Marine Safety Investigation Unit

Transport Malta

MARINE SAFETY INVESTIGATION REPORT

Safety investigation into the engine-room fire on board the Maltese registered oil / chemical tanker

GRETA K

within Leixões port limits

on 21 March 2023

202303/015

MARINE SAFETY INVESTIGATION REPORT NO. 04/2024

FINAL

Investigations into marine casualties are conducted under the provisions of the Merchant Shipping (Accident and Incident Safety Investigation) Regulations, 2011 and therefore in accordance with Regulation XI-I/6 of the International Convention for the Safety of Life at Sea (SOLAS), and Directive 2009/18/EC of the European Parliament and of the Council of 23 April 2009, establishing the fundamental principles governing the investigation of accidents in the maritime transport sector and amending Council Directive 1999/35/EC and Directive 2002/59/EC of the European Parliament and of the Council.

This safety investigation report is not written, in terms of content and style, with litigation in mind and pursuant to Regulation 13(7) of the Merchant Shipping (Accident and Incident Safety Investigation) Regulations, 2011, shall be inadmissible in any judicial proceedings whose purpose or one of whose purposes is to attribute or apportion liability or blame, unless, under prescribed conditions, a Court determines otherwise.

The objective of this safety investigation report is precautionary and seeks to avoid a repeat occurrence through an understanding of the events of 21 March 2023. Its sole purpose is confined to the promulgation of safety lessons and therefore may be misleading if used for other purposes.

The findings of the safety investigation are not binding on any party and the conclusions reached and recommendations made shall in no case create a presumption of liability (criminal and/or civil) or blame. It should be therefore noted that the content of this safety investigation report does not constitute legal advice in any way and should not be construed as such.

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Voyage Data Recorder – *Greta K*

GLOSSARY OF TERMS AND ABBREVIATIONS

AB	Able seafarer – deck
Auto ignition temperature	The minimum temperature at which a substance in air must be heated to initiate or cause self-sustaining combustion, independent of the heating source.
CCTV	Closed-circuit television
CO_2	Carbon dioxide
CPP	Controllable pitch propeller
DPA	Designated person ashore
ECR	Engine control room
ER	Engine-room
ETA	Estimated time of arrival
GT	Gross tonnage
IACS	International Association of Classification Societies
ISM Code	The International Safety Management Code
kW	Kilowatt
LED	Light emitting diode
LT	Local time
m	Metres
MARINA	Maritime Industry Authority of the Philippines
MDO	Marine diesel oil
MRCC	Maritime Rescue Coordination Centre
MSIU	Marine Safety Investigation Unit
N	North
nm	Nautical miles
OOW	Navigational officer of the watch
PA	Public address
QCVs	Quick-closing valves
RINA	Registro Italiano Navale
RPM	Revolutions per minute
SMS	Safety management system
SOLAS	The International Convention for the Safety of Life at Sea, 1974, as amended
STCW	The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, as amended
ULSD	Ultra-low sulphur diesel
UMS	Unattended machinery space
UTC	Universal time coordinated
VDR	Voyage data recorder

VHF	Very high frequency
W	West

SUMMARY

At about 1542 (LT) on 20 March 2023, *Greta K* departed Sines, Portugal, loaded with a cargo of oil products, bound for Leixões, Portugal, with an ETA of 1500 on 21 March 2023.

Soon after picking up the pilot for Leixões, and as the vessel was about to enter the port, a fire was detected in the engine-room at around 1518 on 21 March 2023. The engine control room was vacated, the quick-closing valves (QCVs) were activated, and the engine-room fire dampers were closed. After all the crew members were accounted for, the vessel's fixed, carbon dioxide (CO_2) fire extinguishing system was released at 1530, with the crew members boundary cooling the area.

At about 1537, tugboat *Tetris* arrived on the scene and started boundary cooling of the casing around the funnel. At 1544, the CO_2 pressure was reported to read zero, confirming the discharge of the bank of CO_2 cylinders. Tugboat *Prometeu* was made fast forward at 1600, to prevent the vessel from drifting ashore. The vessel was towed away to seaward and by 2103, all crew members were disembarked due to safety concerns.

Despite the port authorities' efforts to extinguish the fire, the fire fighting continued up to 27 March, until salvors appointed by the Company declared that the fire was extinct at 1345. On 28 March, the vessel was berthed at 1730, with the assistance of three tugboats.

Greta K was subsequently towed to Genoa, Italy, where the necessary repairs were completed, and brought back into service towards the end of April 2024.

The safety investigation concluded that the cause of the fire was likely to have been initiated by a marine diesel oil (MDO) pipe flange failure. Consequently, a spray of pressurised fuel came in contact with the main engine's turbocharger unshielded exhaust pipe, whilst the main engine was in operation.

Taking into consideration the safety actions already taken by the Company, three recommendations have been issued by the MSIU, addressing fire safety in the engine-room.

1 FACTUAL INFORMATION

1.1 Vessel, Voyage and Marine Casualty Particulars

Name	*Greta K*
Flag	Malta
Classification Society	Registro Italiano Navale (RINA)
IMO Number	9800374
Type	Oil / Chemical Tanker (Type 2)
Registered Owner	Officine Meccaniche Navali E Fonderie San Giorgio Del Porto S.p.A.
Managers	K-Ships S.r.l., Italy
Construction	Steel (Double hull)
Length overall	159.34 m
Registered Length	151.98 m
Gross Tonnage	16,408
Minimum Safe Manning	14
Authorised Cargo	Liquids in bulk
Port of Departure	Sines, Portugal
Port of Arrival	Leixões, Portugal
Type of Voyage	International
Cargo Information	Jet A-1: 4,945.816 mt; and Ultra-low sulphur diesel (ULSD):13,462.017 mt
Manning	19
Date and Time	21 March 2023, at 15:18 (LT)
Type of Marine Casualty	Serious Marine Casualty
Place on Board	Engine-room (lower deck, portside)
Injuries / Fatalities	None
Damage / Environmental Impact	Extensive damage to the engine-room / None
Ship Operation	Normal Service – In passage
Voyage Segment	Arrival
External & Internal Environment	Daylight, good visibility, Northwesterly moderate breeze, and a low, Northerly swell
Persons on Board	19 crew members and one pilot

1.2 Description of Vessel

Greta K (**Figure 1**) was built by Officine Meccaniche Navali San Giorgio Del Porto S.p.A. Shipyard in Genoa, Italy, and delivered in 2016. As a Type 2 oil / chemical tanker, it was primarily designed to carry oils and chemicals in accordance with the International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk. The vessel was managed by K-Ships S.R.L. (the Company), based in Genoa. *Greta K* was registered in Malta and classed by Registro Italiano Navale (RINA).

The vessel had a length overall of 159.34 m, and a moulded breadth of 26.00 m. At a summer draft of 7.90 m, it had a deadweight of 19,875.5 mt. *Greta K*'s drafts at the time of the fire were 7.90 m (even keel).

Figure 1: MV *Greta K*

1.2.1 The machinery space and vessel's propulsion

Greta K was fitted with a MAK 8M43C eight-cylinder, four-stroke, medium speed, marine diesel engine, producing 8,000 kW at 500 rpm. The propulsion diesel engine drove a four-bladed right-hand controllable pitch propeller (CPP), through a reduction gear box (155 rpm) and an intermediate and a propeller shaft. The propulsion shaft penetrated the aft engine-room bulkhead and ran through the stern tube. The vessel reached an estimated maximum speed of 15.0 knots. The vessel was also fitted with a bow and stern thruster, each rated at 650 kW.

The engine-room boundaries are highlighted in red, in **Figure 2**.

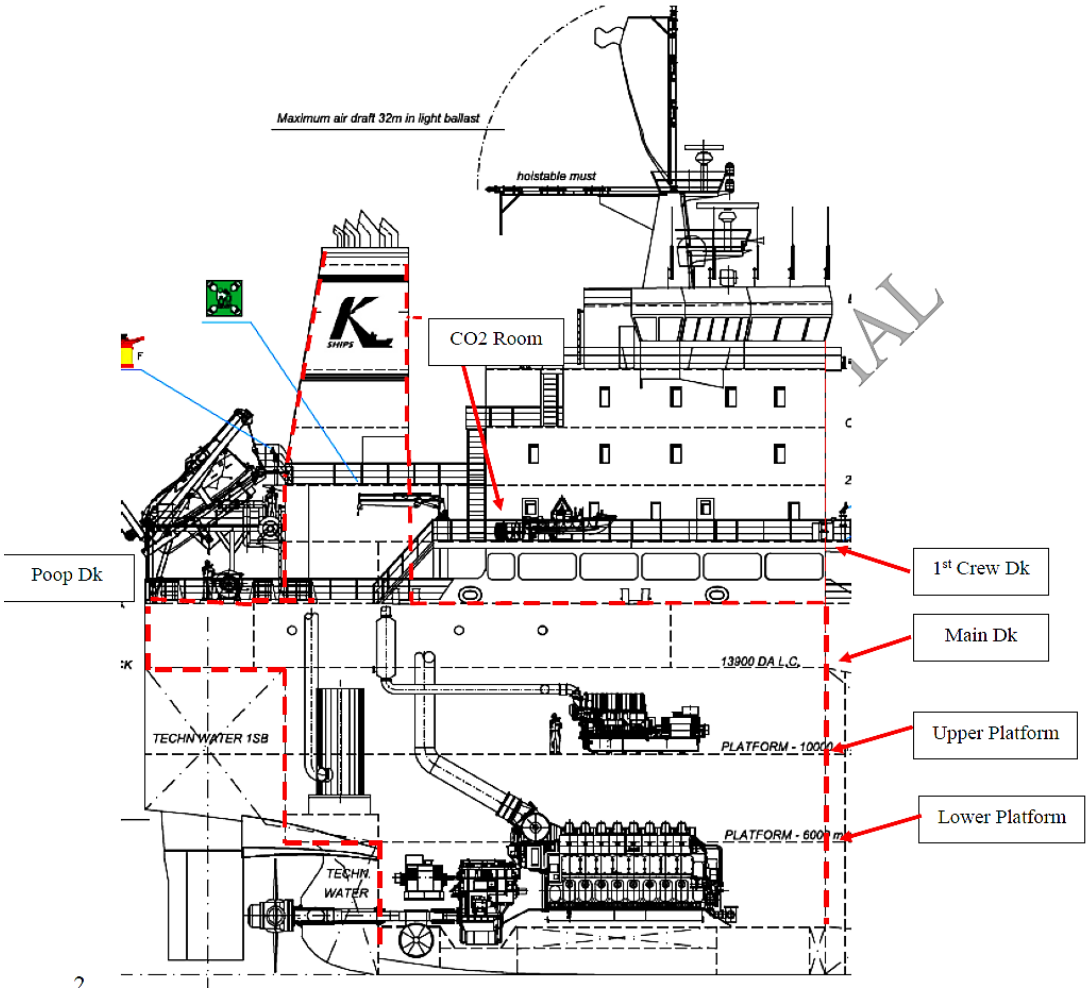

Figure 2: Engine-room layout below the main deck

The engine control room (ECR) was located on the main deck level, port side, (Error! R eference source not found.**3**).

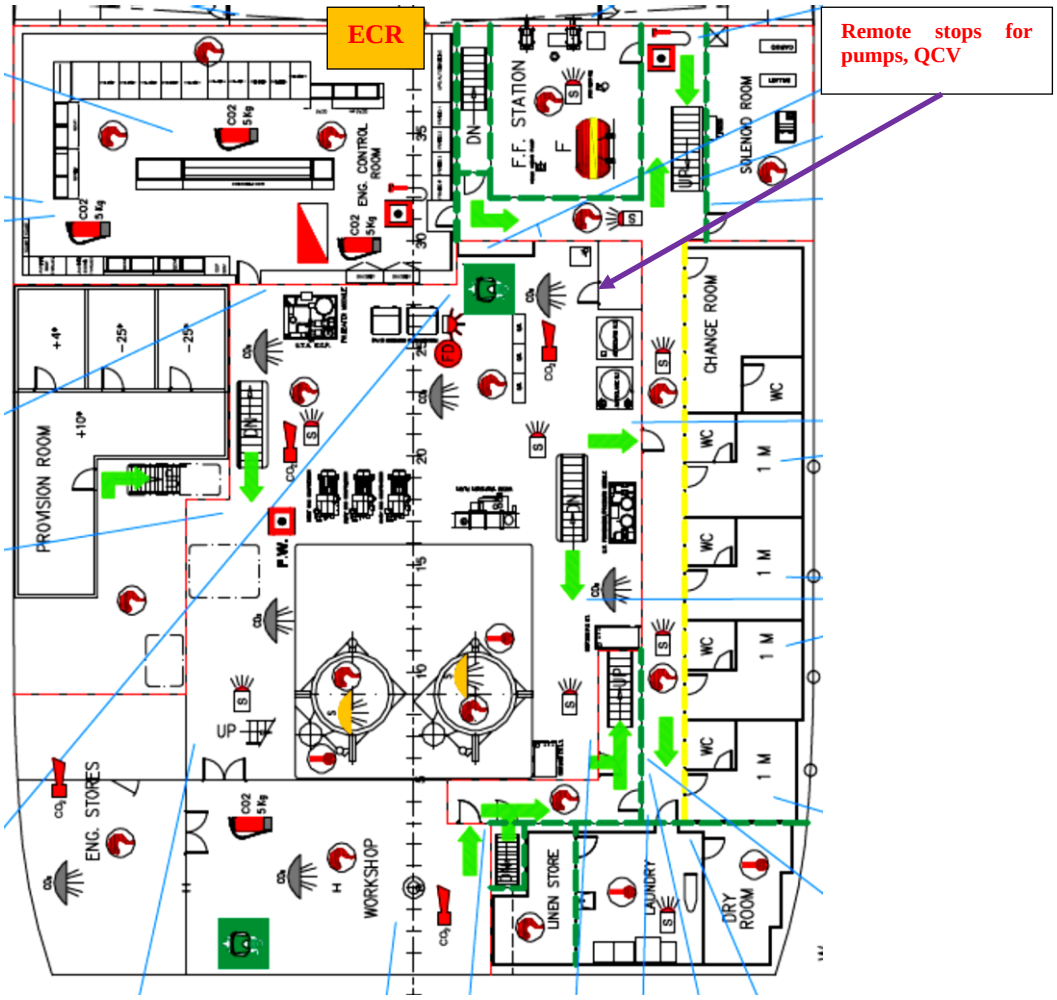

Figure 3: Layout on the engine room on the main deck level

A closed-circuit television (CCTV) camera system had been installed in 2016. The system was configured to record and display live images from seven locations, with cameras located at the:

- diesel generators' platform;
- boiler;
- aft mooring deck;
- forward mooring deck;
- main engine (facing aft);
- purifier room; and
- the ECR.

The system was also connected to two remote displays located on the bridge and inside the cargo control room.

There were four access doors, in total, to the engine-room from the accommodation. Two access doors from the starboard alleyway and the ECR were located on the main deck. There were two further access doors, one from a stairwell located forward, leading into the upper platform, and the other on the first crew deck from the aft athwartship alleyway into the funnel casing (**Figures 4** and **5**).

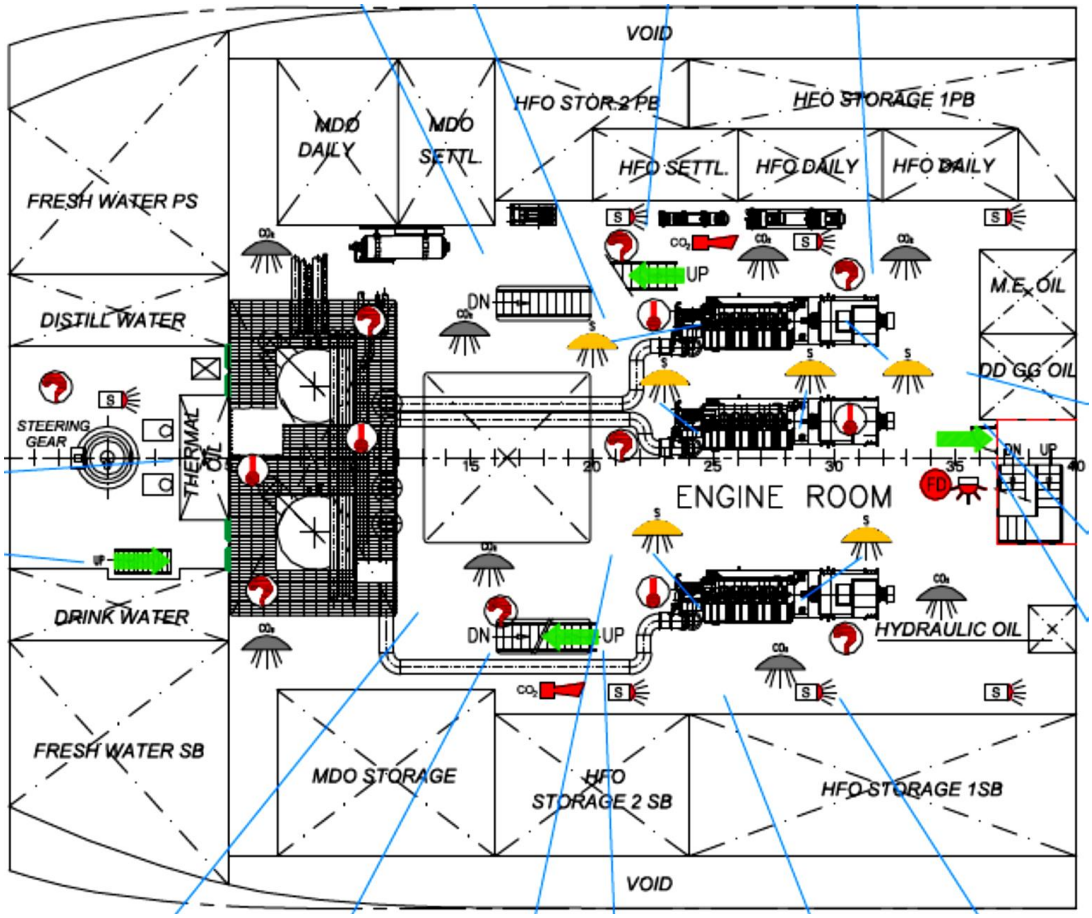

Figure 4: Engine-room upper platform layout

The vessel's funnel was fitted at the second crew deck and was provided with an access on the port side, at frame no. 13. Funnel casings extending upwards provided space for the exhaust outlets from the main engine, the auxiliary boiler, the diesel generators, and the incinerator.

Engine-room ventilation was supplied by two fans located on the navigation deck, ducted down to the engine-room through ventilation trunks. The main engine and

diesel generators' exhaust trunks extended up through the engine-room casing on the appropriate side, to emerge separately at the funnel top along with the incinerator and the boilers' flue uptakes. All the air outlets and inlets were protected by louvre-type fire dampers that were operated automatically.

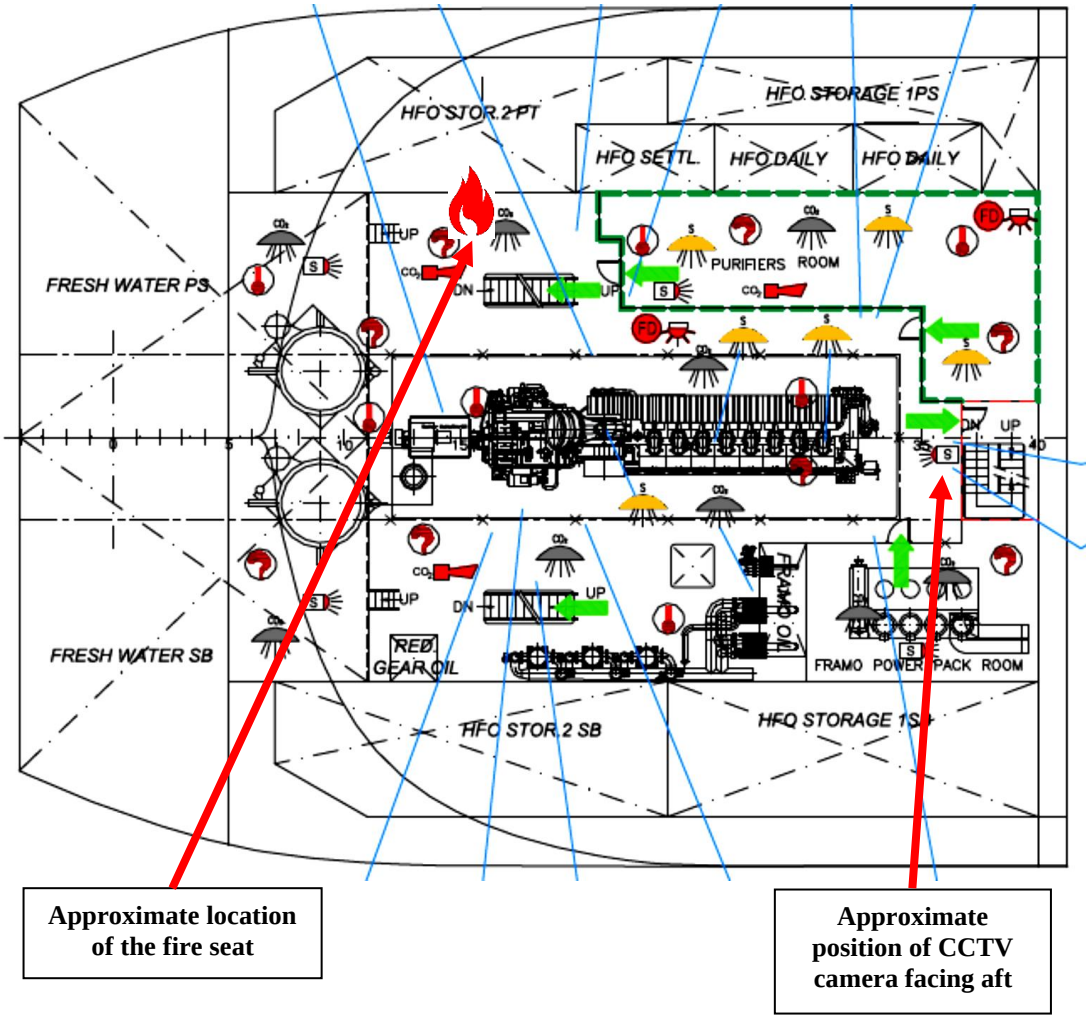

Figure 5: Engine-room lower platform layout

1.2.2 Fire detection and extinguishing system

The fire detection system within the engine-room was fitted with a comprehensive system of smoke and heat detectors, and manual call points located throughout the engine-room and accommodation spaces. The system comprised of six loops covering all the necessary locations on board the vessel, with loop no. 1 covering the engine-room. The system's central alarm panel was located on the bridge (**Figure 6**), which was manned continuously at sea. A repeater panel for the fire detection system was also located in the ECR.

Figure 6: Central fire alarm panel located on the bridge

From these positions, it was possible for crew members to identify the location of any activated loop or zone from the panel. The fire detection system could hold a permanent record of all the generated alarms, retrieved from an in-built memory. Through LED and internal buzzers, it provided audio and visual indicators, if a fire was detected.

The engine-room was protected by a fixed, CO_2 fire extinguishing system and hyper-mist system. The CO_2 room was located on the first crew deck (starboard side), forward of the engine-room casing (**Figure 2**).

The system consisted of the following number of cylinders:

- 82 * 45 kg main engine-room, including purifier room;
- 2 * 45 kg inert gas room; and
- 2 * 45 kg emergency generator room.

The system was last inspected by shore contractors on 05 July 2022, and was regularly tested by the vessel's crew members.

The fuel oil service tanks were all fitted with quick-closing valves (QCV), operated from a cabinet outside the ECR (**Figure 7**). When activated, these valves closed instantly, and cut off the fuel oil supply to the engines and other machinery.

Figure 7: QCV cabinet located outside the ECR

1.2.3 Hyper-mist fire extinguishing system

A hyper-mist fire extinguishing system (local application) was also fitted to protect various sections of the engine-room. On *Greta K*, the system worked through a piping system fitted with a specially designed nozzle to vaporise the water that was pumped at a high pressure, creating a water mist on demand to areas that were

protected. The system[1] covered the main engine, auxiliary engines, purifier room, incinerator, and the boiler space.

The system comprised of a freshwater storage tank, a high-pressure pump, and a local control panel located in the steering gear compartment. The system on board could be operated either manually and / or automatically. Automatic activation was triggered by the remote sensors in the presence of a fire. Alternatively, manual activation points were located in the fire station, either by using local panels within the respective spaces, or operating the valves manually from within the steering gear compartment that was located outside the engine-room (**Annex 1**).

The hyper-mist fire extinguishing system was designed to provide a continuous supply of water for 20 minutes from the time of activation. The design limited the fire fighting to one compartment only. According to the vessel's records, the hyper-mist system was tested on three-monthly cycles and had last been tested successfully on 19 March 2023. The test was limited to the operation of the main control valves (open and close positions).

1.3 Crew

At sea, the engine-room was operated in the unattended machinery space (UMS) mode. However, as the vessel approached port and about to pick up a pilot to berth, procedures stipulated that the engine-room was required to be manned by the chief engineer, duty engineer (third assistant engineer) and a rating.

At the time of the fire, the following crew members were reported to have been present in the engine-room:

- chief engineer (out-going);
- chief engineer (in-coming);
- second engineer;
- third assistant engineer; and

[1] A hyper-mist system extinguishes / controls the fire by displacing oxygen, using hyper-mist to achieve radiant heat attenuation. The exceptional cooling effect of hyper-mist is a result of converting the water into fine droplets, which increases the total surface area available to absorb heat and maximises the evaporation rate of the water. The process of evaporation takes the heat away from the flame and fire plume. The expanding water vapour displaces normal air and reduces the amount of oxygen in the vicinity of the fire.

- wiper (assisting with the watch).

The bridge was manned by the master, the chief mate, and an able seafarer – deck (AB) who was steering the vessel manually.

All personnel were found to be duly certified in accordance with the relevant requirements of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, as amended (STCW). The total number of crew members was 19, exceeding the minimum number stipulated on the Minimum Safe Manning Certificate (14), issued by the flag State Administration on 16 July 2021. All crew members were Filipino nationals.

1.3.1 Chief engineer (out-going)

The chief engineer was 41 years old, with about 12 months of experience in his rank and had been with the Company for about seven years. He had joined the vessel on 07 September 2021. His certificate of competency (STCW III/2 – 3,000 kW or more), was issued in 2021 by the Maritime Industry Authority of the Philippines (MARINA).

1.3.2 Chief engineer (in-coming)

The in-coming chief engineer was 37 years old. He had just joined the Company, and this was his first appointment as a chief engineer. He had embarked at the vessel's last port of call (Sines) on 19 March 2023. His certificate of competency (STCW III/2 – 3,000 kW or more) was issued in 2023 by MARINA.

1.3.3 Second engineer

The second engineer was 32 years old, with about 9 years of seagoing experience in different ranks, including six months as second engineer. This was his first appointment with the Company. He had joined the vessel on 07 February 2023. His certificate of competency (STCW III/2 – 3,000 kW or more), for a chief engineer, was issued in 2022 by MARINA.

1.3.4 Third assistant engineer

The third assistant engineer was 28 years old. It was his first contract with the Company, and he had been on board the vessel for about 5.5 months. He had joined the vessel on 12 October 2022. His certificate of competency for an officer in charge of an engineering watch (STCW III/1) was issued in 2022 by MARINA.

1.4 Safety Management System

Greta K complied with the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code). The vessel's Safety Management Certificate was issued by RINA on 04 February 2022, and was valid until 10 February 2027. The last external audit (ISM Renewal) was carried out on 01 February 2022 and found the vessel's Safety Management System (SMS) in compliance with the requirements of the ISM Code.

The vessel's last, annual internal audit was carried out on 22 May 2022 by the vessel's designated person ashore (DPA). The audit raised two non-conformities.

The Company was issued with a Document of Compliance (DOC) by RINA on 11 January 2022 and the first annual verification of the DOC had been completed on 14 November 2022. The Company was certified to operate chemical and oil tankers.

1.5 Environment

The vessel's records indicated that at the time of the occurrence, it was daylight and visibility was good. A moderate breeze was blowing from the Northwest. The swell was from the North, with a height of about 1.0 m to 1.5 m.

1.6 Narrative[2]

1.6.1 Events leading up to the fire and muster

At about 1542 on 20 March 2023, *Greta K* departed Sines with 4,944.329 mt of Jet A-1 and 13,464.654 mt of ULSD, bound for Leixões. The vessel's ETA at Leixões pilot boarding ground was about 1500 on 21 March.

On 21 March, at 1330, a one-hour notice was communicated to the engine-room to prepare for arrival. By 1455, the vessel's engines were tested ahead and astern, and the bow thruster, navigational and bridge equipment were also tested and found satisfactory. The pilot boarded at 1509 in position 41° 08.0' N 008° 43.3' W. Shortly afterwards, the master and the pilot completed the master / pilot information

[2] Unless otherwise stated, all times are local (LT = UTC).

exchange, and the vessel headed towards the breakwater, where it was expected to make fast tugs to assist with the berthing.

At about 1518[3], the master heard the pre-warning alarm on the fire alarm panel and asked the chief mate to call the ECR to clarify the nature of the alarm. The chief engineer picked up the telephone and confirmed that there was a fire in the engine-room but did not give a location. The message was relayed to the master, who informed the pilot of the matter. At the same time, the fire alarm was activated, and an announcement was made on the public address (PA) system. The vessel's position was about two nautical miles from the breakwater (**Figure 8**) and the approach into port was aborted.

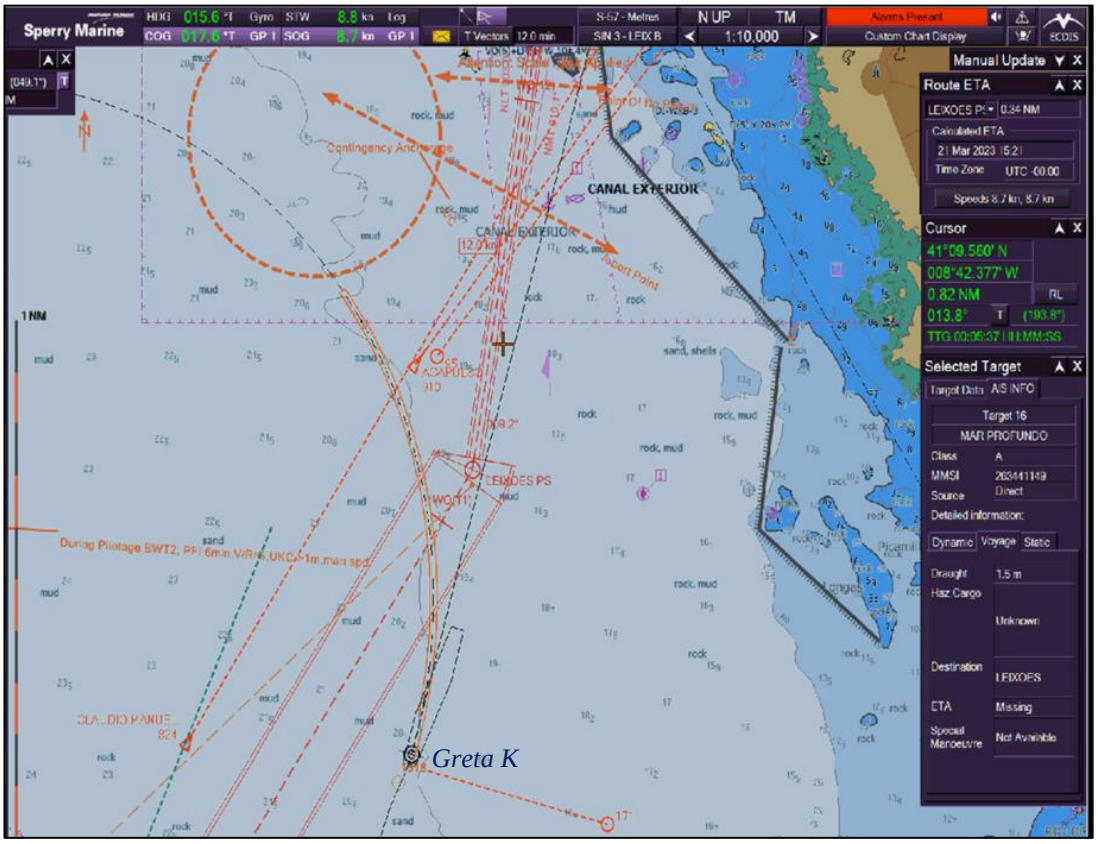

Figure 8: Screenshot from *Greta K*'s ECDIS showing its position when the fire broke out

The chief engineer, the third assistant engineer and the electrician remained in the ECR, whereas the rest of the crew members vacated the engine-room. The chief mate proceeded to the poop deck to muster the crew members, having been relieved of his duties on the bridge by the second mate to assist the master. After completion of the

[3] The voyage data recorder (VDR) indicated that the fire alarm activated at 15:18:57.

muster, two crew members donned fire suits and breathing apparatus to enter the engine-room, as soon as instructed. The remaining crew members assisted with preparations for boundary cooling. By 1524, a distress alert was broadcast by the vessel, and the pilot advised the port control on the nature of the emergency.

1.6.2 Emergency response

On activation of the pre-warning alarm, the chief engineer and other crew members looked at the CCTV monitor to briefly observe flames, captured on the engine-room camera only. Within seconds, however, the view captured by the engine-room camera was obscured by smoke and the crew members were unable to determine the origin of the flames.

The second engineer tried to enter the engine-room but was beaten back by the smoke, which entered the ECR quickly. The non-essential engineers abandoned the ECR to muster on deck and on their way out, tripped all the QCVs and pressed the emergency fuel pump shut-down buttons to stop the flow of fuel from the fuel tanks in the engine-room. The engine-room's ventilation and fire dampers were also closed to starve the fire of oxygen.

The chief engineer, along with the electrician and the third assistant engineer, stopped the main engine and started the emergency fire pump. Other crew members started boundary cooling of the engine-room, but the decision to send a team equipped with fire suits and BA sets into the engine-room to investigate and fight the fire, was aborted due to the thick smoke.

Within a few minutes, at about 1526, the main electrical power was lost due to the closing of the QCVs, and the fuel pumps' emergency shut down. The emergency generator started automatically, to provide emergency electrical power. The chief engineer then vacated the ECR and in consultation with the master, decided to activate the CO_2 system. By 1529, all the crew members were accounted for and on confirmation that all vents, exits and entrances to the space were shut, the CO_2 was released at 1530. The Company was informed of the emergency at 1533.

1.6.3 Post fire events

At about 1537, tugboat *Tetris* arrived on scene and started boundary cooling of the funnel casing. At 1544, the CO_2 pressure was reported to read zero, confirming discharge of the bank of CO_2 cylinders. Tugboat *Prometeu* was made fast forward at 1600 to assist the vessel from not drifting ashore.

At about 1649, the port's rescue boat was alerted to deploy on scene in case any assistance would be required. The master also established contact with the maritime rescue coordination centre (MRCC) of Lisbon, and it was decided that Leixões Port Control would act as the coordinator in this emergency. The pilot disembarked from the vessel at 1700 and at 1702, the Port Control instructed that the vessel is towed about 2.0 nm seawards from her current position.

At about 1709, 12 crew members were disembarked for safety reasons, on to the port rescue craft. The persons remaining on board were the master, the two chief engineers, the chief mate, the second mate, the bosun and the pumpman. Soon afterwards, at about 1718[4], the emergency generator stopped working as a result of seawater from the tugboat's boundary cooling, flooding the compartment.

Tugboat *Prometeu*'s position was adjusted at 1746 and made fast on the port side main deck so that the anchor remained clear to let go. A third tugboat, *Doris*, joined the firefighting efforts and was made fast on the starboard bow at 1920. At 1958, concerned about their safety, the increase in smoke inside the accommodation block and the bridge, and the loss of emergency power, the master requested that he and the remaining crew members be disembarked from the vessel. At about 2103, the remaining crew members disembarked from the vessel. The master, along with the chief engineer and second mate, transferred on to tugboat *Doris* so that they could assist the firefighting efforts remotely.

On 22 March, at about 0830, a naval vessel arrived on scene and requested the transfer of the master, the chief engineer and the second officer. On board the naval vessel, the firefighting team discussed the situation on board and with the permission

[4] This time is based on the VDR record when the power mode changed from the main power supply to the battery.

of the Company, boarded *Greta K* at about 1629 to assess the situation together with the master, the chief engineer and the second officer.

On 23 March, tugboat *Achilles* arrived on scene and was made fast aft. The crew members also assisted with replacing tugboat *Tetris*' line with the vessel's emergency towing system.

On 24 March, at 1031, the master, the chief engineer and four naval firefighters boarded the vessel. The naval team located the area of the fire to be in the lower and upper platforms and attempted to extinguish it using portable fire extinguishers. The attempt was unsuccessful and on completion, the crew members were landed ashore.

On 25 March at 1506, six crew members, including the master and two firefighters from a salvage organisation appointed by the Company, boarded the vessel for their initial assessment. They cast off tugboat *Doris* and made fast tugboat *Castelo Obidos* forward. Tugboat *Achilles*, located aft, was also released at 1837. The master transferred to tugboat *Castelo Obidos* to assist the operations. The other crew members returned ashore.

The salvors continued to fight the fire on 26 and 27 March, and finally declared the fire to be extinguished at 1345 on 27 March.

On 28 March, following an assessment of the condition of the vessel at 1128, the authorities permitted the vessel to berth. At about 1336, with the assistance of three additional tugboats along and two pilots, the vessel was towed to the designated berth, where it was made fast alongside at 1730.

After its cargo was unloaded, *Greta K* was subsequently towed to San Giorgio del Porto Shipyard in Genoa, Italy, where she arrived on 02 May 2023 and underwent extensive repairs. It re-entered service towards the end of April 2024.

1.6.4 Damage to the engine-room and post fire survey

The engine-room sustained extensive fire damage, bar the purifier room and the ECR, where the damage was limited to either smoke or heat. The accommodation stores and cabins located above the engine-room remained intact but sustained a degree of

heat and / or smoke damage. **Figures 9** to **14** catalogue the extent of fire damage in the engine-room.

Figure 9: Auxiliary engine (port side)

Figure 10: Main engine view forward

Figure 11: Auxiliary engine (starboard side)

Figure 12: Staircase to the lower platforms

Figure 13: Cargo control room

Figure 14: ECR

2 ANALYSIS

2.1 Purpose

The purpose of a marine safety investigation is to determine the circumstances and safety factors of the accident as a basis for making recommendations, to prevent further marine casualties or incidents from occurring in the future.

2.2 Limitations of the Safety Investigation

When the MSIU boarded the vessel in Leixões, the vessel's source of electrical power was from the emergency generator. Due to the fire damage, there was no lighting in the accommodation and machinery spaces, and the inspection of the machinery spaces was carried out in complete darkness, with the aid of a handheld torch light. The photographs taken for the purpose of the safety investigation were therefore not of an optimal quality.

The ECR was fitted with an alarm printer for the machinery spaces. When the various engine-room alarms were compared with the events recorded on the VDR, the safety investigation concluded that the timings on the alarm log printout were about five minutes and 16 seconds slower than the VDR timings.

The Company attempted to retrieve the saved CCTV data that could have assisted the safety investigation in understanding better the cause and source of the fire. However, only the data from the ECR could be saved in a format that allowed it to be replayed, albeit without any time stamps.

The vessel's fire detection system control panel on the bridge was not fitted with a printer, and no data could be recovered by the manufacturer from the equipment to establish the time and sequence of the fire detectors' activation. However, the VDR recorded some limited information, which is discussed further below.

2.3 Fatigue and Alcohol

Analysis of the hours of work records showed that they were not in excess of those required by the STCW and the Maritime Labour Convention, 2006 (as amended). The safety investigation was unable to determine the quality of the crew members' rest, however, in the absence of any evidence that would indicate otherwise, fatigue was not considered a contributing factor to this accident.

Alcohol tests were not carried out as most of the crew were landed ashore due to safety concerns. However, the crew members' actions did not suggest that alcohol was a contributing factor to this accident.

2.4 Timing and Seat of the Fire

Since the vessel's fire detection system was not fitted with a printer, the exact time of the first fire detector's activation could not be ascertained. Moreover, the manufacturers could not extract data from the equipment due to the damage caused to the equipment during the fire. However, the VDR replay indicated that the fire alarm was activated at 15:18:57, in line with the pre-alarm heard in the bridge audio (**Figure 15**).

The VDR records of the fire detection system indicated the first two sections to pre-alarm were:

- Loop 01.048 – H U. Lower deck main; and
- Loop 01.047 – H U. Lower deck main (this section immediately alarmed within one second).

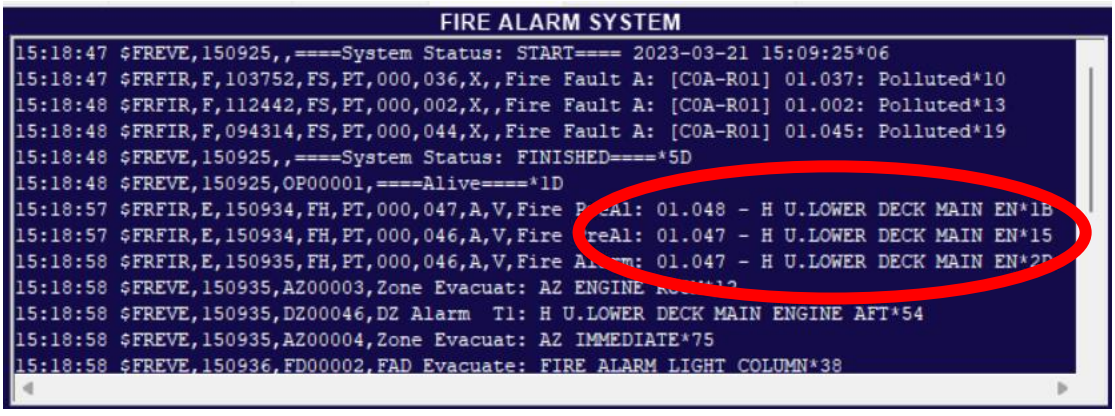

Figure 15: Record of fire detection alarm captured on the VDR

The next detector to alarm was 01.036, followed by 01.038. **Table 1** lists the location of fire detectors in Loop 1 of the system.

Table 1: List of loop detectors that activated

Loop	Location	Detector type
1.036	Lower deck main engine fwd stbd	Smoke
1.038	Lower deck fwd stbd	Heat
1.047	Lower deck main engine aft	Heat
1.048	Lower deck main engine fwd port	Heat

It can be concluded that the fire started in the region where detectors 1.047 and 1.048 were fitted, which was the port side of the main engine lower deck. This was also in line with the recollection of the engine-room crew members who briefly saw the flames on the port side in the CCTV, when the fire alarm activated[5].

2.5 When did the Fire Actually Start?

The fact that the flames were visible on the CCTV for a few seconds before the area in the engine-room became engulfed in black smoke, suggested that the fire had started prior to the fire alarm's activation.

Considering that the seat of the fire was in the engine-room around the main engine's turbocharger exhaust gas turbine (at lower platform level), one would have expected the smoke and heat detectors located above the lower platform around the engine-room and those above the main engine, to initially detect smoke and then the heat, to set off the fire alarm.

The review of the ECR CCTV indicated that after an alarm was heard by those in the ECR, two crew members attempted to leave the ECR to enter the machinery space but as soon as they opened the ECR door, thick smoke entered the ECR from the engine-room and forced them to close the door and leave the ECR through a door leading into the accommodation.

[5] This is further discussed in Section 2.5 of this safety investigation report.

According to the chief engineer's recollection of the events, the alarm that was heard in the ECR was the fire alarm. Considering that the seat of the fire was around the lower platform and the ECR was located two decks higher on the main deck, it meant that heat and smoke detectors in the engine-room failed to detect either the heat or the smoke when the fire was being developed. Noting that fire detectors are very sensitive and detect heat / smoke almost immediately, the safety investigation was concerned on the functionality of the fire detection system in the engine-room prior to the start of the fire.

Based on VDR records, at least three detectors (**Table 2**) were faulty since 18 March 2023[6] (**Figure 16**).

Table 2: The three detectors recorded as faulty based on VDR records

Loop	Location	Detector type
1.037	Lower deck Framo room	Smoke
1.002	2nd crew deck casing	Smoke
1.045	Lower deck aft port	Smoke

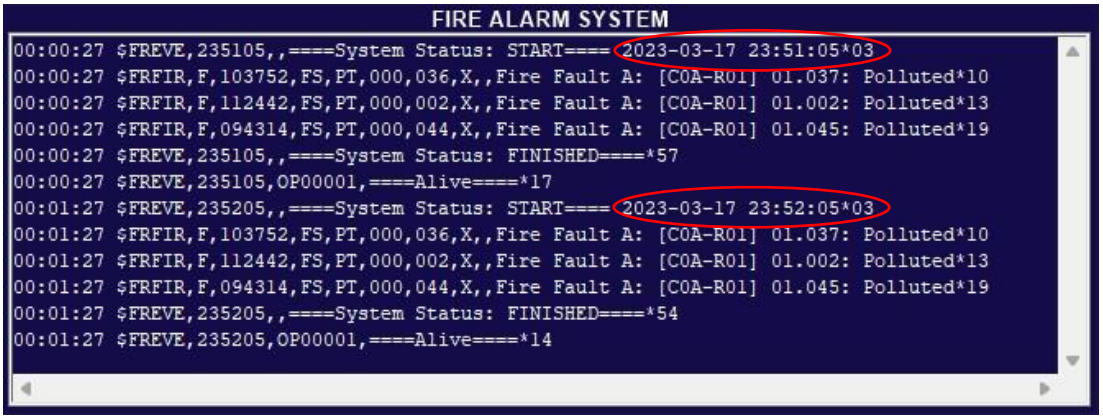

Figure 16: Screengrab showing fire alarm system faults

The safety investigation was of the view that the smoke detector located in the area (1.045) should have triggered the fire alarm first, but the VDR records indicated that it was faulty.

[6] The records of the weekly test on 19 March indicated that the tests returned satisfactory results.

As mentioned above, the safety investigation established that there was a time delay of about 5.27 minutes between the VDR timings and the engine-room alarm log printout. An analysis of the engine room-alarms using the adjusted timings, indicated the following relevant alarms prior to the discovery of the fire:

121041: M/E EXH GAS TEMP TC OUT	HIGH ALARM	15:15:18
121082: M/E EXH GAS TEMP SLD	LOW ALARM	15:15:40
150007: ER LOC APPLICATION FAIL	ALARM	15:19:06
M/E OIL MIST CONC. IN CRANKCASE	ALARM	15:19:32

Using the adjusted timings, the engine-room's alarm log indicated that the main engine turbocharger's outlet high temperature alarm activated at 15:15:18, *i.e.*, approximately 3.65 minutes before the fire alarm was triggered, and which the safety investigation believed to be as a result of the fire. This led the safety investigation to conclude that the fire had started at least three minutes, before the first fire alarm had been activated.

2.6 Cause of the Fire

Fire experts on board suggested that the cause of the fire appeared to be related to the MDO pipe's flanged connection failure, which allowed MDO to spray onto the main engine's exhaust gas turbine. A small unshielded section, where the turbocharger connected to the exhaust manifold, ignited the MDO as it reached its auto-ignition temperature. This observation was based on the loose nut and bolt found on the MDO pipe's flange during the post fire survey and the direction of fuel spray seen on and around the main engine's turbocharger exhaust gas turbine.

According to the engine-room alarm log, after lunch, the third engineer was busy transferring MDO from the MDO storage tanks on the starboard side of the upper platform to the MDO settling tank on the same platform but on the port side. The third engineer later used the MDO purifier to purify and fill the daily MDO tank, taking suction from the MDO settling tank.

Noting that the MDO purifier failure (*i.e.*, manual stoppage) alarm activated at 1430 due to a high level alarm on the MDO service tank, the safety investigation did not

expect that either the MDO transfer pump or the MDO purifier lines to be pressurised beyond 1430. While the likelihood of an MDO leakage in spray form under static head from either the MDO service or the settling tank filling pipes was very low, accident data indicated a spray of fuel emanating from height, and from the direction of the pipeline, onto the unshielded section of the exhaust pipe on the main engine's exhaust gas turbine.

Although the MDO service tank's oil level was high at 3.80 m (*i.e.,* 90% of the tank's capacity), it was below the tank's overflow pipe level. An MDO service tank overflows into the settling tank as it is normally filled from the settling tank via the separator / purifier. Since the tank's oil filling line was situated above the overflow pipe, the likelihood of the tank's content returning through the filling line was nil.

Nevertheless, the failed MDO pipe flange, mentioned above, was located under the engine room's upper platform on the port side. Although no reported recent work had been undertaken in the vicinity of the pipework since the vessel's last dry dock in 2021, it was considered likely that the nut became loose over time, even as a result of vibration. Due to the intensity of the fire, it was also not possible to establish, whether the flanged unions had been fitted with anti-spray tape or not, although other flanges that were not affected by the fire were noted to be covered with intact anti-spray tape.

Figure 17 shows the main engine's turbocharger from below, on the aft portside of the main engine. The red arrow shows the location of the gap in the exhaust pipe's insulation and the yellow arrow shows the oil droplets residue on the engine's casing. The unaffected paint below the turbocharger casing indicated that the oil spray came from above and port side of the engine. Therefore, in the absence of any accident data, which indicates otherwise, the fire was considered likely to have been caused by fuel spraying on to a hot surface, that had a temperature which exceeded 220 °C.

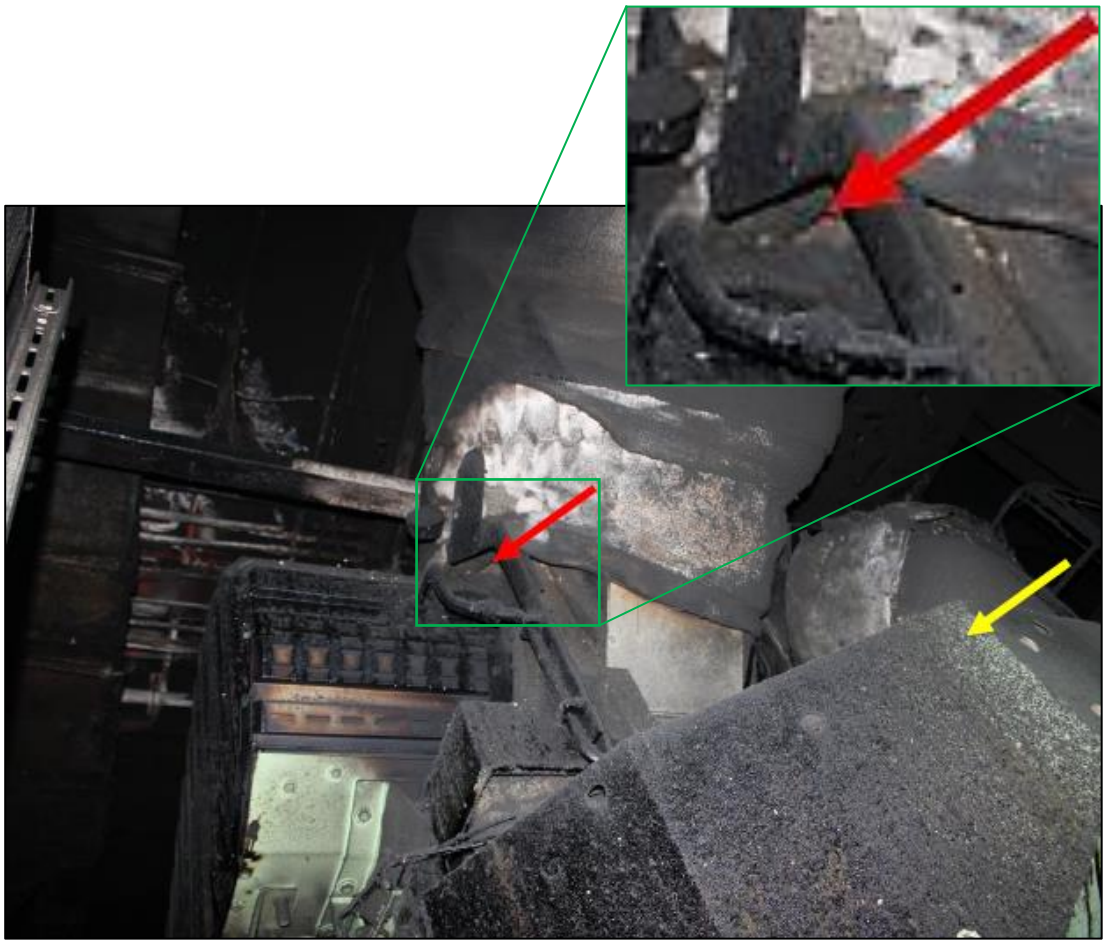

Figure 17: Main engine turbocharger on the aft portside with oil spray residues

Source: The Company

2.7 Ventilation Damper

The fire could not be extinguished until 27 March, despite the rapid response by the crew members to stop the ingress of fresh air into the engine room, the tripping of all the QCVs, and the release of the fixed CO_2 firefighting system.

During the examination of the engine-room's ventilation dampers on the engine casing (in way of first crew deck – **Figure 18**), the lower damper was found to be fully closed; however, the upper damper was found in the partially opened position with the louvres bent inwards and deformed due to mechanical damage. The lowest louvre was also noted to be hanging on one pivot (**Figure 19**).

Figure 18: Lowest louvre covered in soot

Figure 19: Lower louvre seen in a clean state

The crew members closed all ventilation and dampers soon after the discovery of fire and within approximately seven minutes before the release of the CO_2, while a tugboat was tasked to boundary cool the engine-room using its powerful firefighting cannons. While there was no data to suggest that the damper failed due to a defect in its closing mechanism, the only reasonable explanation of the noted damage was that it may have been caused during the boundary cooling efforts by the water pressure from the tugboat's powerful water jets. Similar damage was also noted on the ventilation dampers of the emergency generator room, which caused the generator to stop working at about 1817, a few hours into the firefighting efforts.

It was therefore concluded that the damage to the fire damper during the early stages of the fire, reduced the effectiveness of the CO_2, had likely contributed to the prolonging of the fire, and kept it alive with the ingress of fresh air from the damaged ventilation damper.

2.8 Fire Fighting Efforts

A fire at sea is one of the most dangerous situations which crew members may have to face. If not handled correctly and in a timely manner, it can lead to dire consequences. The crew members had significant challenges to detect, control and extinguish the fire as quickly as possible.

The engine-room was fitted with two means of fixed, fire extinguishing systems. A fixed hyper-mist (local application) fire extinguishing, and a fixed CO_2 fire smothering system. While the crew members considered the use of the CO_2 system, they did not consider the use of the hyper-mist system.

Although the hyper-mist fire extinguishing system automatic activation had failed at 15:19:06, it could have been operated manually from inside the steering gear compartment. However, the crew members would have to be certain which machinery or compartment was on fire to release the hyper-mist over that particular area. The crew members were unlikely to have known the exact location of the seat of the fire to activate the system, hence they may have been hesitant to use the hyper-mist system – *i.e.*, if the system was functional. If the system remained functional, it

would have been a matter of starting the freshwater package pump and switching the respective compartment's automatic[7] valve to 'manual' position.

The fact that the engine-room alarm log system registered the alarm "*ER LOC APPLICATION FAIL*" at 15:19:06 on 21 March, indicated that the hyper-mist system was on 'automatic' mode but failed to deliver the hyper-mist; potentially either due to a faulty control system that had developed soon after the fire alarm, or the package pump was left in 'manual' position when the system was tested two days prior to the fire (on 19 March). It is not uncommon on ships to change the water supply pump's mode to 'manual' in order to test the system. If that was the case, the hyper-mist system's failure would be explained.

The hyper-mist system was approved by Class on 11 August 2016, and installed in accordance with the requirements of the International Convention for the Safety of Life at Sea, 1974, as amended (SOLAS) and Class. The fault on the control system may be explained by the cables becoming damaged due to effect of the fire. Class rules specifically stipulate when fire-resistant cables are required when feeding fire extinguishing systems, which are installed in high fire risk areas. However, cables which are installed in the same space as the fire-extinguishing system, are exempt.

Paragraph 2 of IACS's Unified Requirement E-15[8] (**Annex 2**) confirmed this requirement and since in the case of *Greta K*, the cables were installed in the same space as the fire extinguishing system which the cables served, they were only required to be 'flame-retardant', and not 'fire-resistant'[9]. It was therefore considered probable that the "*ER LOC APPLICATION FAIL*" alarm activated as a result of the detector's cable being affected by the flames (prior to fire alarm activation), since the cables were not required to be fire-resistant.

The vessel's hyper-mist system was inspected post-fire, on 14 November 2023 in Genoa, Italy. According to the brief inspection certificate, all 'auto / manual' directional valves were found in 'closed' position, which was expected of them as the

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[7] Electrically operated automatic valve 1 as shown in **Annex 1**.

[8] Electrical Services Required to be operable Under Fire Conditions and Fire Resistant Cables.

[9] Typically, flame-retardant cables resist the spread of fire into a new area, whereas fire-resistant cables maintain circuit integrity and continue to work for a specific time under a set of defined conditions.

electrical control valves were designed to ‘close’ or remain in the ‘closed’ position, as a result of electrical power loss.

The inspection report also referred to a manual ball valve (arrow in **Figure 20**) as the ‘MAIN’ valve.

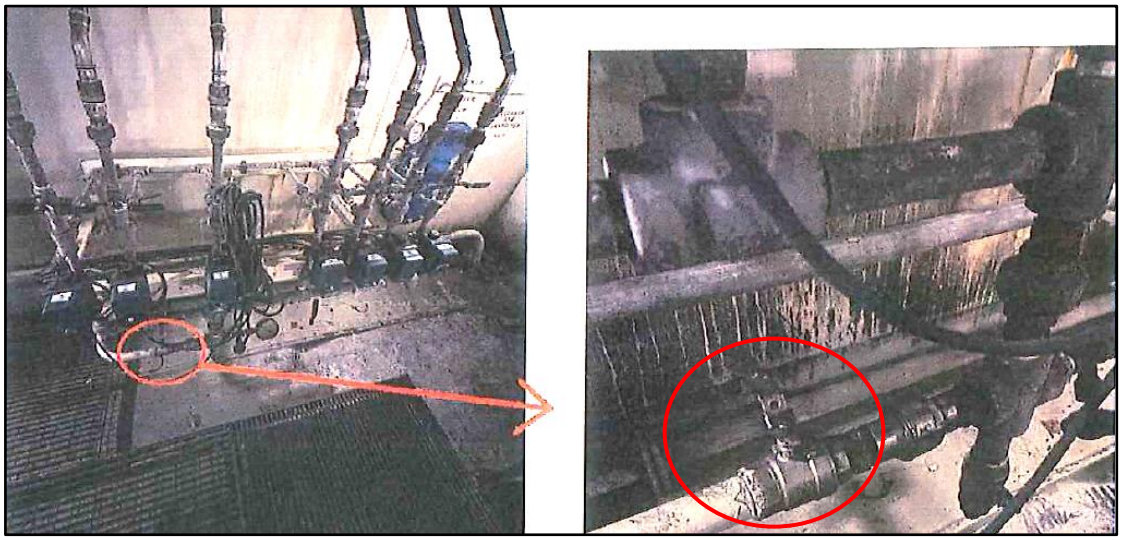


Figure 20: Hyper-mist system piping arrangement in the steering gear compartment

This valve was found in the ‘CLOSED’ position. Unless its position had been changed, this may have been the reason behind the hyper-mist system not activating. However, due to a gap of about eight months between the fire and post-fire inspection in the dry dock, the position of the ball valve may have been inadvertently changed and may not have been in its actual position prior to the start of fire on 21 March 2023.

As a result of hyper-mist system failure, the vessel’s engine-room was flooded by the release of 82 CO_2 cylinders at 1530. Based on the engine-room’s volume, 82 full CO_2 cylinders should have extinguished the fire within 30 minutes of being released, but the fire continued to burn and was eventually extinguished on 27 March 2023. It was not known if the failure of the CO_2 to extinguish the fire was due to insufficient CO_2 in the cylinders (due to leakage) or the failure of the ventilation flaps to seal the engine-room as discussed above.

Investigation into the CO_2 cylinders’ contents indicated that the cylinders had been weighed during the vessel’s dry dock in Poland, in October 2021. Moreover, they had

been re-inspected with a liquid level indicator for their content, during July 2022, in Belgium. The safety investigation had no reason to suspect of any leakage after the last inspection 9 months ago.

2.9 Emergency Response by the Vessel

The crew members' reaction to the discovery of the fire was in line with the training provided to each seafarer before joining a vessel and the routine drills, which they undertake during their stay on board.

Within about 12 minutes of the discovery of the fire, the crew members had shut the ventilation flaps, started boundary cooling, and released the CO_2 system. It was also fortunate that the tugboats meant to assist with the berthing were nearby and could assist with the boundary cooling. Despite the extensive damage to the main engine-room compartment, the fire doors surrounding the compartment contained the fire within the space. The only damage noticed outside the engine-room was the extensive smoke damage located around the main deck in the ECR and in the accommodation spaces.

After the initial phase of firefighting, the master turned his attention to the crew members' safety and arranged for unessential personnel to disembark ashore. Despite the failure of the emergency generator at 1718, the master and the remaining six crew members coordinated with the port authorities. The failure of the emergency generator meant that there was neither light nor power on board, except for the radio equipment that was being powered by the emergency batteries. It was only when smoke started to enter the bridge that the master disembarked the vessel with his remaining crew members. Along with the chief engineer and the second officer, he opted to transfer to a tugboat so that they could assist with the firefighting efforts.

The master and some crew members reboarded the vessel between 22 March and 25 March to assist with the assessment of the fire, and the release and adjustment of attending tugboats along with the local authorities and the salvors who had been contracted to deal with the fire. The master returned on board the vessel again on 26 March and 27 March to assist with the firefighting efforts, until it was declared extinct on 27 March.

The crew members' efforts in attempting to contain and fight the fire were exemplary and their dedication to repeatedly return on board the vessel to assist with the emergency can be considered above and beyond their call of duty.

THE FOLLOWING CONCLUSIONS, SAFETY ACTIONS AND RECOMMENDATIONS SHALL IN NO CASE CREATE A PRESUMPTION OF BLAME OR LIABILITY. NEITHER ARE THEY BINDING NOR LISTED IN ANY ORDER OF PRIORITY.

3 CONCLUSIONS

Findings and safety factors are not listed in any order of priority.

3.1 Immediate Cause of the Accident

.1 Fuel oil sprayed out from a fuel pipe flange that was either not tight or became loose due to vibration.

3.2 Conditions and Other Safety Factors

.1 A gap in the main engine turbine's exhaust gas piping insulation provided the heat source to ignite the leaking oil spray;

.2 The engine room's smoke and heat detectors did not detect the fire as they appeared to have been either isolated or faulty;

.3 Failure of the hyper-mist fire extinguishing system was likely to have contributed to the spread of fire and further damage to the machinery and engine-room;

.4 The damage to the automatic fire damper during the early stages of the fire may have likely contributed to prolonging the fire as it reduced the effectiveness of the CO2 and kept the fire alive with an intake of air from the damaged ventilation.

3.3 Other Findings

.1 The routine functional test of the hyper-mist system on 19 March 2023, did not ascertain the system's proper functionality;

.2 The fire detectors appeared to have been faulty for more than three days prior to the fire and remained unreported.

4 ACTIONS TAKEN

4.1 Safety Actions Taken During the Course of the Safety Investigation

The Company ensured that *Greta K* was safely manned at all times. During the ship's stay in Leixões, Portugal, crew members and members of the salvors' team remained on duty for safety reasons and to ensure that developments were assessed on a 24-hour basis. Moreover, a manning of 12 crew members was constantly kept on board during the repairs at the shipyard in Genoa, Italy.

5 RECOMMENDATIONS

In view of the conclusions reached and taking into consideration the safety actions taken during the course of the safety investigation,

The Company is recommended to:

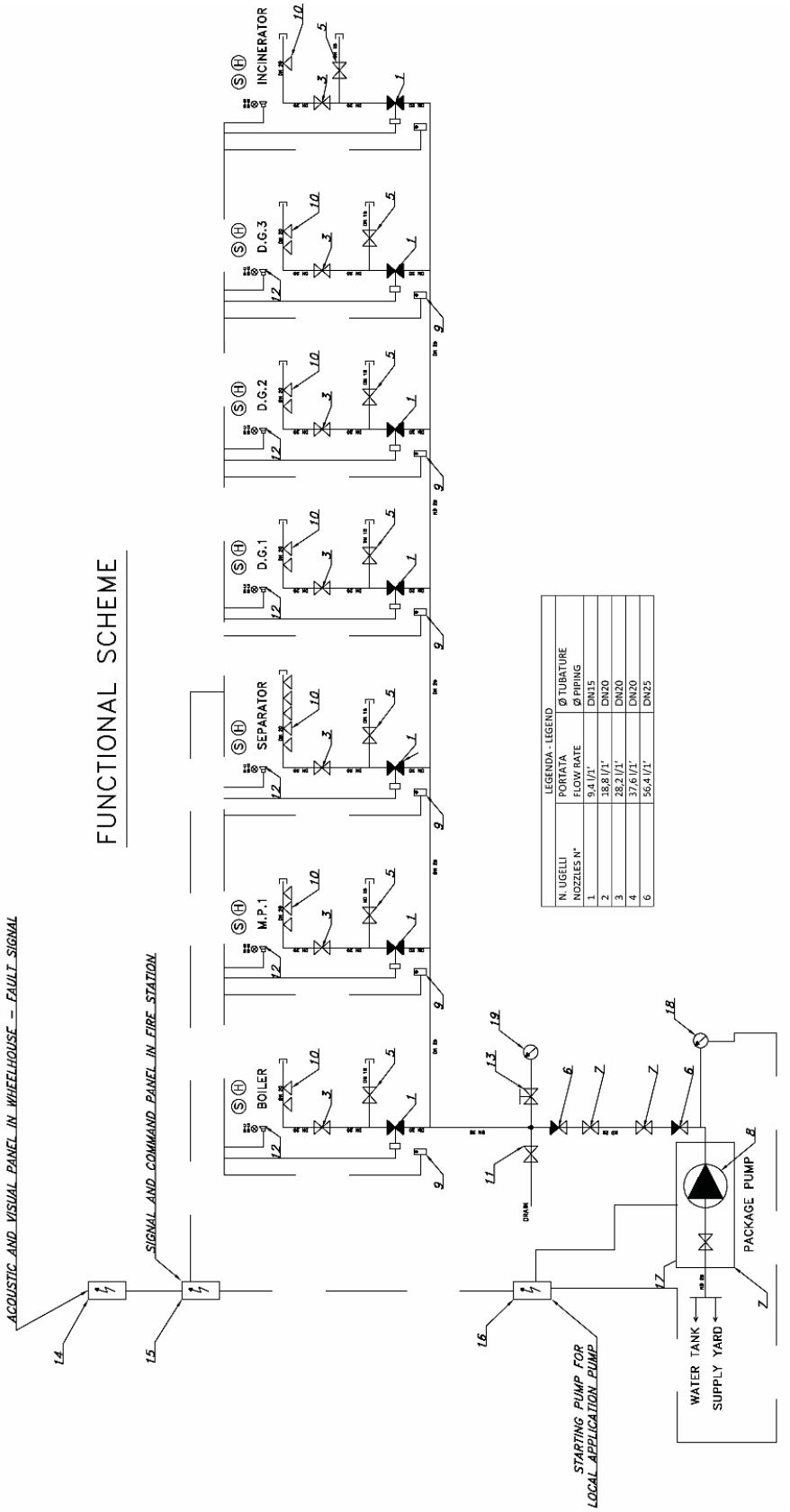
04/2024_R1 Circulate the findings of this safety investigation to all vessels under its management;

04/2024_R2 Review the routine testing regime of the hyper-mist system on board and consider the re-routing of the system and / or establish that it is suitably protected to withstand elevated temperatures;

04/2024_R3 Inspect the shielding of pipe flanges carrying fuel oil and heated surfaces, to eliminate the risk of fire.

ANNEXES

Annex 1: Schematic Drawing of the Hyper-mist System



Annex 2: IACS Unified Requirement E15

E15 Electrical Services Required to be Operable Under Fire Conditions and Fire Resistant Cables

(Nov 1999) (Rev.1 May 2004) (Rev.2 Feb 2006) (Rev.3 Dec 2014) (Rev.4 Dec 2020)

1 Electrical services required to be operable under fire conditions are as follows:

- Control and power systems to power-operated fire doors and status indication for all fire doors
- Control and power systems to power-operated watertight doors and their status indication
- Emergency fire pump
- Emergency lighting
- Fire and general alarms
- Fire detection systems
- Fire-extinguishing systems and fire-extinguishing media release alarms
- Low location lighting
- Public address systems
- Remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and/or explosion

2 Where cables for services specified in 1 including their power supplies pass through high fire risk areas, and in addition for passenger ships, main vertical fire zones, other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the service in any other area or zone. This may be achieved by either of the following measures:

a) Cables being of a fire resistant type complying with IEC 60331-1:2018 for cables of greater than 20 mm overall diameter, otherwise IEC 60331-21:1999+AMD1:2009 or IEC 60331-2:2018 for cables with an overall diameter not exceeding 20 mm, are installed and run continuous to keep the fire integrity within the high fire risk area, see Figure 1.

Notes:

1. Rev.3 of this UR is to be uniformly implemented by IACS Societies from 1 January 2016.
2. Rev.4 of this Unified Requirement is to be uniformly implemented by IACS Societies on ships contracted for construction on and after 1 January 2022.
3. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.

E15
(cont'd)

b) At least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

c) Systems that are self monitoring, fail safe or duplicated with cable runs as widely separated as is practicable may be exempted.

3 The electrical cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source(s) of power and prime mover(s). They are to be of a fire resistant type, in accordance with 2 (a), where they pass through other high fire risk areas.

Notes:

a) For the purpose of E15 application, the definition for "high fire risk areas" is the following:

(i) Machinery spaces as defined by Regulation 3.30 of SOLAS Chapter II-2, as amended by IMO resolutions up to MSC.421(98) (hereinafter the same), except spaces having little or no fire risk as defined by paragraphs (10) of Regulation 9.2.2.3.2.2 of SOLAS Chapter II-2. (Including the interpretations for tables 9.3, 9.4, 9.5, 9.6, 9.7 and 9.8 given in MSC/Circ.1120 as amended by MSC.1/Circ.1436 and MSC.1/Circ.1510)

(ii) Spaces containing fuel treatment equipment and other highly flammable substances

(iii) Galley and Pantries containing cooking appliances

(iv) Laundry containing drying equipment

(v) Spaces as defined by paragraphs (8), (12), and (14) of Regulation 9.2.2.3.2.2 of SOLAS Chapter II-2 for ships carrying more than 36 passengers

b) Fire resistant type cables should be easily distinguishable.

c) For special cables, requirements in the following standards may be used:

IEC 60331-23:1999: Procedures and requirements – Electric data cables
IEC 60331-25:1999: Procedures and requirements – Optical fibre cables

E15
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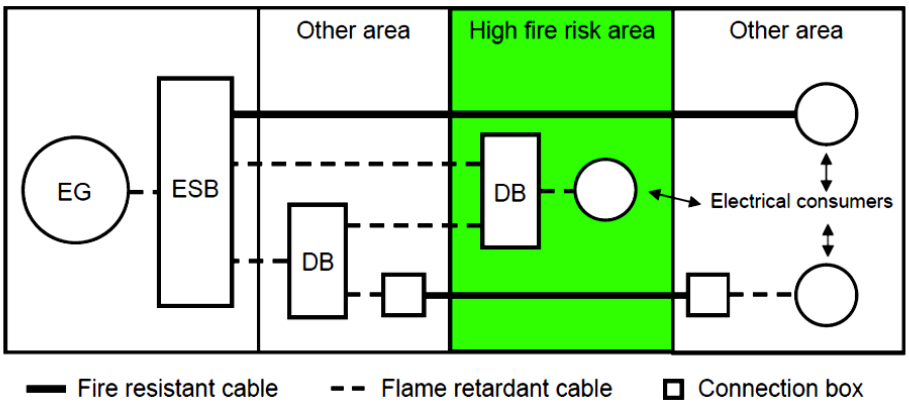

Figure 1

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