THE COMMONWEALTH OF THE BAHAMAS

M.v. BOUDICCA

IMO Number 7218395
Official Number 8001101

Report of the investigation into an Auxiliary Engine Room Fire on the 25th January 2015

The Bahamas conducts marine safety or other investigations on ships flying the flag of the Commonwealth of the Bahamas in accordance with the obligations set forth in International Conventions to which The Bahamas is a Party. In accordance with the IMO Casualty Investigation Code, mandated by International Convention for the Safety of Life at Sea (SOLAS) Regulation XI-1/6, investigations have the objective of preventing marine casualties and marine incidents in the future and do not seek to apportion blame or determine liability.

It should be noted that the Bahamas Merchant Shipping Act, Para 170 (2) requires officers of a ship involved in an accident to answer an Inspector's questions fully and truly. If the contents of a report were subsequently submitted as evidence in court proceedings relating to an accident this could offend the principle that a person cannot be required to give evidence against themselves. The Bahamas Maritime Authority makes this report available to any interested individuals, organizations, agencies or States on the strict understanding that it will not be used as evidence in any legal proceedings anywhere in the world.

Date of Issue: 25th July 2016

Bahamas Maritime Authority
120 Old Broad Street
LONDON
EC2N 1AR
United Kingdom

CONTENTS

List of Appendices:

1 SUMMARY

1.1 The Boudicca sailed from the port of Cadiz, Spain on the 24th January 2015 enroute to the Port of Arrecife, Lanzarote (Canary Islands) with an estimated time of arrival of 0700 UTC on the 27th January.

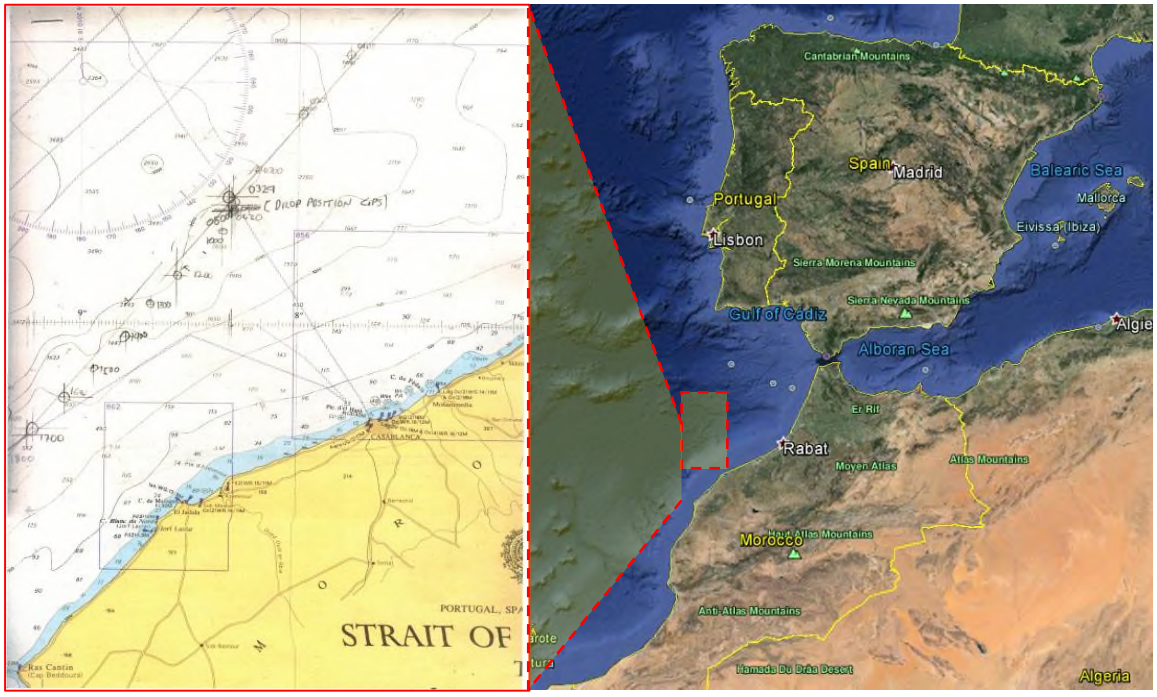


Figure 1: Position of Fire off the coast of Morocco

1.2 On the morning of the 25th January at 0324 UTC the fire alarm sounded on the bridge and in the engine control room indicating a fire had established in the Auxiliary Engine Room and that auxiliary engine No.1 was ablaze.

1.3 The exact location of the fire was found to be at the forward, starboard side, of the auxiliary engine No.1. Upon further investigation it was determined that the fire was initiated by fuel leaking from a broken fuel oil pressure gauge supply line, igniting on contact with a hot surface in the vicinity of the turbo charger, resulting in significant damage to auxiliary engines No.1, 2 and 3 and the surrounding space including cabling, deck head, fixtures and fittings.

1.4 The crew were notified of the fire by two methods. Senior safety critical crew received, via pager, a transmission "Red Fox" interpreted to mean 'Code Bravo' and via public announcement (PA) initiated by the Officer of the Watch (OOW) on the bridge. The 4th Engineer in the Engine Control Room (ECR) reported the fire with the exact location to the OOW prior to commencing initial actions.

1.5 Initial actions were in accordance with emergency response procedures and conducted to good effect by utilizing Marioff Hi-fog fixed firefighting system. As a result the fire was confirmed as extinguished by 0433. Propulsion and auxiliary power was subsequently restored by 0725 thereafter and the vessel diverted its destination to the Port of Tenerife, Spain arriving on the 27th January at 1856 UTC.

1.6 As a direct result of the damage sustained due to the fire, multiple services were affected. Propulsion and primary power generation to all services was rendered temporarily out of action while some nonessential services were rendered out of action until shore side support could be provided.

1.7 A list was determined shortly after the fire had been extinguished by approximately 5° to port. This provoked an investigation to establish the root cause that was later determined to be associated with the significant quantity of water as a result of the firefighting effort. After further investigation it was determined that the Hi-fog had continued to function due to a system override allowing one compartment within the machinery space to flood.

***

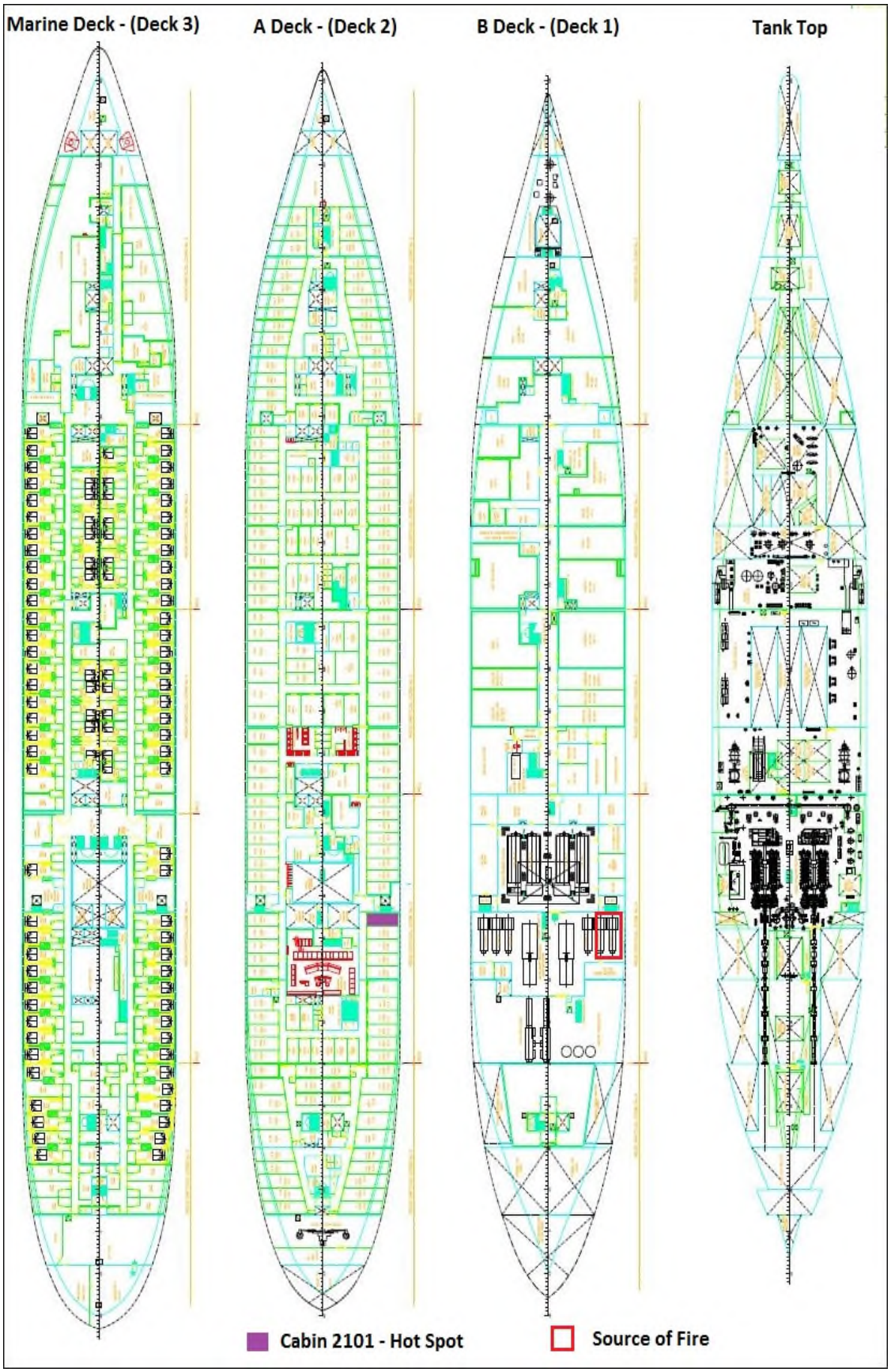


Figure 2: General Arrangement Plan

2 DETAILS OF INVOLVED VESSEL(s) AND OTHER MATTERS

2.1.1 The Boudicca is a purpose built passenger vessel owned by Boudicca Cruise Ltd of London, UK and managed by Fred Olsen Cruise Lines of Ipswich, UK and registered in the port of Nassau, Bahamas. The principal details as at 1st June 2015 are as follows:

IMO Number	7218395
Keel Laid	1971
Builders	Oy Wartsila Ab Shipyard, Finland
Gross Tonnage	28,551 tonnes
Nett Tonnage	11,714 tonnes
Length (overall)	206.96 metres
Length (bpp)	175.10 metres
Breadth	25.10 metres
Depth	13.67 metres
Class Society	Det Norske Veritas
Class Notation	1A1 Passenger Ship (unrestricted sea-going service)
Propulsion	4 x MAN B&W 7L32/40 diesel engines driving 2 x CP propellers
Auxiliary Generators	3 x MaK 6M20 1020kW, 2 x Wartsila 824TS, 1 x Wartsila 6R 32 BC
Shaft Power	14,000kW
Service Speed	18.5 kts

2.1.2 The vessel is designed and certified for the carriage of one thousand and three hundred (1,300) persons of which nine hundred and sixty (960) are passengers. At the time of the incident the vessel was at 88% capacity with 784 passengers and 356 crew on board.

2.1.3 The Boudicca has seven generators installed; five are located in the auxiliary engine room on deck 1, zone 4 (AE1 – AE6, AE5 was removed from the vessel). The auxiliary engine No. 7 (AE7) is located in the casing and ventilation space on deck 1 in zone 3. The emergency generator is located on deck 8 port side in zone 4. Additionally the vessel has three fire pumps of

which one is the emergency fire pump; these are situated on the tank top in pump room No. 2 (emergency fire pump) zone 2, pump room No. 3 zone 2 and the main engine room, port side, zone 4.

2.2 Vessel Certification

2.2.1 At the time of the incident the vessel was classed with DNV-GL and all statutory certificates remained valid.

Primary Certificates:

Certificate of Class	issued	28 Apr 2011	expiry	12 Feb 2016
International Tonnage Certificate	issued	14 Jan 2011	expiry	-
International Load Line Certificate	issued	11 Mar 2011	expiry	19 Feb 2016
Passenger Ship Safety Certificate	issued	27 Jun 2014	expiry	19 Feb 2015
Safety Management Certificate	issued	07 Jun 2011	expiry	17 May 2016
Document of Compliance	issued	07 Nov 2014	expiry	19 Oct 2019
Maritime Labour Certificate	issued	08 Aug 2013	expiry	22 Jun 2018
Safe Manning Document	issued	01 Jul 2013	expiry	30 Jun 2018

2.3 Port State and Flag State Inspections

2.3.1 The last Port State Control (Paris-MoU) inspection was carried out by MCA in Liverpool, UK on the 05th January 2015 with no deficiencies recorded.

2.3.2 The last Bahamas Annual Safety Inspection (ASI) was carried out on the 27th March 2014 in Tenerife, Spain with no deficiencies recorded.

2.4 Weather

2.4.1 At the time of the incident an area of high pressure existed in the proximity of the vessel, resulting in moderate to slight conditions with a North Easterly breeze of between 11-16kts, Beaufort scale 4, and a sea state of 3-4, providing a NE swell of between 1-1.5m.

2.5 Duty Watchkeepers

2.5.1 The following watch team members were on watch in their respective locations between the hours of midnight to 0400:

Bridge Watchkeepers

Third Officer (OOW) – Joined Fred Olsen Cruise Lines as a Deck Cadet in 2012, promoted to Officer in Charge of a Navigation Watch upon obtaining his Certificate of Competency (Seafarer Training Certificate in Watchkeeping (STCW II/1)) in 2014.

Ordinary Seaman (Lookout) – Joined Fred Olsen Cruise Lines in 2005 and had served as an Ordinary Seaman (STCW II/4) since 2014.

Engine Watchkeepers

Fourth Engineer (EOOW) – Joined Fred Olsen Cruise Lines in 2007, promoted to Officer in Charge of Engineering Watch upon obtaining his Certificate of Competency (STCW III/1) in 2014.

Motorman – Joined Fred Olsen Cruise Lines in 2008 and had served as a Rating forming part of an engineering watch (STCW III/4) since 2013, becoming a Motorman in 2014.

Oiler – Joined Fred Olsen Cruise Lines in 2011 and had served as a Rating forming part of an engineering watch (III/4) since 2013, becoming a Oiler in 2014.

2.6 Fatigue

2.6.1 All watchkeepers on duty during the midnight to 0400 watch, were in compliance with the statutory hours of rest requirements[1]. The vessel uses the Fidelio Time and Attendance computer system to record the hours of rest for all crew members, the hours of rest records were found to be satisfactory.

2.7 Substance Abuse

2.7.1 Although no alcohol testing was carried out following the incident. There was no evidence to suggest that substance abuse was a contributory factor.

2.8 Emergency Organisation - Code Bravo

2.8.1 Code Bravo is a code name used to indicate a fire on board. In the event of an engine room fire the engineer on duty and the motorman on duty is despatched to investigate the nature of the incident. Once the Code Bravo is confirmed, the following teams are mustered as per the Emergency Procedures Manual and assembled at their designated locations:

1	Central Command Team	Location: bridge
2	On Scene Command Team	Location: scene of incident
3	Area Control Team	Location: scene of incident
4	Rapid response Team	Location: scene of incident
5	Fire Teams	Location: various

2.9 Hi Fog System

2.9.1 The Marioff Hi-Fog fire extinguishing system uses water under high pressure, through specially designed spray heads that cause the water to enter the space at high speed as a fine fog (mist). The small droplets yield a very large total water surface area, providing efficient cooling of the fire and surrounding gases.

[1] Required by the International Convention of Standards of Training, Certification and Watchkeeping for Seafarers. 1978 as amended (STCW) and the Maritime Labour Convention, 2006 (MLC 2006)

3 NARRATIVE OF EVENTS

3.1 All times noted in this report are given in the style of the standard 24-hour clock without additional annotations. The vessel time used on board at the time of the incident was Universal Coordinated Time (UTC). The vessel's time having been retarded 1 hour at 0200 (UTC+1) that morning to 0100 UTC.

3.2 Arrival and Departure Cadiz

3.2.1 At 2300 on the 23rd January the auxiliary engine No.1[2] (AE1) was stopped in advance of the vessel's arrival in Cadiz, Spain, in order to allow sufficient time for the engine to cool down in preparation for the following day´s 30,000 hour scheduled maintenance. The previous service of AE1 had been carried out on 19th August 2013 at 69,812 hours.

3.2.2 During the vessel´s stay in the Port of Cadiz, Spain on the 24th January, the AE1 was maintained by the 2nd Engineer (2/E) and included overhaul of the injector valves. On completion the covers were replaced and the engine was started and found to be working satisfactorily.

3.2.3 The vessel departed the port of Cadiz, Spain at 1930 on the 24th January, having completed bunkering at 1817; with a total complement on board of 1,140 persons, made up of 784 passengers and 356 crew. On departure the vessel's draft was recorded as 7.09m forward and 7.21m aft.

3.2.4 The vessel was destined for the port of Arrecife, Canary Islands. Her estimated time of arrival (ETA) at Arrecife was 0700 on the morning of 26th January. In order to meet her arrival time the vessel had to make an average speed of 16kts. At the time of the incident, the vessel's speed was 18.5kts operating all four engines at 95% load.

3.3 Fire in Engine Room

3.3.1 The midnight to 0400 watch consisted of 4th engineer (4/E), motorman and oiler, who spent the watch monitoring the safe operation of the engine room and ancillary equipment, the 4/E being the Officer in charge.

[2] Auxiliary engine – Generator No.1 (AE1)

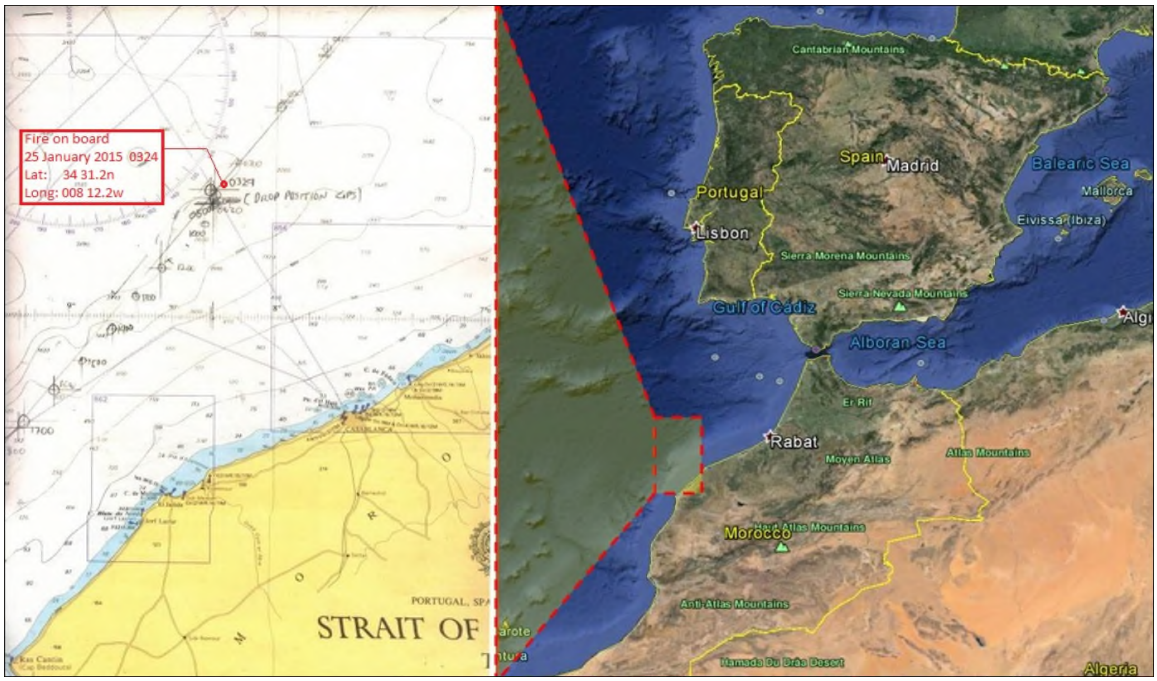


Figure 3: Position of vessel, when Fire Alarm activated.

3.3.2 At 0324 on the morning of Sunday 25th January, the vessel was approximately 50nm North West of Casablanca, Morocco in position 34° 31'.2N 008° 12'.2W on passage to Arrecife, Canary Islands.

3.3.3 The fire alarm on the Autotronica Fire Detection System (see figure 4) sounded on the bridge and engine control room (ECR) at 0324, indicating a fire on the starboard side of the auxiliary engine room on deck 1, fire zone 4. The 4/E who was attending to the engine room logbook, immediately called by radio the Oiler and Motorman who were in the process of conducting a routine inspection of the engine room, to proceed to the auxiliary engine room and investigate the fire alarm and report any findings. A significant time discrepancy was noted during the course of the investigation between the ships time and the Autotronica Fire Detection System time code, a difference of 19 minutes.

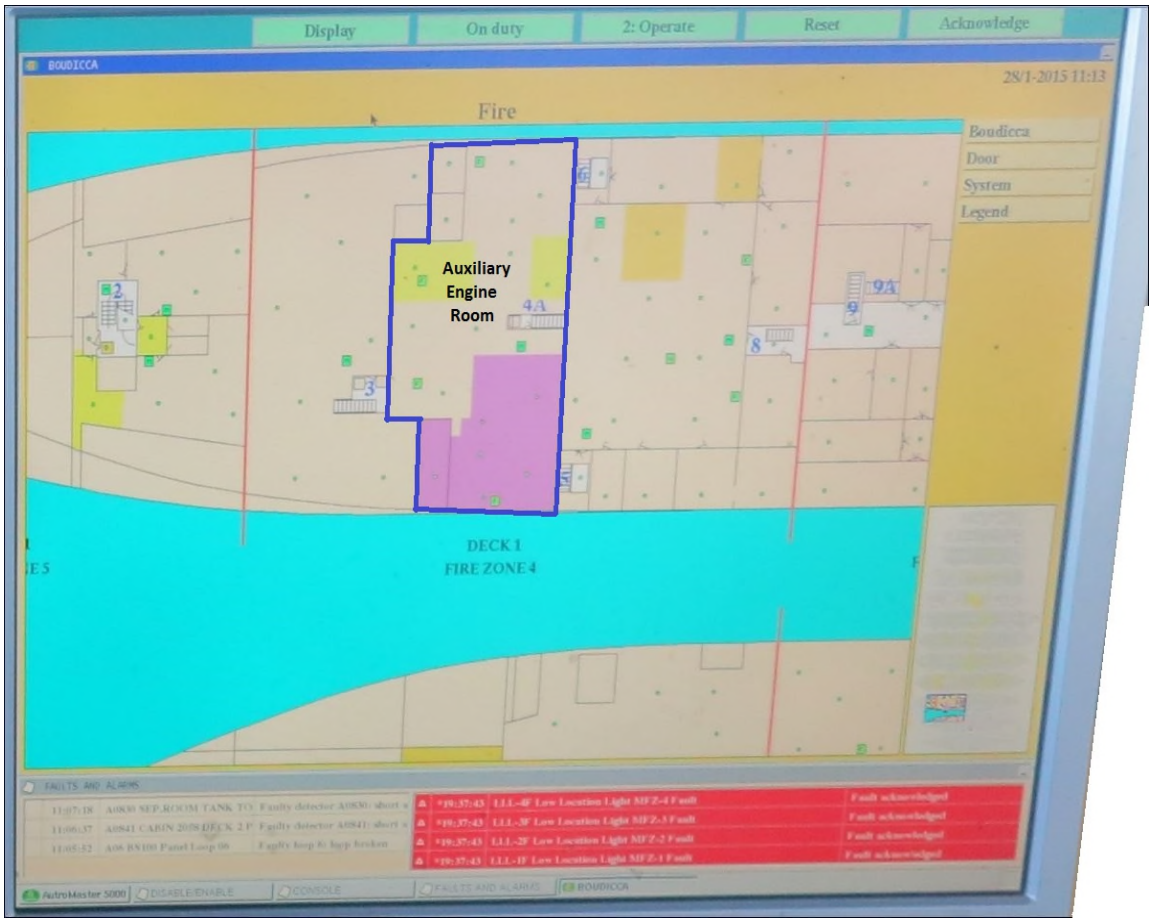


Figure 4: Autotronica Fire Detection System – Bridge Display

3.3.4 The Oiler reported "*when I arrived in the main engine room I see a lot of smoke in boiler room"* (auxiliary engine room). This was confirmed by the closed circuit television circuit (CCTV) monitor, displayed in the ECR and witnessed by the 4/E.

3.3.5 On the bridge, the 3/O on watch, hearing the fire alarm, acknowledged the alarm and confirmed the location. Conversations overheard on the UHF radio by the 3/O, between the 4/E, Oiler and Motorman also alerted the bridge to the fire. This was quickly followed with a phone call from the 4/E in the ECR to the bridge, advising *"he had a fire in the engine room, boiler room auxiliary engine No.1"* (AE1). The 4/E then proceeded to shut down the AE1, which is located on the starboard side of the auxiliary engine room.

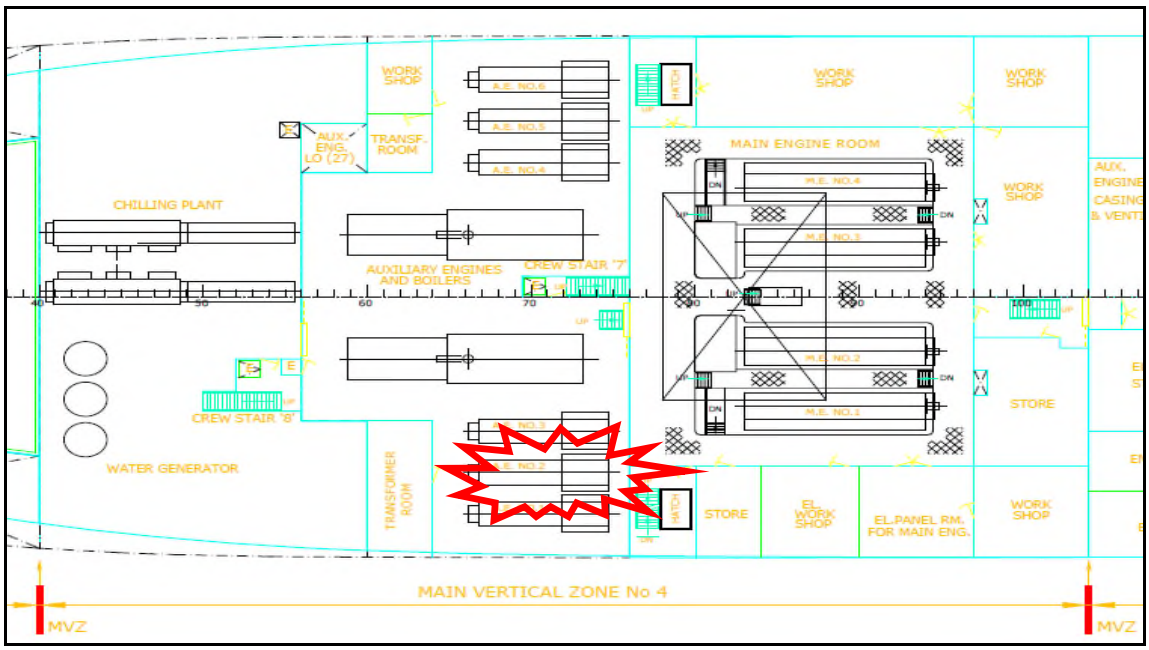


Figure 5: Location of Fire (AE1 - Deck 1, Fire Zone 4)

3.3.6 During this short period of time the Oiler and the 4/E were communicating on the UHF radio in Tagalog and not in the common language of the ship - English. As the 3/O did not speak Tagalog he was unable to understand what was being communicated and therefore unable to monitor the situation or any progress achieved by the actions of the initial responders.

3.3.7 Once the 4/E was satisfied the fire in the auxiliary engine room was confirmed by the Oiler, he manually activated the Marioff Hi-fog system for the affected area covering generators No.1, 2 and 3, via the sprinkler head No.M2 (see figure 6) by utilizing the Hi-Fog control panel (see figure 7).

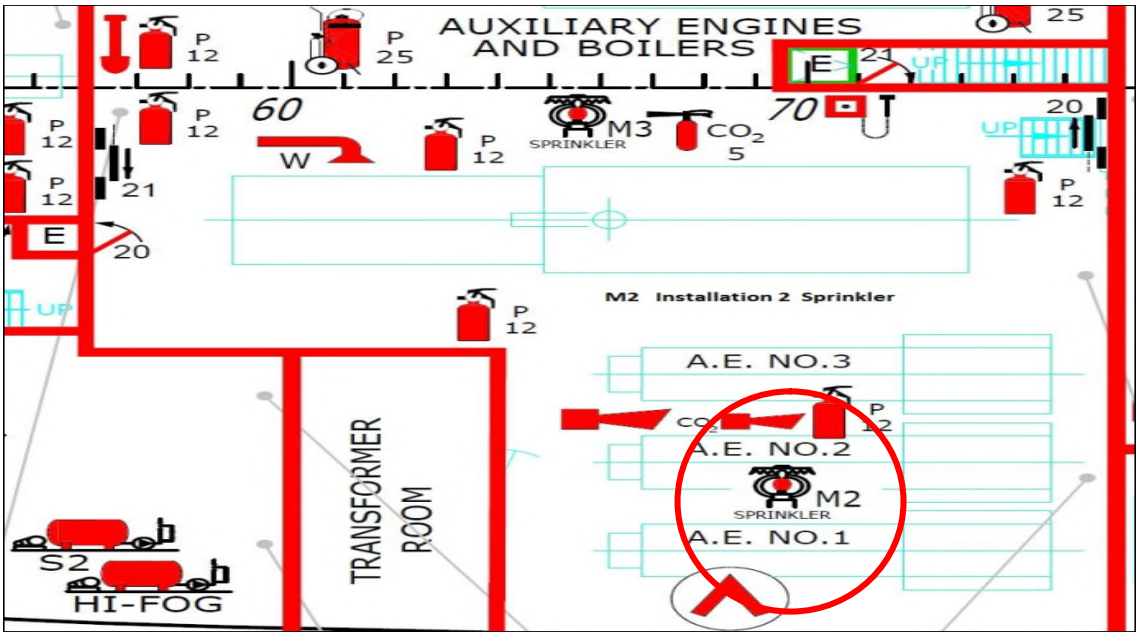


Figure 6: Location of Hi-fog sprinkler – M2 (circled in red) adjacent AE1 and AE2 generators.

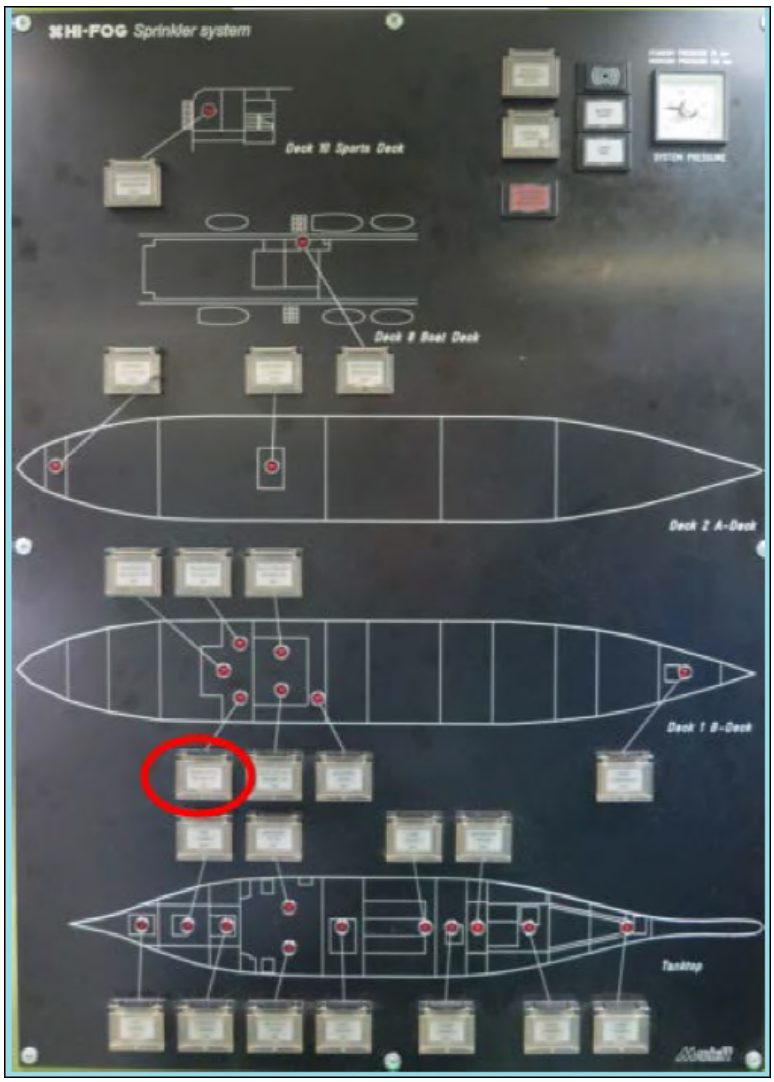


Figure 7: Hi Fog Control Panel

3.3.8 The Oiler immediately took a portable fire extinguisher accompanied by the Motorman and attempted to extinguish the fire. Due to the intense heat and restricted visibility the two were unable to fight the fire however they were able to contain the fire by isolating watertight doors in adjacent fire zones. On entering the space through the forward watertight door (WTD) No.20 they proceeded aft to close WTD No.21 before backing out of the space the way they entered and closed WTD No.20 behind them. The Safety Officer who was wearing a Multi ABEK[3] respiratory facemask proceeded to investigate the fire from forward to aft. On arrival at the WTD No.20 he met with the Motorman and the Oiler who had exited the space moments prior.

3.4 Code Bravo

[3] ABEK – Organic; Inorganic; Sulphur Dioxide and Ammonia vapours.

3.4.1 The 4/E called the Chief Engineer (C/E), three minutes after the initial alarm was activated at 0327. At this time the 3/O announced CODE BRAVO from the public address (PA) panel on the bridge, initially this announcement failed as the public address was not properly switched on. A second attempt was made announcing *"CODE BRAVO – boiler room, deck 1 zone 4",* and in accordance with the Emergency Organisation Manual, this Code Bravo was repeated three times. In addition to the Code Bravo announcement, a group paging facility is available on the PA panel which transmits emergency messages to all recipients with a pager. In this instance a transmission was initiated with the intention of transmitting Code Bravo. However the initial message sent Code Red Fox, which caused some confusion to one recipient requiring clarification. Upon hearing the Code Bravo over the PA system, the Master proceeded to the bridge, arriving at the same time as the Chief Officer and the Cruise Director in order to establish Central Command.

3.4.2 Meanwhile the 3/O on the bridge had reduced the ships speed to slow ahead, while the Refrigeration Engineer in the ECR, stopped all the engine room fans and isolated the power supply in the vicinity of the fire, he then reported back his actions to Central Command. Communication lines were established between the Central Command, On Scene Command Team, Area Control Team and Rapid Response Team by UHF radio.

3.4.3 At 0338, *"the affected area was completely isolated and I evaluated the situation again, I found it to be in a secured and safe state and I decided that there was no need for escalating the emergency"* recalled the Master. He then announced to the guests and crew members, *"we have a situation in the engine room and all is under control, so you can all relax and I will keep you updated as we progress this incident"*. By 0345, the quick closing valves were activated from the CO_2[4] room, closing the fuel to AE1, AE2 and AE3 generators. The generator AE5 was unavailable due to routine maintenance, while generator AE6 had stopped due to overheating. The preferential trip on the main switchboard stopped all ships ventilation, caused by the overloading of the electrical equipment on board. At 0347 the vessel had a total loss of power. At this point the emergency generator started automatically providing sufficient power to operate essential emergency systems.

3.4.4 The emergency operations team based in Oslo at Fred Olsen Marine Services were alerted to the incident by the Master at 0347 and remained on hand to provide technical advice and support as required.

3.4.5 All Code Bravo teams were fully accounted for by 0351 and reported to Central Command.

3.4.6 At 0440 the decision was made to shut down all four main engines moments after main engines 2 and 3 had been reported as overheating. The vessel at this

[4] CO_2 – Carbon Dioxide

point was considered navigationally safe as it adopted the status of Not Under Command (NUC)[5] due to exceptional circumstances.

3.5 Fighting the Fire

3.5.1 By 0337, 10 minutes after the announcement of the Code Bravo, 5 fire teams were mustered in firefighting suits and breathing apparatus, forward of WTD 19 where the On-Scene Command Team had been established.

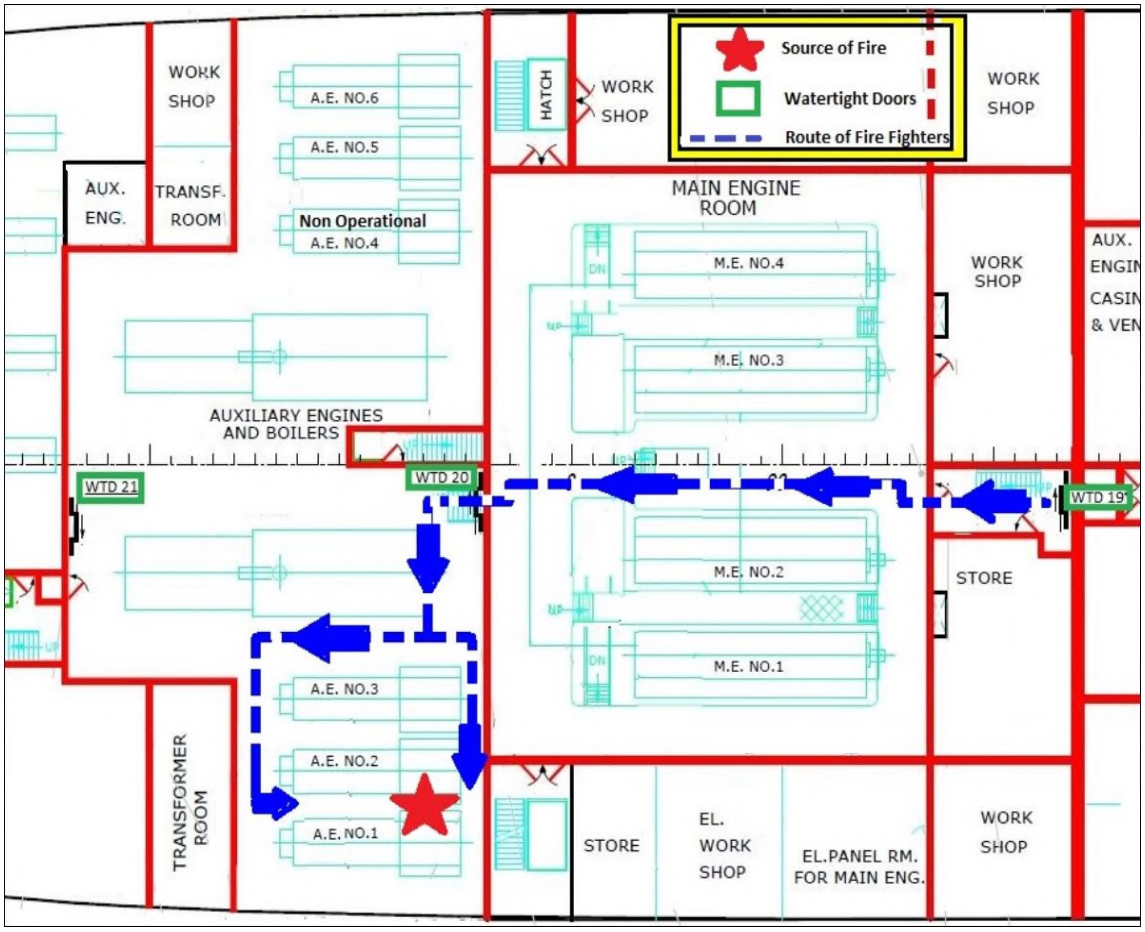


Figure 8: Actual route of firefighting teams

3.5.2 The route established to the seat of the fire, as highlighted within figure 8, enabled all fire teams to proceed through the main engine room via WTD's 19 and 20. Due to the location of the AE1 within the Auxiliary Engine Room, gaining access via the Main Engine Room WTD 20, provided the shortest route possible to reach the fire and provided a bulkhead in close proximity to offer additional protection to the fire teams when fighting the fire.

3.5.3 In total four re-entries were made in the auxiliary engine room, all 5 teams participated, managing to extinguish the fire by 0433, 69 minutes after initial detection.

[5] COLREGS (1972) Rule 3(f) General Definitions

3.5.4 At 0524 after ensuring no further re-ignition of the fire, the Hi-Fog system was stopped from the ECR control panel. However over the course of the next hour it was determined that the vessel was slowly developing a list to port. At 0627, through the combination of the North Easterly force 4 breeze and the build-up of water discharged from the Hi-Fog system the vessel came to rest with a 5° list to port.

3.5.5 At 0725 AE6 was subsequently restarted locally, followed by AE4 and AE7 ensuring adequate electrical power was restored throughout the vessel.

3.5.6 Shortly thereafter, a sounding was taken of the mid tunnel, approximately 500mm of water was recorded which provoked the starting of the emergency bilge pump in order to remove the water and attempt to resolve the port list. At approximately 0745 the vessel re-established an upright condition prior to resuming passage.

3.6 Peripheral Fire Damage

3.6.1 At 0358 hotspots were found on deck 2 in cabin 2101 (see figures 10 and 11), the location of which was immediately above the source of the fire in the auxiliary engine room. The rapid response team conducted boundary cooling containing the situation and preventing the vertical spread of the fire.

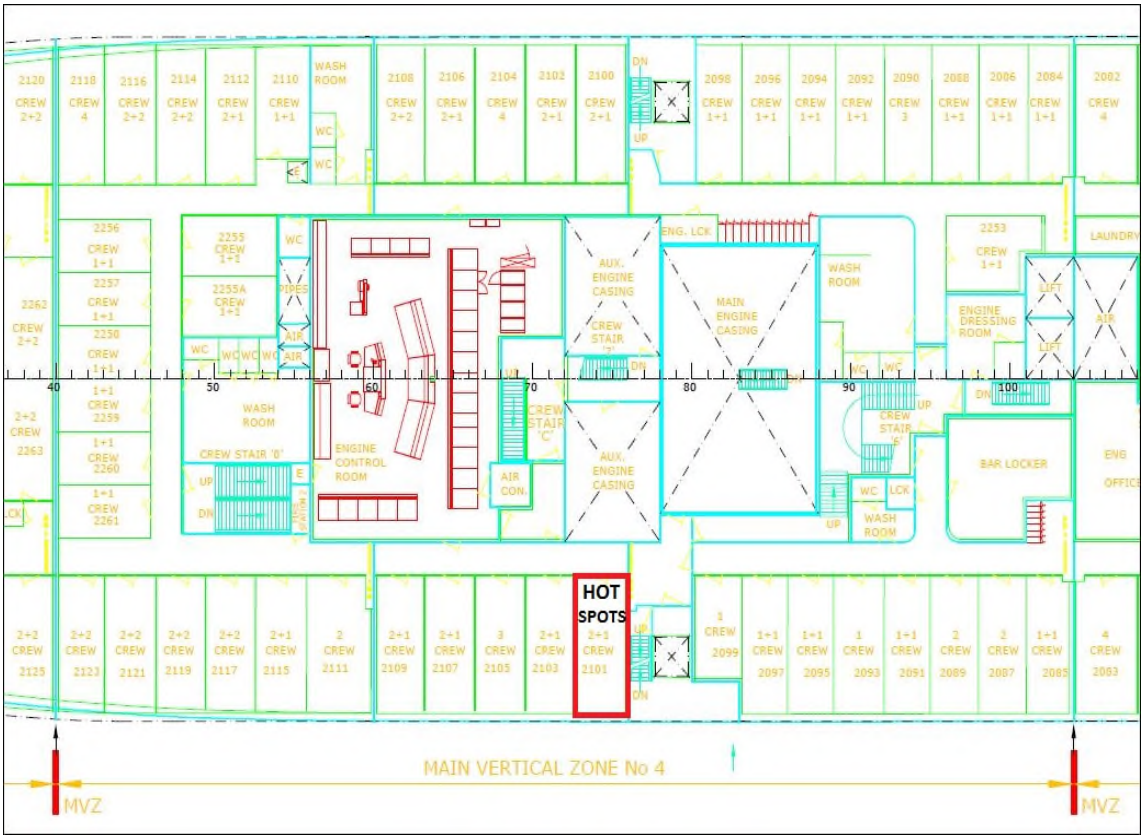


Figure 9: Location on Deck 2 of fire damage in Cabin 2101

Figure 10: Cabin 2101 post boundary cooling efforts

3.7 Passenger Handling

3.7.1 On the evening of the 27th January, the vessel arrived in Tenerife in order to disembark those passengers able to return to the UK. Despite this not being the end of the cruise, due to the severity of the damage it was determined that those passengers capable of flying home, were to do so. Discussions were held between the Managers of the Boudicca, Port State and the Flag Administration, where upon it was determined to terminate the cruise. The cruise was advertised as a NO FLY cruise, with the passengers boarding the vessel in Southampton and completing the cruise in Southampton, this cruise afforded those persons who for various reasons were unable to fly, the opportunity to participate in cruising. Of the 784 passengers on board the Boudicca, 764 passengers were repatriated to the United Kingdom by air. The 20 passengers remaining on board, who were unable to fly, were transferred to suitable cabins on the boat deck. Additional crew were allocated to each passenger in the event of an emergency to ensure their safety, prior to the ship returning to the UK for repairs.

***

4 ANALYSIS AND DISCUSSION

4.1 Auxiliary Engine (AE1) Maintenance

4.1.1 The AE1 was last overhauled in August 2013 at 69,812 running hours which consisted of overhaul of pistons/connecting rods, replacement of big end bearings, piston liners, valve seats and valves of cylinder heads, crankshaft inspection and overhaul of fuel pumps and injection calibration.

4.1.2 On the 24th January AE1 underwent maintenance at 80,503 running hours, having been on load for the preceding 3 days. This was routine maintenance involving, in particular, overhaul of injection valves.

4.1.3 AE1 had operated the following hours each day prior to the incident occurrence.

Date	21.01.2015	22.01.2015	23.01.2015	24.01.2015	25.01.2015
Running hours	17	24	23	9	3

4.1.4 Twenty-four hours prior to arrival in Cadiz, AE1 was stopped to allow the engine time to cool down in preparation for planned maintenance. The planned maintenance of AE1 was conducted as programed upon arrival in Cadiz, Spain.

4.1.5 On completion of the routine planned maintenance, AE1 was assessed by the Chief Engineer to ensure all work was complete and no leaks or malfunctions were visible on first engine start after maintenance. On completion of these checks the engine was placed on load and coupled in parallel for 12 hours. Normal watch routines resumed on AE1 with no abnormalities reported.

4.1.6 The 2nd Engineer (2/E) was on watch between 2000 and midnight, at watch handover the 2/E reported that there were no abnormalities observed or alarms related to any of the auxiliary engines. The first indication of a fire within the Auxiliary Engine Room was received by the on watch 4/E via the fire alarm system, reporting the following location *"AE & Boilers DK – 1 STBD Zone 4"*.

4.2 Mechanical Failure

4.2.1 The initial cause of the fire is known to have originated from a fracture in the fuel oil pressure gauge supply line on AE1. The supply line fitted, fractured at the point of connection to a hex nut (see figure 12). The line is physically connected to a compensation device which is fitted to the supply line connected to the manometer gauge.

Figure 11: Point of fracture in the fuel oil pressure gauge supply line

4.2.2 The fuel supply line is situated on the forward end of AE1 behind the panel holding the manometer pressure gauges. The fuel oil pressure gauge supply line measures the fuel oil supply to the generator by feeding the manometer gauge, the approximate pressure of the fuel within the line is 5 bar. The steel line is inverted 'Z' shape, 6mm wide and 120mm in length, situated (see figure 13) approximately 500mm below the top of the engine and 800mm beneath the turbo charger. At the point of the fracture the pressurized fuel, occupied the atmosphere surrounding the engine. The exact source of ignition cannot be determined, however, there are various components that have a surface temperature sufficient to auto-ignite hot fuel in vapour and liquid form within the immediate vicinity of the fracture. Due to the proximity of the turbo charger to the fuel oil supply line at the front of the engine, it can be concluded with a high degree of probability that the source of ignition was provided by the turbo charger.

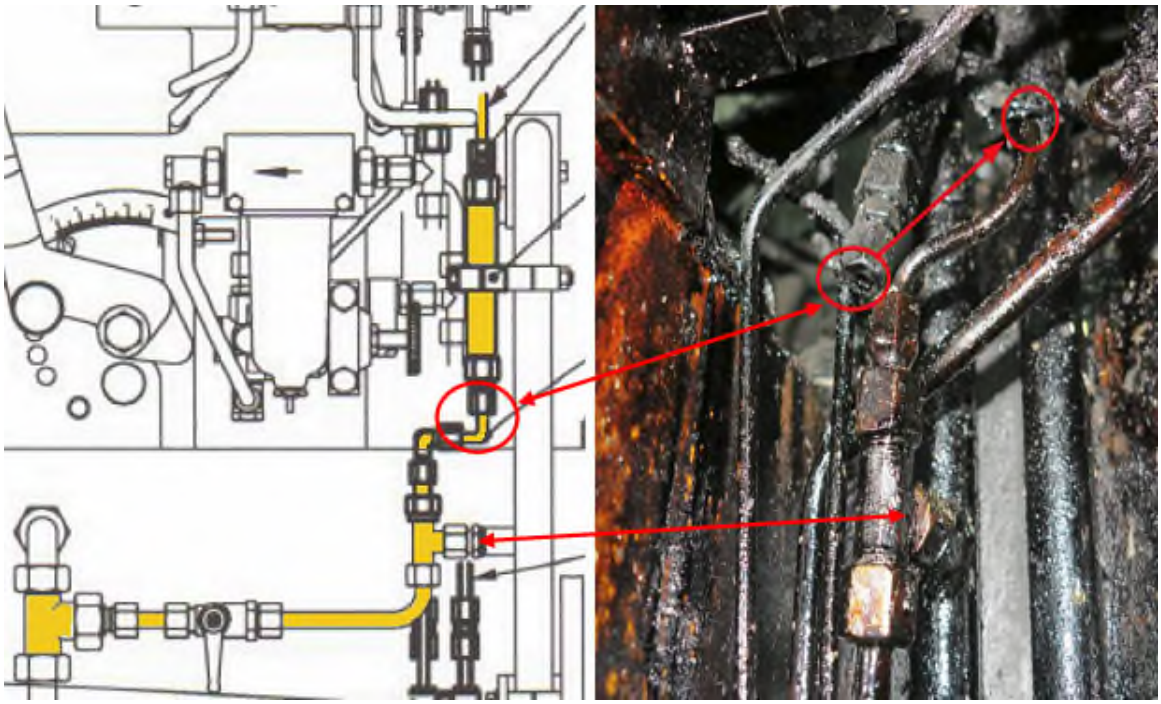


Figure 12: Fractured fuel oil pressure gauge supply line schematic and photograph post fire

4.2.3 The fire engulfed the entire front end of AE1 and spread out and above the point of ignition, moving aft, fuelled by combustible material in the surrounding area. On examination of the scene post fire, significant damage had been caused to cable trays, wiring looms, AE1, AE2, damage to ancillary equipment supplying AE3, insulation, fixtures and fittings throughout the Auxiliary Engine Room.

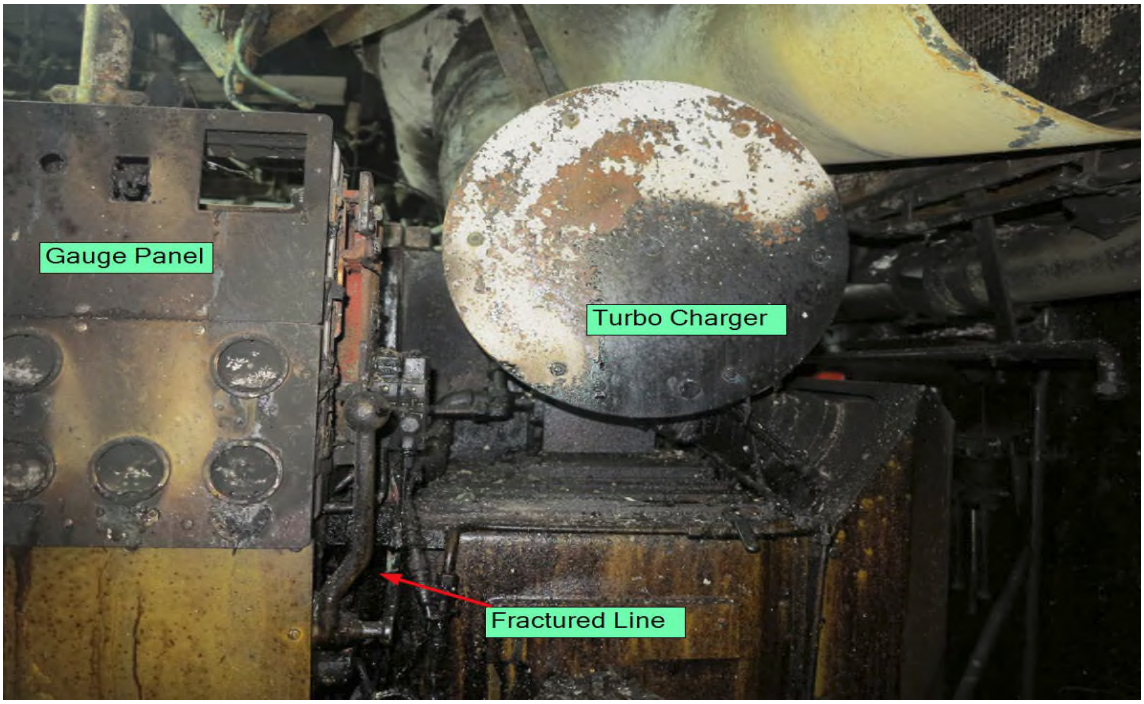


Figure 13: Post incident damage to forward end of AE1

Figure 14: Collateral damage to cable tray (left) and light fixture in vicinity of AE1 (right)

4.2.4 Within the manufacturers' manual, a schematic of the layout of the fuel supply line is provided. On reviewing three of the Auxiliary Engine's fuel oil pressure supply lines, discrepancies exist in the construction and materials used of these supply lines. AE1 and AE2 are configured using different materials compared with that of AE3. AE3 fuel oil pressure gauge supply line is constructed with 90^{O} compression fittings whereas AE1 and AE2 has in a place a steel fabricated line with compression fittings on either end as per the manufacturer's schematic (see figure 12). In addition AE3 has a bracket situated beneath the fuel supply line but does not come into contact with said fuel supply line, therefore providing no support.

4.2.5 Further, the manufacturer's manual includes a valve with valve handle on the schematic. Although the valve is present the handle used to control the supply of fuel to the pressure gauge is missing on all three auxiliary engines. These discrepancies do not appear to have had any measurable impact on the performance of the fuel oil pressure gauge supply line prior to the incident.

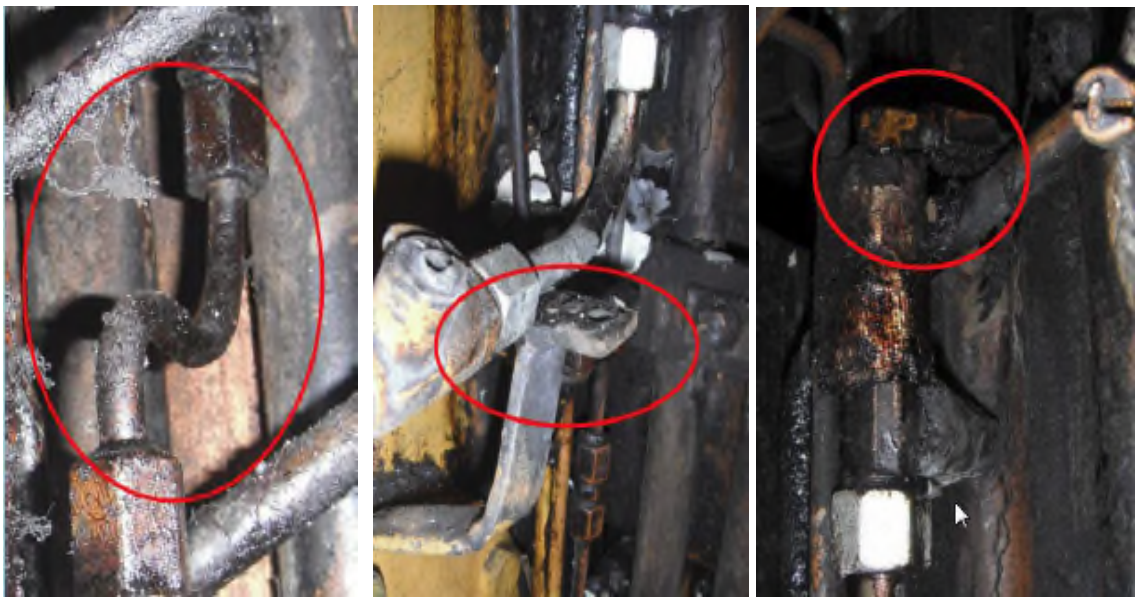


Figure 15: Fuel oil pressure gauge supply lines discrepancies (left to right AE2, AE3 and AE3)

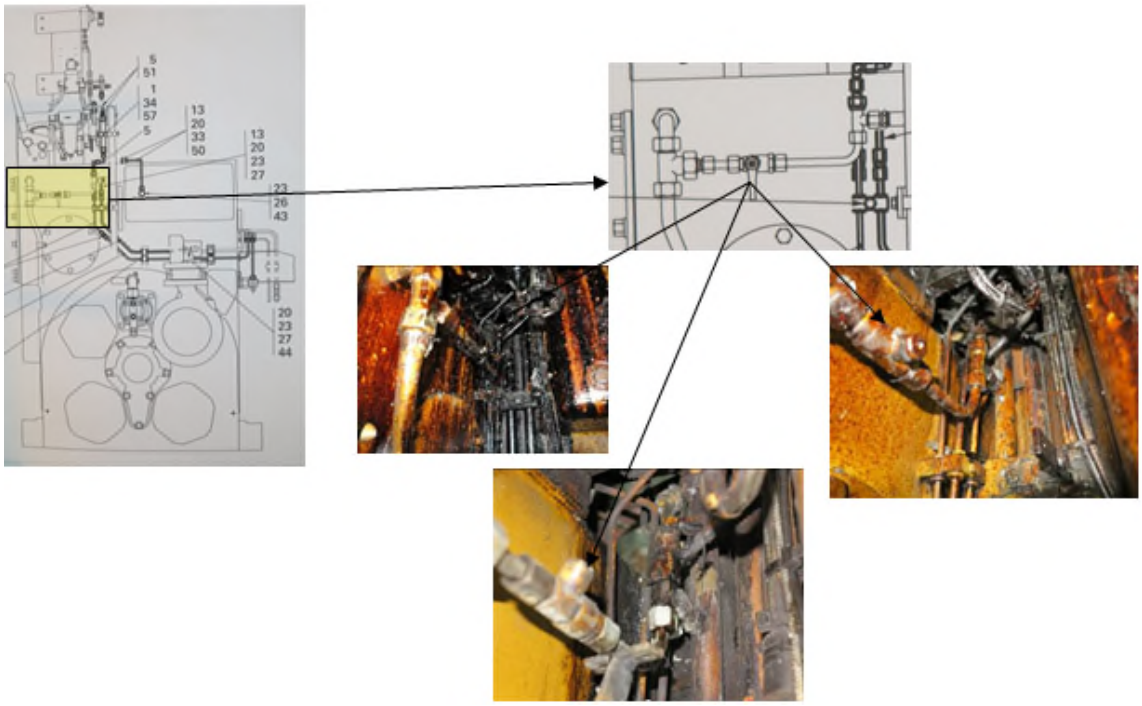


Figure 16: Fuel oil pressure gauge supply lines on AE1, 2 and 3 indicating missing valve handle

4.2.6 In November 2014 the vessel underwent a thermal survey on all auxiliary engines by Thermo Protection Temperaturanalyse who highlighted a number of areas that had surface temperatures in excess of 220°C. The report was received by the technical managers in December 2014 and upon receipt, immediately instructed the vessel's engineers to commence fabrication of insulation protection of those areas identified within the report. At the time of the incident, fabrication of insulation protection on AE1 had not commenced.

4.2.7 The thermal survey concluded that AE1 in vicinity of the fuel oil pressure gauge supply line and turbo charger located towards the rear of the engine had five areas identified via thermal imagery as having a high temperature in excess of 220°C[6].

4.2.8 At the time of ignition AE1 was using heavy oil fuel, which has a typical flashpoint range of between 65~80°C and a typical minimum auto-ignition point of 400°C. Figure 18 identifies the precise surface temperature of the turbo charger whilst under load. As seen on the thermal image the surface temperature recorded ranges from 22.9°C to 234°C. The two areas, SP1 and SP2 highlighted by a red circle have a recorded temperature of 404.8°C and 401.5°C respectively.

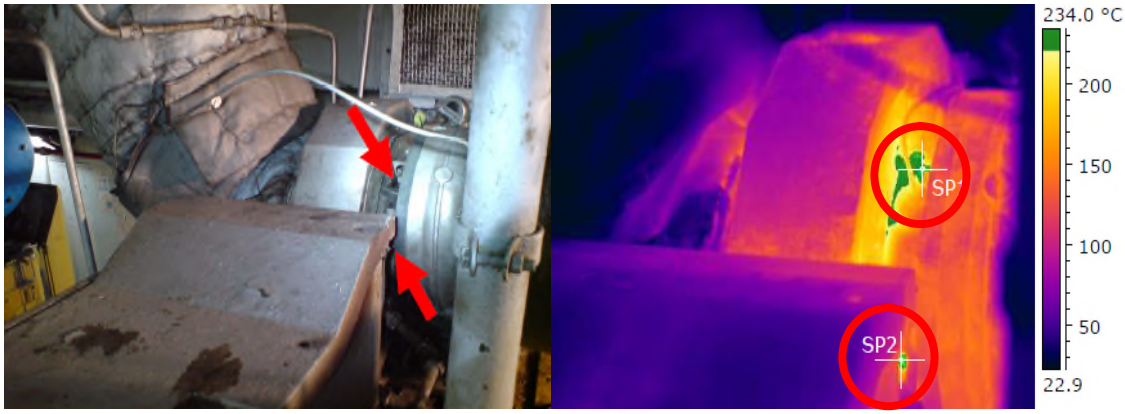


Figure 17: Photo (left) of AE1 turbo charger in vicinity of fuel oil pressure gauge supply line and thermal image (right)

4.2.9 The insulation surrounding the exhaust gas turbo charger identified in figure 19 appears visually adequate[7], however when compared to the thermal image, it clearly detects gaps within the insulation potentially exposing the high temperature surface of the exhaust to the atmosphere.

[6] High Temperature defined within MSC.1/Circ.1321 Guidelines for Measures to Prevent Fires in Engine-Rooms and Cargo Pump-Rooms

[7] "Dry type turbo chargers, if installed, should be completely insulated, as far as practicable, to prevent the existence of high temperature surfaces." MSC.1/Circ.1321 Guidelines for Measures to Prevent Fires in Engine-Rooms and Cargo Pump-Rooms: Chapter 2, paragraph 1.1.4

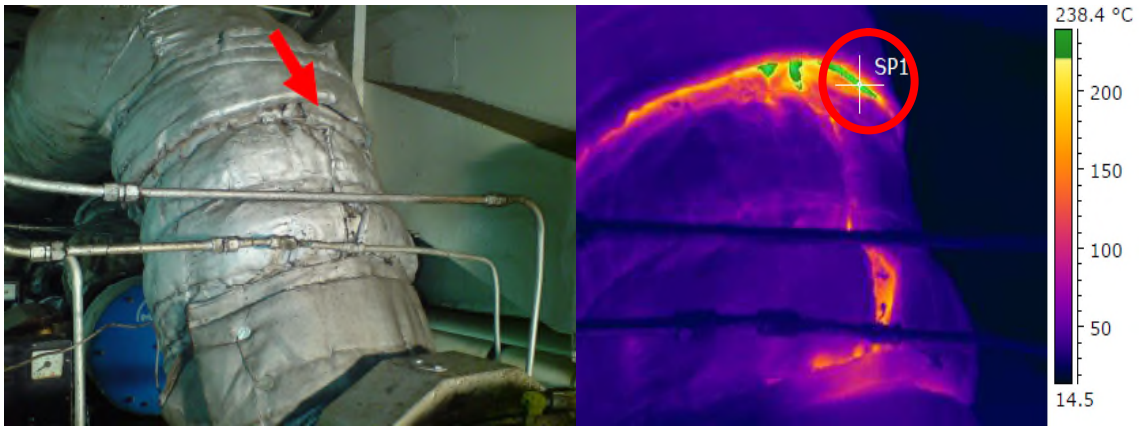


Figure 18: Photo (left) of AE1 turbo charger exhaust in vicinity of fuel oil pressure gauge supply line and thermal image (right)

4.2.10 The thermal image of the bearing housing of the AE1 turbo charger had a maximum-recorded temperature of 445.3°C. The surface of the turbo charger had no insulation or spray shields to prevent flammable oil coming into direct contact with high temperature surfaces.

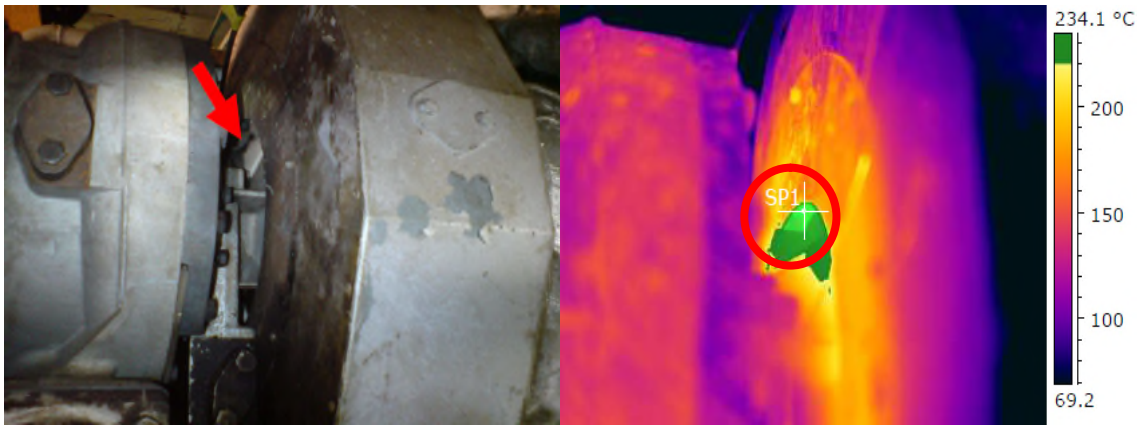


Figure 19: Photo (left) of AE1 turbo charger bearing housing in vicinity of fuel oil pressure gauge supply line and thermal image (right)

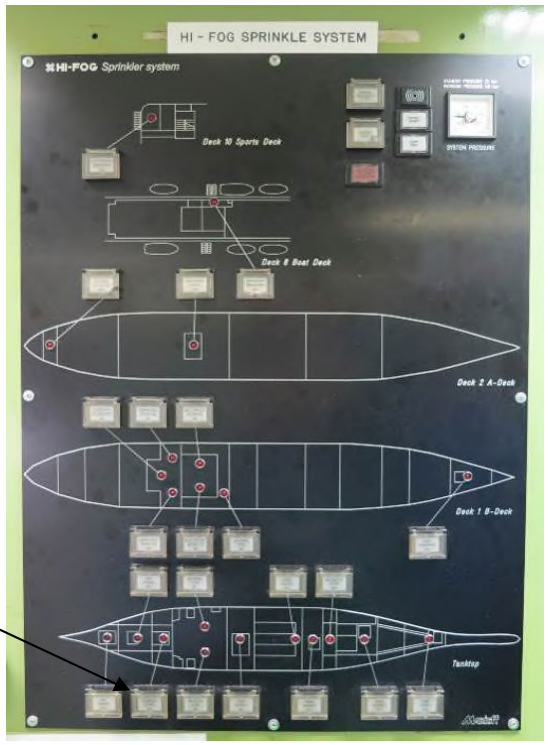
4.3 Hi-Fog Operation

4.3.1 The Hi-Fog zone flooding protection system for machinery spaces is activated when one or more of the release buttons is pressed, opening corresponding section valves, allowing water to the activated section. Water flow in the system results in a signal that is indicated at the Control and Indication Panel.

4.3.2 System control panels are located on the bridge and in the ECR, once activated the decreased pressure flow within the system will activate the relay control unit that will trigger the pump unit to start. The electric motors are started in sequence with a few seconds between each to prevent excessive peak loads.

4.3.3 The Hi-Fog system is fed from a high-pressure tank which is fed from technical water tanks. When the system is activated the level in the high-pressure tank will drop, activating two feed pumps from the technical tanks to resupply the high-pressure tank with seawater via the seawater inlet valves.

4.3.4 The Hi-Fog system was activated in order to extinguish the fire and provide a blanket of water in the vicinity of AE1. The system was activated by the on-watch engineer on the control panel situated in the ECR, in accordance with emergency procedures. Two hours later the Hi-Fog system was stopped having established that the fire had been extinguished.



Button manually activated by the engineer on duty upon confirmation of fire.

Figure 20: HI Fog Sprinkler System Panel

4.3.5 Due to the developing list, which was the first indication the vessel had not restored all systems, it was determined that the Hi-Fog system had continued to operate for 1 hour 14 minutes after the point at which it was assumed it had been stopped. The estimated water discharged into the space during the course of the systems operation was in the region of 80m^3, which was collected in the bilge of the chilling plant and water generation room, aft of the auxiliary engine room that subsequently drained into the tunnel room (tank top).

4.3.6 A Marioff technician, instructed to determine the cause of the system not operating as required, found that at some point during the incident the manual emergency start button had been activated on the bridge panel which starts all high pressure pumps, feed water pumps and overrides the pump units technical tanks high level switch. This resulted in the technical tanks to overflow despite

the reset switch on the ECR control panel being pressed; continuous operation was maintained until the point at which the emergency start button was reset on the bridge control panel.

4.3.7 It may have been apparent to the operator on the bridge if the lamp, indicating the switch was activated had not been faulty, resulting in a delay in switching off the breakers to the system to stop the Hi-Fog system from operating.

4.3.8 Once acknowledged as being the root cause of the 5º list to port, the remaining water was pumped from the bilge restoring the upright condition of the vessel via the onboard emergency bilge pumps.

Figure 21: Bridge – Emergency Start Button

4.4 Command and Control

4.4.1 From receipt of the alarm being raised of a fire within the Auxiliary Engine Room, specifically AE1, the 4/E on watch carried out initial reactions as required, in a timely and controlled manner by instructing the Motorman and Oiler to procced to the location identified on the Autotronica Fire Detection System and investigate the source of the alarm. The Oiler and Motorman conducted a compartment search in accordance with the Chief Engineers Standing Orders and identified the exact location and severity of the fire, which in turn enabled the 4/E to inform the Command Team mustered on the bridge.

4.4.2 Successful command and control of any emergency situation relies on the processing and understanding of information quickly and succinctly by all

members of the emergency organisation. In this instance, in the early stages of determining the severity of the fire, conversations between the Oiler and Motorman, being conducted on the UHF open frequency was not in the common language of the vessel. The 3/O was therefore not in a position to coordinate and control events prior to the emergency organisation establishing itself.

4.4.3 It was determined during the interview that the OOW was unfamiliar with the correct operation of the PA system with regards to which areas the Code Bravo announcement should be made (i.e. crew areas, guest areas). Initially the broadcast was made but immediately after the announcement realised that the incorrect button had been pressed in order to transmit the broadcast. A lack of familiarity is apparent with the operating procedures of fundamental safety equipment designed to expedite a response to an emergency.

4.4.4 An additional emergency procedure exists on board to ensure the Emergency Organisation establishes itself in the quickest possible fashion. Aside from the public address (PA) system, the vessel has a pager system sending a pre-set signal to alert all crew with a pager the appropriate emergency code. The system on board the vessel sent the unrecognised emergency signal 'Red Fox' instead of Code Bravo.

4.4.5 During the course of the investigation, it became apparent that Autronica Alarm System was not synchronized with the ships clock, which being the basis for time on board, meant that multiple systems were recording the same event but displaying a different time. In one case there was a 19 minute discrepancy between the ships clock and the Autronica System. When conducting an investigation and evaluating the evidence from different sources, it is vital that the time each event occurs is accurate in order to piece the events back together.

4.4.6 During the initial investigation phase, the Oiler and Motorman were able to proceed from forward to aft, unobstructed through WTD 20, continuing aft to WTD 21, which they closed prior to backing out of the space via WTD 20, closing it behind them. Both these doors are classified as category B[8] watertight doors. This door should be closed, but left open for the length of time personnel are working in the adjacent compartment. The watertight integrity of the vessel relies on the correct operation and adherence to WTD policy, further, the containment of smoke is paramount in order to avoid smoke ingress to adjacent compartments potentially rendering them unattainable.

[8] A watertight door that fulfils the technical requirements in SOLAS regulations II-1/13.5.1 to 13.5.3 and 13.6 (previous SOLAS regulations II-1/15.6.1 to 15.6.4), which also includes the requirements in paragraph 7 of SOLAS regulation II-1/13 (previous SOLAS regulation II-1/15), and may be opened during navigation when work in the immediate vicinity of the door necessitates it being opened, according to SOLAS regulation II-1/22.3 (previous SOLAS regulation II-1/15.9.2). The door must be immediately closed when the task which necessitated it being open is finished.

5 CONCLUSIONS

5.1 The routine maintenance conducted on AE1 does not reveal any mechanical failure of the fuel oil gauge supply line prior to the fire. Due to the varying fuel oil supply lines on board, determining what may have caused the fuel oil supply line to fracture cannot be determined by simply comparing fuel oil supply lines on other engines with similar operational hours. During the course of the investigation it has been determined that the maintenance and inspection conducted on AE1 refrained from disturbing, disconnecting or tightening of the compression fitting of the fuel oil pressure gauge supply line.

5.2 In conclusion, the steel fuel oil pressure gauge supply line may have suffered from fatigue failure through engine-generated vibrations causing the steel pipe to work-harden resulting in the supply line to become brittle and therefore more susceptible to fracture in vicinity of the compression fitting. It remains inconclusive whether fatigue was responsible for the material failure of the pipe however it should be recognised that AE1 had 4,345 more running hours[9] than the remaining Auxiliary Engines at the time of the casualty.

5.3 The fracture caused the fuel to be sprayed upwards and in the vicinity of the hot surface generated by the turbo charger. If the thermo-protection insulation been fabricated in the vicinity of the turbo charger, thereby providing a barrier to prevent fuel in vapour and liquid form from coming into contact with the exposed hot surfaces of the turbo charger, it could be concluded with a high degree of probability that the fuel in vapour or liquid form would not have had sufficient attributes required to ignite.

5.4 The initial reaction by the crew in establishing a timely emergency response should be commended. The instinct and professionalism exhibited by the crew was instrumental to the successful outcome and proved effective in containing the spread and extinguishing the fire without casualties.

5.5 The operation of the Hi-Fog system was well understood by the crew in regard to its activation. However, it was determined after the fire had been extinguished, whilst in the process of restoring emergency systems that the Hi-Fog remained in operation. Due to a lack of understanding of the electrical control system, by activating the manual emergency start in conjunction with a faulty bulb masking the indication that the system was in operation, the system never restored fully which consequently resulted in a 5° port list.

5.6 Despite the unrecognised emergency pager signal transmitting to senior safety critical crew, it did not seem to delay the response of the emergency organisation. However, this did indicate to the investigator that the pager

[9] The Owners acknowledge that the difference in running hours between the auxiliary engines is planned to ensure the overhaul of all auxiliary engines occur at different times.

system had not been used during any drill prior to the 24th January or else this unrecognised signal would have been identified by the emergency organisation.

5.7 The Company continued to prioritise passenger safety and well-being up until repatriation to the passenger's place of residence. Those passengers who were unable to fly due to personal circumstances were catered for accordingly and without detriment to their health or safety. The Company worked with the relevant authorities to ensure the relevant legislative requirements were in place to the satisfaction of the flag Administration.

***

6 RECOMMENDATIONS

Recommendations for the operator:

6.1 Consider fabricating insulation protection for those areas identified within the Thermo Protection Temperaturanalyse report. In addition, it is recommended that thermal surveys be conducted at regular intervals and on completion of any maintenance or repair of equipment that has been carried out, to ensure that the insulation material has been properly reinstalled or replaced.

6.2 The fuel oil supply lines fitted to the auxiliary engines should meet the manufactures recommended arrangement and only be constructed using the appropriate and approved material and/or components.

6.3 Review the safety management system to ensure it contains specific procedures to identify vibration fatigue. Further, inspect all fuel lines on all auxiliary engines on all vessels in the fleet to ensure where practicable, all lines are secured in a manner to eliminate vibration where possible.

6.4 Ensure the operating procedures of the Marioff water mist suppression system is fully understood by all members of the emergency response team to ensure effective operation and system restoration on completion of use.

6.5 Ensure all members of the bridge watch team are competent in the safe operation of all bridge equipment, particularly equipment required for emergency response procedures.

7. ACTIONS TAKEN

7.1 All Officers and crew have been reminded that the language of the ship is english and of the importance that this is enforced, especially on the bridge, engine control room during all emergency situations.

7.2 A review of the vessel's departure checklist has been updated to include a time check which is to be conducted on all data recording devices and clocks prior to vessel departure from the berth.

7.3 The Owners have implemented a procedure to ensure all WTD's are operated and monitored in accordance with the vessel's stability booklet, DNV Class direction and the BMA bulletin No. 96 (Maintaining Passenger Ships WTD's Open During Navigation).

7.4 A review of the paging system to ensure the code which is transmitted to senior safety critical crew reflects the nature of the emergency and sends the appropriate pre-planned message.

7.5 All Officers of the Watch to have reviewed and understood the operating procedures of the PA system with particular regard to making emergency announcements.

7.6 Operating instructions are now located in the vicinity of both Hi-Fog panels and a review of the standard operating procedures in the use of Hi-Fog operating system has been conducted.

7.7 All fuel lines with similar configurations have been inspected on all vessels to ensure fuel oil pressure gauge supply lines are sound and free from vibration.

LIST OF APPENDICES

I. **Hi-Fog post incident report**

II. **Auxiliary Generator Front End Schematic (MaK 6M20 1020kW)**

III: **Additional photos**

***

Appendix I: Hi-Fog post incident report

HI-FOG® water mist fire protection

REPORTSHEET

Site :	MS Boudicca	Proj. ref:	30127	Date :	29.1.2015
Customer :	Fred. Olsen Cruise Lines Ltd.				
Address :	C/O Fred. Olsen Marine Services [redacted]				
Tel. :	[redacted] Technical Superintended				
Service ☒ Commissioning ☐ Training ☐ Warranty ☐ Other ☐					

Type of Fault or Work To Be Done Described by The Customer:

Post fire inspection on board MS Boudicca.

Description of Work Carried Out:

System condition was following when ship arrived to Teneriffe on 27.1.All motor circuit breakers for hi-pressure and feed water pump were switched off and nitrogen release solenoid plug was disconnected. Pump unit had a start request all the time active so crew couldn't stop the pump unit by resetting the system, that's why the pump unit was stopped by switching off motor circuit breakers.
After a short investigation was found out that manual emergency start signal was all the time active at the pump unit, this manual emergency start signal starts all the hi-pressure pumps, feed water pump and overrides pump unit's break tank high level switch which is controlling feed water pump starting and feed water solenoid valve for tank filling which caused the break tanks overflowing and preventing to stop the system by resetting.
Manual emergency start signal was activated from bridge's mimic panel, my opinion is that emergency start was activated during the fire and because button is a latching type and indication lamp was broken nobody noticed that it is activated, which caused previously mentioned pump unit's continuous activation and stopping the pump unit by switching off breakers.
As the pump unit was stopped by switching off motor breakers and perhaps crew tried to switch breakers on again, this caused motor no. 4 breaker F4 to damage, F4 breaker was connecting only 2 phases as 1 phase contact was broken.
Motors shouldn't be stopped and started by main three phase 63A breakers, for this reason there is control breakers 2A which are controlling motor contactors in starter cabinet. Breaker is now changed by using a spare breaker from ship's stock.
During testing was noticed that stabilization valve doesn't close each time after stabilization, valve overhauled with a repair kit.

List of functionality tests and repairs which are done during this visit:

- *Cleaned water filter and pump unit's break tank, verified correct operation of feed water pump and valve.*
- *Motor no. 4 breaker F4 replaced.*
- *Bridge mimic panel manual emergency start button indication lamp replaced.*
- *Manual emergency start tested from all three panels.*
- *Flow start, low pressure start and machinery start for pump unit tested.*
- *Redundancy motor start tested.*
- *Nitrogen back-up release tested electrically.*
- *Stand-by pump replaced.*
- *All spray heads from section M3 replaced and four spray heads from section M2 replaced with new ones.*
- *Loose connection on bridge mimic panel's dimmer knob fixed.*
- *Stabilization valve (NS12) overhauled with a repair kit.*
- *Section M3 wet tested, section released from ECR release panel and from local release button inside protected area.*

System left in fully operational and stand-by mode.

Marioff Corporation Oy, Field operations • Äyritie 24, FI-01511 Vantaa, Finland
Tel. +358 (0)10 6880 000 • Fax +358 (0)10 6880 010 • www.marioff.com
Trade reg. no. 355.854 • VAT no. FI06033807

Figure 22: Hi-Fog post incident report (page 1)

Page 2 of 2

HI-FOG® water mist fire protection

Engineer's Comments / Recommendations / Notes:

Recommended to replace Hi-Fog piping in burned area because of smoke damages.
Recommended to order repair kit for stand-by pump (Maximator) or a new spare pump to ships stock.
Recommended to order one 63A ABB breaker + auxiliary contact to ships stock.
Recommended to replace bridge mimic panels and ECR release panels pressure gauge as it is not working now.
Recommended to replace cable (2x1,5) between junction box and M2 section valve solenoid because of slightly damaged insulation of the cable.
Recommended to connect fire detection system to Hi-Fog system in order to have automatic release operational.

Materials Used, Description:	Qty :	Code :	Site Time Info				
			Date :	Hours :		Travelling :	
				Norm:	Overtime:	Hours :	Km:
NS12 Repair kit D0.7	*1*	*V11070.A*	*27.1.2015*	*4h*		*10*	
Spray head 4S1MC8MB1000	*6*	*C31120*	*28.1.2015*	*12h*			
			29.1.2015	*4h*			
			30.1.2015			*10**	

*estimated

MARIOFF CORPORATION OY

Engineers Signature: [redacted]

Clarification of signature

Customers' Signature/Date: [redacted] 29.1.2015

Clarification of signature [redacted]

Marioff Corporation Oy, Field operations • Äyritie 24, FI-01511 Vantaa, Finland
Tel. +358 (0)10 6880 000 • Fax +358 (0)10 6880 010 • www.marioff.com
Trade reg. no. 355.854 • VAT no. FI06033807

Figure 23: Hi-Fog post incident report (page 2)

Appendix II: Auxiliary Generator Front End Schematic (MaK 6M20 1020kW)

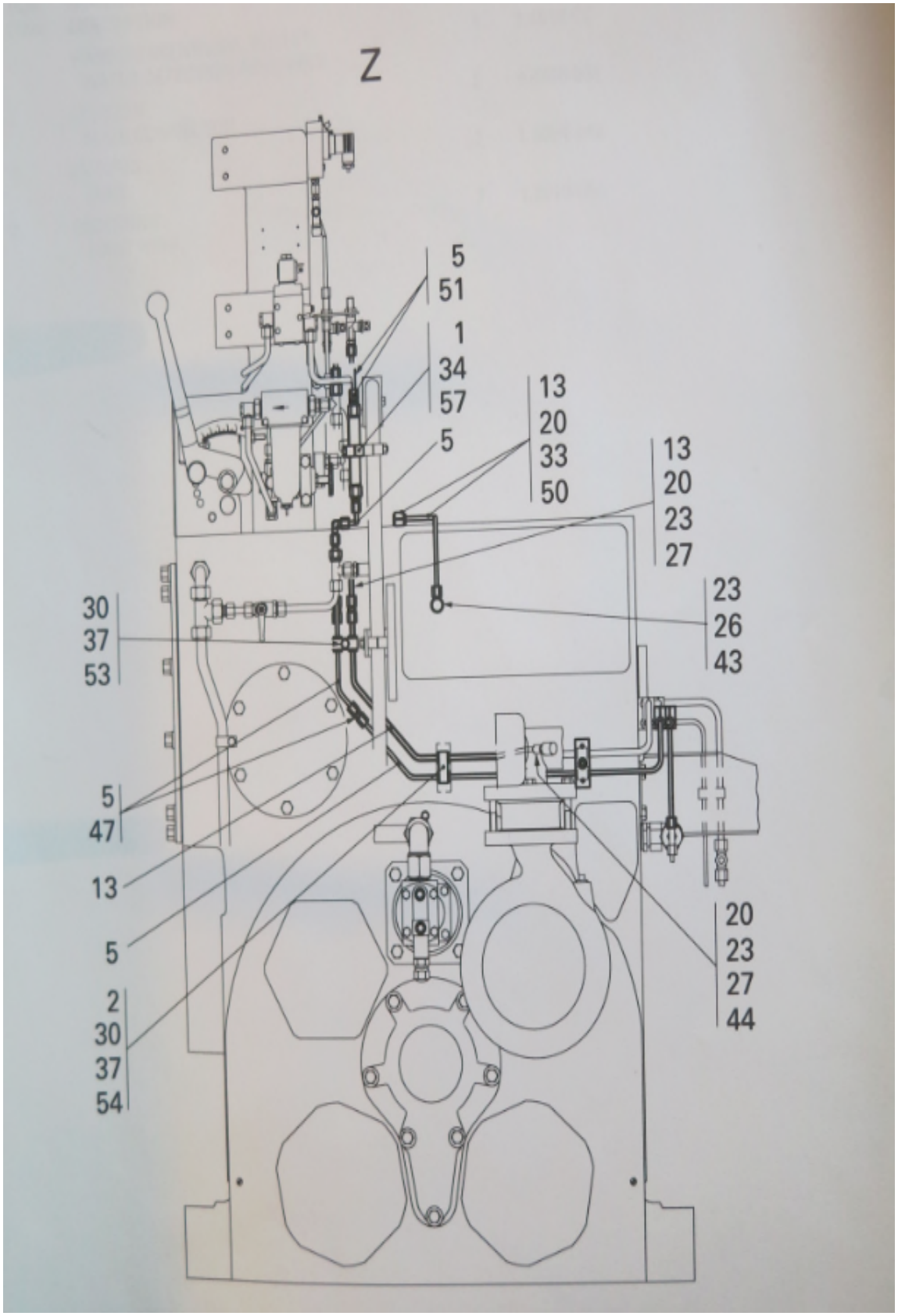


Figure 24: Front End MaK 6M20 Auxiliary Engine

Appendix III: Additional Photos

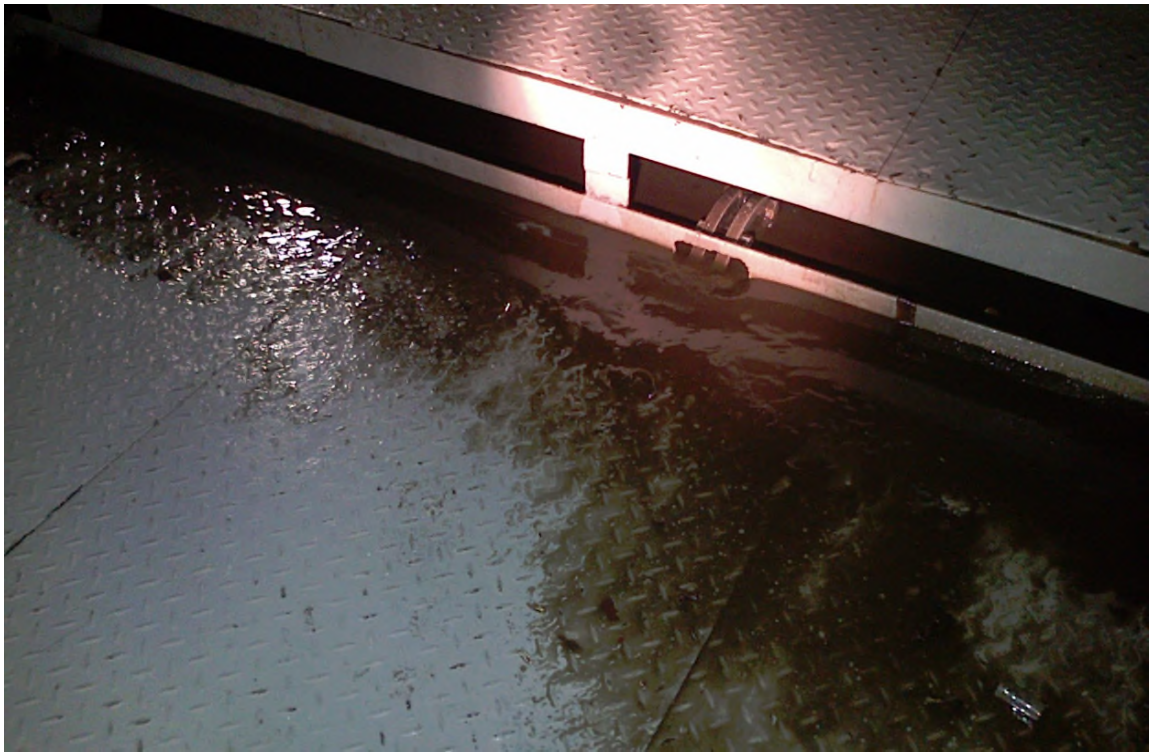


Figure 25: Mid tunnel tank top flooding (Frame 40-60)

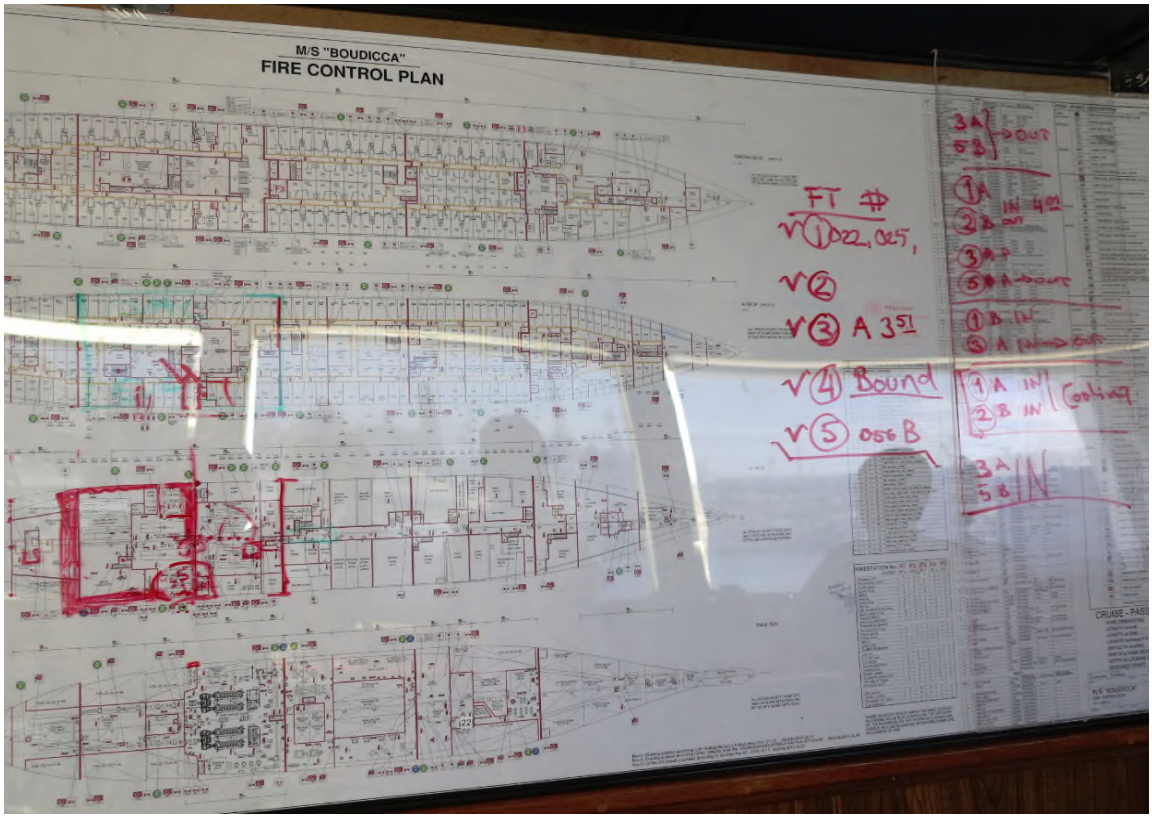


Figure 26: Fire Control Plan

Figure 27: Fractured fuel oil pressure gauge supply line

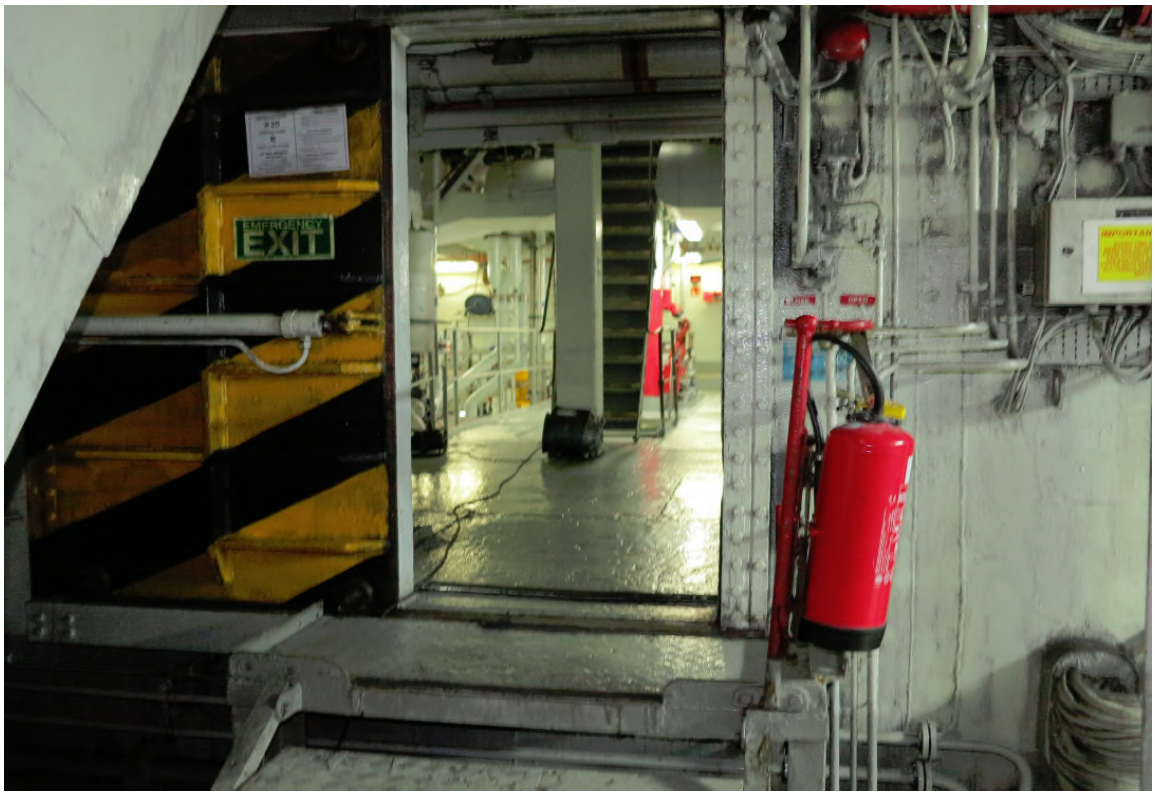


Figure 28: WTD No. 20 looking aft into the Main Engine Room