred.

It is probably that the Engineer A operated the FD fan for the purge in the furnace.

It is probably that the existence of the MGO a highly concentrated flammable gas was as follows. Under slimy wax-like material stuck to strainer etc., which was clogged causing the MGO pressure drop but the MGO pressure did not drop to fuel oil low pressure alarm set point, the MGO to the rotary cup burner flow reduced. The primary air and the secondary air was supplied as same volume as before MGO clogging, the MGO was blown away and the atomizing MGO became unevenly stable. The flame was cooled by the excess air and flame pattern was broken causing the combustion status very bad and remaining unburnt MGO in the furnace and unburnt MGO vaporized.

It is probably that the carbon monoxide gases heated by incomplete combustion and flame existed in the furnace because the FD fan stopped by the Furnace (Flame-Eye) Abnormal alarm, the 2nd Damper was closed, secondary air was not supplied, and combustion continued under insufficient air quantity.

It is probably that the strainer was clogged as follows. When the Vessel used the MGO containing a large amount of paraffin wax and the Cold Filter Plugging Point of it was high, the temperature around the Oil Burning Apparatus was below the cold filter plugging point of the MGO and the paraffin wax precipitated in the strainer.

5 SAFETY ACTIONS

It is considered somewhat likely that the accident occurred as follows. In the night time, under existence of flammable gases vaporized (i.e. unburned MGOs) or carbon monoxide gases heated by incomplete combustion and flames in the furnace, the Engineer A operated the FD fan and the secondary air was supplied. Then the explosion occurred in the furnace and the Oiler A was confirmed dead and the Engineer A was transported to a medical center by a burn. The Oil Burning Apparatus was damaged.

It is probably that the existence of the MGO as highly concentrated flammable gas was as follows. Because under slimy wax-like material stuck to strainer, which was clogged causing the MGO pressure drop but the MGO pressure did not drop to fuel oil low pressure alarm set point, the MGO to the rotary cup burner flow reduced. The primary air and the secondary air

was supplied as same volume as before MGO clogging, the MGO was blown away and the atomizing MGO became unevenly stable. The flame was cooled by the excess air and flame pattern was broken causing the combustion status very bad and remaining unburnt MGO in the furnace and unburnt MGO vaporized.

Accordingly, for the purpose of preventing the reoccurrence of explosion accident as this, the Company A needs to take measures as follows for the crew on board vessels which enter the North Sea area in Europe and North Sea area in America in winter and use MGO.

(1) In winter, the Company A supplies the Cold flow improvers that reduces the Cold Filter Plugging Point of MGO, and analyze the Cloud Point, the Cold Filter Plugging Point, the Pour Point, etc. of MGO, then vessels use the Cold flow improvers as necessary, or use it for each bunkering without analyzing them.

(2) The Company A educates the crew about the risk of paraffin wax precipitation of MGO and notifies the use of the Cold flow improvers according to the instructions of the Company A.

(3) About the auxiliary boiler, the Company A notifies as follows.

(i) There is the risk of explosion in case secondary air is supplied under the existence of flammable gas or carbon monoxide gas by incomplete combustion and flame in the furnace.

(ii) There is as effective method that the secondary air damper keeps open condition.

(4) During operation of the auxiliary boiler, confirm the operation of the pressure adjusting valve and overhaul the pressure adjusting valve when the malfunction of the pressure adjusting valve is found.

5.1 Safety Actions Taken

5.1.1 Safety Actions Taken by the Company A

The Company A had no experience of explosion of the auxiliary boiler due to poor combustion when the fuel oil pressure dropped while using MGO. The Company A took the following safety actions to prevent occurrence of a similar accident after consultation with the Company B.

(1) To crew and vessels which enter the North Sea area in Europe and North Sea area in America in winter and use MGO ;

(i) The Company A educated the crew about the risk of paraffin wax precipitation of MGO and notified the use of the Cold flow improvers according to the instructions of the Company A.

(ii) About the auxiliary boiler, the Company A notified the risk of explosion in case secondary air is supplied under the existence of flammable gas in the furnace.

(2) To auxiliary boilers which are equipped with the oil burning apparatus and rotary cup burner;

(i) Flame eye was in duplicate.

(ii) The Fuel oil low pressure emergency trip set point was changed from 0.15 MPa to 0.2~0.24 MPa to detect low fuel oil pressure in an earlier stage. The pressure detection location was set after passing through the two Main Solenoid Valves and the supply pressure to the rotary cup burner was detected.

(iii) There are possibilities of backdrafts, when Furnace (Flame-Eye) Abnormal alarm is activated. To avoid this situation, highlighting alarm on the control panel was indicated for easier understandings of the Furnace (Flame-Eye) Abnormal alarm.

(iv) There are possibilities that unburned fuel oil remains in the furnace, causes incomplete combustion and carbon monoxide is generate, when the boiler stops by the emergency stop of the boiler. To avoid this situation, the secondary air damper keeps open condition and ventilation in the furnace is continued at all time.

(v) The reset could only be done when the operation switch on the auxiliary boiler control panel was at the stop position. (for both auto / manual. mode) avoiding FD fan automatically operation.

(vi) The fixing metal fittings of the burner unit door were changed to a stronger one.

(vii) Warning plate was posted about the response to the occurrence of the Furnace (Flame-Eye) Abnormal.

(viii) An "entry restricted area" was set in the front of the oil burning apparatus and painted on the floor.

(ix) During operation of the auxiliary boiler, make sure that the fuel oil pressure is operating at setting pressure. When the fluctuation of fuel oil pressure is observed at the time of changing from heavy fuel oil to MGO, adjust the fuel oil pressure by the pressure adjusting valve to setting pressure.

5.1.2 Safety Action Taken by Company B

The Company B developed and provided the following safety actions following the accidents.

(1) Strengthening the fixing metal fittings of the burner unit door

The fixing metal fittings of the burner unit door were changed to a strong one in order to lower the possibility of opening the door due to a large explosion in the furnace.

(2) Enhancement of interlock when abnormality occurs

① Progressed resetting procedure for shut-downs

The reset can be done only when the operation switch on the control panel is at the stop position. (For both auto / manual mode)

This is to prevent repeated resets of the burner operation by the crew, and to avoid unintended operation of the fan.

② Interlocks for repeated trips

When shut-downs happen several times in a certain period, the burner control panel is interlocked and the warning to the crew is indicated.

(3) Prevention of backdrafts

There are possibilities of backdrafts, when the furnace is filled with carbon monoxide gas by fire in the furnace. To avoid this situation, the following measures can be taken.

① Highlighting alarm on the control panel

New indications for easier understandings of the Furnace (Flame-Eye) Abnormal alarm.

② Automatic damper opening after burner stop

The secondary air damper opens automatically when the burner stops. This prevents carbon monoxide gas to be filled in the furnace which may cause backdrafts.

(4) Prevention of combustion failure due to fuel oil pressure and flow fluctuation

The insufficient combustion is detected at early stage by monitoring fuel oil pressure / flow in order to prevent consequent accidents.

① Fuel oil flow monitoring

Install a flow meter to detect the gap between the actual flow volume and target values preset at each combustion load. When this gap is large, an alarm will be given to stop operation.

② Fuel oil pressure monitoring

Install a pressure transmitter to alarm at point of the High / Low pressure in order to keep proper fuel oil pressure and to avoid fluctuation.

③ Fuel oil pressure switch alarm setting

Change the Fuel oil low pressure alarm point to a higher value to detect low fuel oil pressure in an earlier stage.

(5) Prevention to become semi-solid of MGO

The semi-solid MGO is clog the strainer resulting lack of fuel oil flow. In order to prevent such situation, company B took the following measures.

① MGO temperature monitoring

Install a thermos resistance bulb to set high and low temperature alarm for control of the MGO temperature.

② Detection of MGO clogging

Install two pressure transmitters to detect the fuel oil pressure difference before and after the strainer. It is able to check if the strainer is clogged by the semi-solid MGO.

③ MGO Warmer

Install the MGO warmer to warm the fuel oil inside the strainer for avoiding MGO to become semi solid. This unit is connected to the thermos resistance bulb to keep the MGO temperature between 25°C to 50°C.

(6) Smoke monitoring

Install a smoke indicator to detect white / black smoke to notice the crew when the fuel / air ratio balance is bad.

5.2 Safety Actions Required

For the purpose of preventing the reoccurrence of explosion accident as this accident, ship owner and ship management company need to take measures as follows for the crew on board a vessel which enter the North Sea area in Europe and North Sea area in America in winter and use MGO.

- (1) In winter, ship owner and ship management company supply the Cold flow improvers that reduces the Cold Filter Plugging Point and analyzing the Cloud Point, the Cold Filter Plugging Point, the Pour Point, etc. of MGO, then vessels use the Cold flow improvers as

necessary, or use it for each bunkering without analyzing them.

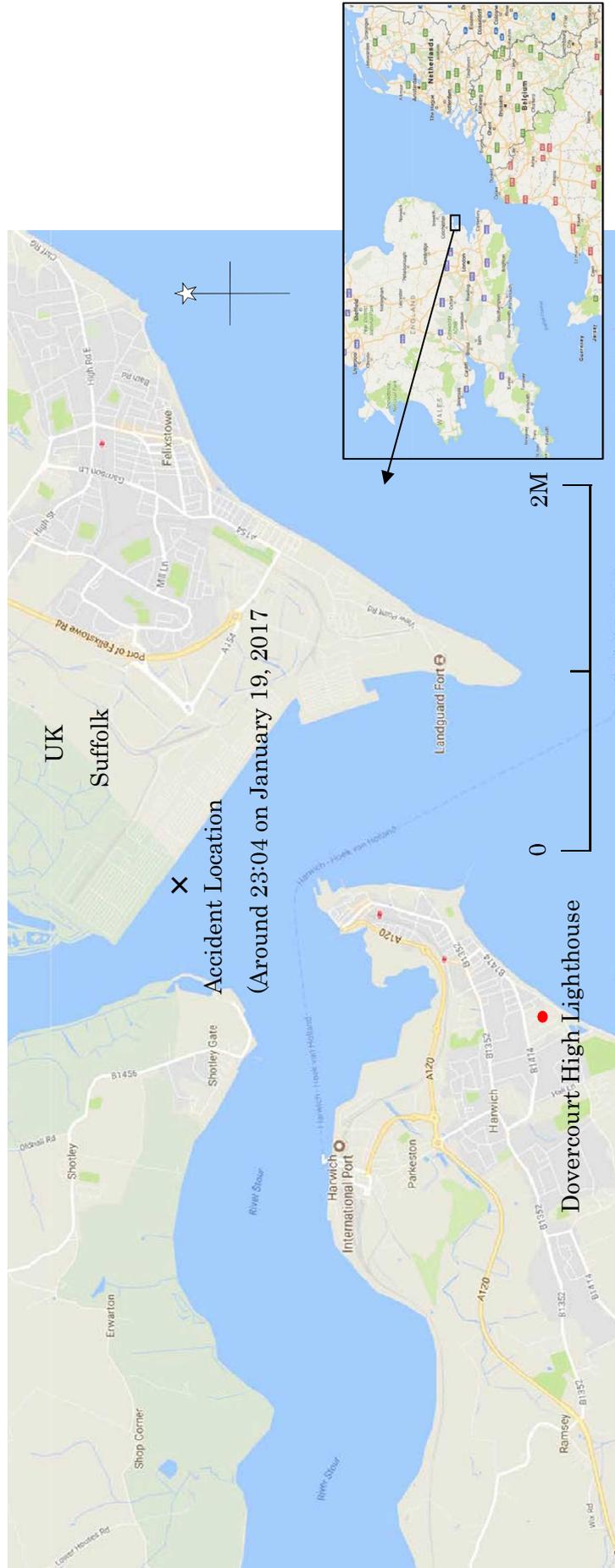
(2) Ship owner and ship management company educate the crew about the risk of paraffin wax precipitation of MGO and notify the use of the Cold flow improvers according to the instructions of the Company A.

(3) About the auxiliary boiler, ship owner and ship management company notify as follows.

(i) There is the risk of explosion in case secondary air is supplied under the existence of flammable gas or carbon monoxide gas by incomplete combustion and flame in the furnace.

(ii) There is as effective method that the secondary air damper keeps open condition.

Attached Figure 1 Outline Map of the Location of the Accident Events



Attached Figure 2 General Arrangement Plan

