

Final Report

FIRE ON BOARD MAERSK HONAM AT ARABIAN SEA ON 6 MARCH 2018

MIB/MAI/CAS.035

Transport Safety Investigation Bureau
Ministry of Transport
Singapore

5 October 2020

The Transport Safety Investigation Bureau of Singapore

The Transport Safety Investigation Bureau (TSIB) is the air, marine and rail accidents and incidents investigation authority in Singapore. Its mission is to promote transport safety through the conduct of independent investigations into the air, marine and rail accidents, and incidents.

TSIB conducts marine safety investigations in accordance with the Casualty Investigation Code under SOLAS Regulation XI-1/6 adopted by the International Maritime Organization (IMO) Resolution MSC 255(84).

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SYNOPSIS

On 6 March 2018 at about 1945H (Local Time), in fine weather, the Singapore registered container ship Maersk Honam (MH), which was carrying 7860 containers, while en route from Singapore to Suez Canal, encountered a severe fire that started from no.3 cargo hold when the ship was in the Arabian Sea, about 900 nautical miles west of the coast of India.

All the 27 crew responded to fight the fire by commencing boundary cooling and subsequent release of carbon dioxide (CO₂) into the cargo hold but were not successful in extinguishing the fire. The crew sent out a distress signal and eventually abandoned ship at about 2215H.

On 7 March 2018 at about 0130H, another ship, the ALS Ceres¹, which had responded to the distress signal, picked up a total of 23 crew from the lifeboat. Four crew members were reported unaccounted for and declared missing. Search and Rescue (SAR) operations of the surrounding seas were carried out. One of the surviving crew succumbed to the injuries while en route ashore for medical treatment.

After MH was abandoned, continuous firefighting and boundary cooling was carried out² by several assisting ships for about five days, due to smouldering (hotspots) inside the cargo holds forward of the accommodation, to bring the raging fire under control.

On 10 March 2018, the salvage team boarded MH for firefighting and SAR operations, where they recovered remains of three of the four missing crew the next day.

Due to the severe fire occurrence that affected the accommodation space, no.1, 2 and 3 cargo holds, MH was unfit to proceed on voyage, and the Company arranged for the ship to be towed to United Arab Emirates (UAE) as the port of refuge after the smouldering of the cargo hold had subsided.

The Transport Safety Investigation Bureau classified the occurrence as a very serious marine casualty.

¹ Ship ALS Ceres established communication with Maritime Rescue Coordination Centre (MRCC) Mumbai for firefighting and SAR operations.

² The ships involved in firefighting and boundary cooling were Indian Coast Guard ship(s) and six Company's engaged crafts and about 32 personnel were involved in firefighting and boundary cooling operations.

As most of the evidence was destroyed by fire, the investigation team was not able to conclusively determine the cause of the fire. However, there was evidence that the integrity of SDID³ in no.3 cargo had been compromised such as the chlorine-smell smoke, the irritating and uncomfortable feeling, including breathlessness experienced by the crew at the onset of the event. The heat generated by spontaneous self-decomposition of the SDID worsened, as it was carried in block stowage.

Apart from looking at the cause of the fire, the investigation also covers the appropriateness of emergency responses of the crew, the emergency response plan and the design of the fire containment and firefighting equipment on board the ship.

Despite the good efforts demonstrated by the crew in taking care of each other and saving lives during the emergency, it was noted that the fire alarm was not raised at the onset of the event causing a delay in the closure of the magnetic fire doors of the accommodation, and non-closure of exterior ventilation vents. These had resulted in toxic smoke entering and spreading within the accommodation areas.

The muster list did not clearly identify the roles of everyone on board, which resulted in some of the crew waiting to be given instructions. The investigation also revealed that the firefighting flow charts under the ship emergency response plan did not ensure that all the ventilator flaps/ dampers on board were closed as one of the primary firefighting actions, regardless of the location of fire.

The investigation team also noted that due to the intense heat and smoke all ventilator flaps on the sides of No.3 cargo hold hatch covers had proven to be challenging to close.

In addition, the investigation revealed that the secondary hazards of chemical decomposition/ instability of SDID had not been identified in the IMDG⁴ Code. This is because SDID was classified under Class 9 in the IMDG Code, instead of the more stringent Class 5.1 (oxidising substances), despite having similar chemical properties as those in Class 5.1.

³ Sodium Dichloroisocyanurate Dihydrate (SDID) - under Class 9 is an active ingredient in dry bleaches, dishwashing compounds, scouring powder detergent sanitizers, swimming pool disinfectants, water, and sewage treatment. SDID contains a chlorine content of 56% as compared to Dichloroisocyanuric acid in which the chlorine content is 62%.

⁴ International Maritime Dangerous Goods.

VIEW OF MAERSK HONAM



Figure 1

DETAILS OF SHIP

Name	Maersk Honam
IMO Number	9784271
Flag	Singapore
Ship type	Container Carrier ⁵ - Twin Island type ⁶
Year Built ⁷	31 August 2017
Owner	A.P. Moller Singapore Pte. Ltd.

⁵ Container carrier is a seagoing ship specifically designed, constructed, and equipped with the appropriate facilities to carry cargo containers. These containers are stowed in cargo spaces (i.e. in cargo holds below deck) and on hatches and cargo areas located on the weather deck. A fully cellular type carries only containers with cell-guides under deck and the necessary fittings and equipment on deck.

⁶ The accommodation (forward) and engine room (aft) are separated from each other to maximise the cargo carrying capacity.

⁷ Keel laid before 1 Jan 2016

Company ⁸	Maersk Line A/S
Classification Society ⁹	American Bureau of Shipping (ABS)
ISM ¹⁰ RO - Document of Compliance (DOC ¹¹)	Lloyds Register of Shipping (LR)
ISM RO ¹² - Safety Management Certification (SMC ¹³)	ABS
Gross tonnage	153,153
Length overall	353.02m (Distance from mid-accommodation to mid-engine room casing about 172m) See figure 2 showing Plan for MH upper deck
Breadth	53.56m
Depth	29.90m
Summer draft	16.02m
Displacement	193,377.16tonnes / 207,748 tonnes (Summer)
Height	72.85m
Main Engine(s)	Hyundai-MAN B&W 8G95ME-C9.5 MCR: 54,960kW

⁸ Company means owner of the ship or any other organisation or person who has assumed responsibility for operation of the ship...and who on assuming such responsibility has agreed to take over all the duties and responsibility imposed by the International Safety Management Code.

⁹ Also referred to as a Recognised Organisation (RO), which means an organisation that has been assessed by a flag State and has the delegation of authority to perform statutory certification and services on behalf of the flag State. All statutory certificates issued by ABS on behalf of the flag State were as per the relevant conventions and valid till 30 August 2022.

¹⁰ International Safety Management System (ISM) means a structured and documented system enabling the Company to effectively implement the Company's Safety and Environmental Protection policy.

¹¹ DOC means a document issued to a company which complies with the requirements of the ISM Code.

¹² Flag Administration approved RO for issuance of Safety Management Certificate.

¹³ SMC means a document issued to a ship which signifies that the Company and its shipboard management operate in accordance with the approved safety management system.

	NCR: 49,464kW
Diesel Generators	Four nos. Hyundai Himsen @ 6H32/40 2850 kW
Shaft Generator	One no. Siemens@3200kW
Speed	21.90kts @ N.C.R 49,464kW x 77.2rpm
Propeller	One five-blade fixed right-handed propeller
Thruster ¹⁴	Two (Bow) + two (Stern) @ 25 tons/each
Nominal TEU In Hold On Deck / Hatch	15,282TEUs ¹⁵ (Total: 1000 reefer plugs) 8'6" (normal) x 10 tiers + 9'6" (high cube) x 1 tier 8'6" x 11 tiers
Fire Fighting Equipment and Systems ¹⁶	
Two pumps serving as combined Fire and General Service (G/S) pump	Fire mode: 310m ³ /h@11 bar G/S mode: 555m ³ /h@3 bar
Emergency Fire Pump (One set)	Capacity 72m ³ /h
Self-Contained Compressed Air Breathing Apparatus with two spare air cylinders ¹⁷	Two sets at the A-deck ¹⁸ (Fire Control Station). (See figure 3 showing MH accommodation block and its deck levels) Two sets at Funnel deck (engine casing) One set at Bosun store (forward) c/w chemical suit
Heat Resistance protective suit	Two sets at A-deck (Fire Control Station)

¹⁴ The bow and stern thrusters are placed in the through-and-through tunnels which open at both sides of the ship. There are two such tunnels – at forward and aft ends of the ship. The thruster takes suction from one side and throws it out at the other side of the ship, thus moving the ship in the opposite direction. These thrusters (bow thruster or stern thruster) are a transversal propulsion device to make the ship more manoeuvrable.

¹⁵ TEU stands for Twenty-Foot Equivalent Unit (standard 20' container) which are used to measure a ship's cargo carrying capacity.

¹⁶ The ship's construction for fire protection, fire detection and fire extinction per the relevant sections of the SOLAS 2012 Amend/ Chapter II – 2 as per the approved fire control plan.

¹⁷ The two spare air cylinders were located inside the Wheelhouse Air-Cond Unit Room at the upper deck on the port side.

¹⁸ Refer to figure 3 showing deck layout of the forward accommodation.

(Complete Fireman's suit)	Two sets at Funnel deck (engine casing)
Emergency Escape Breathing Device (EEBD)	Five sets at A-deck (Fire Control Station) 10 sets located strategically inside Engine Room
Fixed Fire Extinguishing System for Cargo Hold	Carbon Dioxide (CO ₂) gas used as a medium for fire extinguishing system for engine room and cargo holds. A CO ₂ tank capacity of 29,722kg is located inside CO ₂ room at the Under-deck space below the accommodation. The tank was having a CO ₂ quantity of about 28,500kg (minimum required was 23,931kg for the largest space)
Life-Saving Appliances ¹⁹	
Lifeboat (Gravity type-fully enclosed)	34-person capacity – total two, located at Accommodation A-deck (port and starboard side).
Life rafts (with embarkation rope ladder)	20-person capacity - total four, with hydrostatic release unit located at Accommodation A-deck (Two port and Two starboard). 6-person capacity - total four, manual launching. Two each located at the main deck forward and engine casing, with one on each side of the ship.
Departure Condition (from Singapore and at the time of the occurrence)	
Draft at Forward / Aft / Midship	15.09m / 15.16m / 15.12m
Metacentric height (GM)	3.50m

Table 1

¹⁹ The ship's Life-Saving Appliances and arrangements are as per the relevant sections of the SOLAS 2017/ Chapter III/ Amendment (98th) as per the approved life-saving appliances plan.

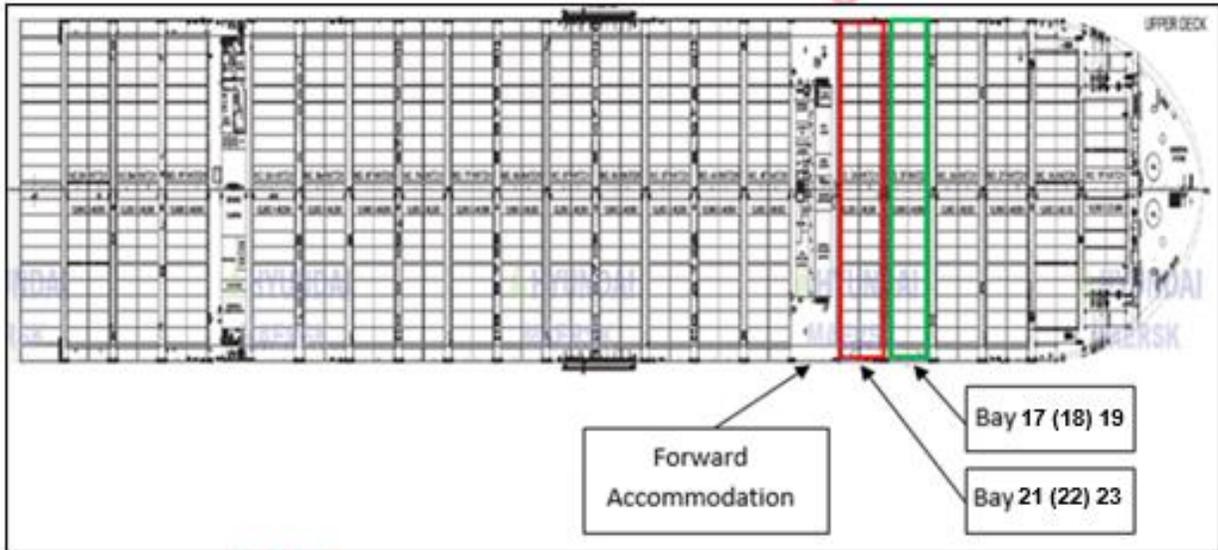


Figure 2 - Upper Deck Plan²⁰ indicating no.3 cargo hold consisting of bays 17~23

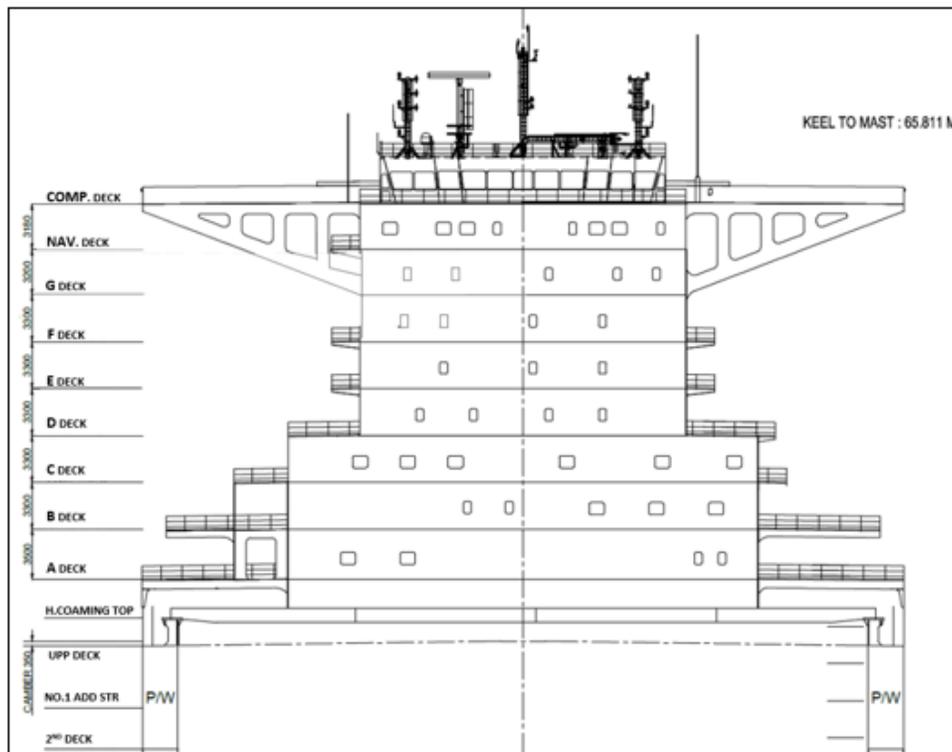


Figure 3 - Accommodation viewed from the bow

²⁰ Bay 17 (18) 19 in-way of no.3 cargo hold forward section (green box)
 Bay 21 (22) 23 in-way of no.3 cargo hold aft section (red box)

1 FACTUAL INFORMATION

All times used in this report are Ship's Mean Time (SMT) unless otherwise stated. SMT is five hours ahead of Coordinated Universal Time (UTC²¹).

An independent Fire Forensic Expert²² was engaged by the Company to determine the origin and cause of the fire on board MH.

In May 2018, the investigation team, together with the Fire Forensic Expert, boarded the MH off Dubai, UAE, for an on-site assessment of the condition.

In addition to the information gathered from an on-site assessment and that provided by the Fire Forensic Expert, the investigation team had access to and reviewed the ship's voyage data recorder, video recordings provided by the Company, event logs from the ship's alarm systems and statements of the 22 survivors.

The investigation team also conducted phone interviews of the relevant crew to validate some of the information that was not in the statements.

1.1 Narrative²³

According to the Master

1.1.1 On 1 March 2018 at about 2000H, MH completed its routine cargo operations in Singapore which included discharging of 725 containers, loading of 3401 containers, and re-stowing of 27 containers. The ship departed²⁴ with a mean draught of about 15.1m, bound for Europe via the Suez Canal, Egypt. MH estimated time arrival (ETA) Suez Canal was on 11 March 2018.

1.1.2 In addition to cargo operations, MH had carried out a scheduled crew change. Since more than 25% of the crew had been changed²⁵, the Master had planned to carry out an abandon-ship and fire drill within 24 hours of the ship's departure from Singapore.

²¹ UTC – is the primary time standard by which the world regulates clocks and time.

²² Dr J H Burgoyne & Partners DMCC (hereinafter referred to as “the Fire Forensic Expert”). The investigation team had no objection for this appointment.

²³ Combination of statements and information obtained from the Company.

²⁴ During the ship's port stays in Singapore, containers were loaded and discharged as per the cargo plan and the ship departed Singapore with 7860 boxes of containers.

²⁵ The International Convention for the Safety of Life at Sea (SOLAS) 1974, Chapter III/ Reg.19, part 3.2 – Abandon-ship drill, requires that the drills of the crew shall take place within 24H of the ship leaving a port if more than 25% of the crew have not participated in abandon ship and fire drills on board that particular ship in the previous month.

- 1.1.3 On the following day, 2 March 2018, the Master carried out accommodation inspection which was followed by an abandon-ship drill and a table-top exercise for accommodation fire, as part of the ship's drill planning schedule²⁶. During the abandon-ship drill, a full mustering of the crew was carried out which was followed by testing of lifeboat engines, launching procedures for the lifeboats and life rafts, in addition to familiarisation and use of Life-Saving Appliances (LSA).
- 1.1.4 During the table-top exercise for the fire drill, the Chief Mate (CM) conducted the training and briefing as follows:
- a. Duties of each crew during a fire emergency; and
 - b. Familiarisation with on board firefighting equipment (FFE).
- 1.1.5 After completion of the drills, the LSA and FFE used for demonstration were restored to their designated locations in a satisfactory condition.
- 1.1.6 Due to the hectic schedule expected after crossing Suez Canal, the Master had planned an evening of daily routine deck inspection (usually lasting about two hours) to commence from the bow towards the stern, and for it to be completed before the ship's transit.
- 1.1.7 On 6 March 2018, as usual at about 1530H, in fine weather condition²⁷ with cloudy sky, the Master commenced rounds on the main deck. The Master saw the crew were washing the accommodation deck, main deck, and cross-deck aft of the accommodation and noted that there was no activity, maintenance, or repair works being carried out forward of the accommodation. By about 1730H, the Master returned to the cabin after completing the deck inspection.
- 1.1.8 At about 1945H²⁸, while resting inside the dayroom, the Master was alerted by an alarm²⁹ inside the Master's cabin. Following that, the Master received a phone call from the bridge with the CM reporting of smoke detection system³⁰ alarm from no.3 cargo hold mid³¹ (located forward of the accommodation). The

²⁶ A fire drill for cargo space (under-deck) was planned for 7 March 2018.

²⁷ 6 March 2020 - The air and sea temperatures recorded during 12-4 watch was 26°C and 29°C respectively. The Company's data exchange system recorded an average of 28°C for a 4-day period.

²⁸ Ship's position Latitude 10°45.58'N Longitude 065° 55.45'E recorded on the Voyage Data Recorder (VDR).

²⁹ Triggered by smoke in the cargo hold.

³⁰ This system detects the atmosphere inside the cargo hold.

³¹ No.3 mid – position of the sampling pipe in-way of bay 19 and 21.

Master took a walkie-talkie³² from the cabin (pre-set at channel 7³³) and started to check the cargo bay plan (spotting list) for no.3 cargo hold with the CM. At about 1951H, the Master instructed the CM (through the walkie-talkie) to raise the fire alarm³⁴.

- 1.1.9 On the way up to the bridge, the Master recalled hearing the general alarm³⁵. Arriving at the bridge, the Master could sense smell of chlorine³⁶, but could not see any smoke.
- 1.1.10 As per the ship's muster list³⁷, in the event of fire on deck, the Master was to take over the navigational watch and be in-charge of all operations. The Master was to be assisted by the Second Mate (2M) in the conduct of radio communications, and one Able Seafarer Deck (ASD-4) on the steering wheel.
- 1.1.11 At about 1955H, the Master duly took over the conn³⁸ from the CM and announced on the public address (PA)³⁹ system about the fire⁴⁰ in no.3 cargo hold and for all personnel to proceed for muster station.

³² In addition to telephone, the ship was provided with several sets of walkie-talkies for internal communication. To assist communication from any locations on board the ship, booster units with relays were provided. These booster units were supposed to be connected to the emergency source of power.

³³ Indicated in the muster list – UHF (walkie-talkie) channel 7 had been assigned for on board communication during emergency.

³⁴ Alarms described in the muster list were as follows:

General alarm - at least seven short blast followed by one long blast on the ship's whistle followed by public address PA-announcement.

Fire Alarm – alarm bells and alarm sirens sounded continuously – referenced as a two-tone alarm - (followed by PA-announcement), and one long blast for a period of not less than 10 seconds at least three times. The two-tone alarm is a distinct alarm, comprising a hooter and ship's bell. *It can be activated by pressing the manual call points located on various parts of the ship, including a console on the bridge. Pressing this alarm activates and closes the magnetic fire doors within the accommodation. The alarm also gets activated if a detector of the fire detection system gets activated and is not reset within three minutes.*

Abandon ship – order is given verbally by the Master or the substitute either in person or by radio.

³⁵ It can be either activated manually or by selecting the "auto" button and is located on a console on the bridge. Activating this alarm does not affect the closure of the magnetic fire doors in the accommodation.

³⁶ Ship's crew later reported encountering of white coloured smoke with strong bleach/ chemical smell, besides breathing difficulty, also caused skin and eyes irritation.

³⁷ SOLAS 1996 – 1998 Amend/ Chapter III/ Regulation 8 and SOLAS 2017 Amendment (98th) Chapter III/ Reg.37 on muster list and emergency duties. The muster list was provided by the Company. The muster list had designated the bridge as a safe area for control station and safety centre in the conduct of firefighting on board the ship. The fire control station (FCS) was the designated muster station for all the crew in a fire emergency.

³⁸ Conn of the ship refers to having command of the ship's movement at sea.

³⁹ As required by SOLAS 1974, III/ 6.4, as amended, as a part of emergency alarm system for summoning crew to muster station and to initiate the actions included in the muster list. The PA and the ship's auto telephone were connected to the emergency source of power. PA system was located in the navigation bridge, while each cabin and common spaces were fitted with a telephone. It was also possible to make announcement using a 'paging' facility on the telephones, by pressing '0'.

⁴⁰ The fire alarm was not raised at this time.

According to the CM

- 1.1.12 MH's stay in Singapore for all operations was uneventful. Cargo operations specifically involved no.3 cargo holds were:
- a. At Bay⁴¹ 22⁴²
 - Discharge of 50 containers from inside the cargo hold and 11 containers from the above deck: and
 - Loading of 204 containers inside the cargo hold and 89 containers above deck.
 - b. At Bay 18
 - Re-stowing of a container on the deck.
- 1.1.13 Following the standard industry and shipboard practice, before commencing loading operations, the CM received detailed information from the agent and cargo planner about the planned cargo loading which, amongst others, included the quantity, weight, and stowage location of each container. The CM also received detailed information, for the different types of containers e.g. reefer, out of gauge (i.e. outside), IMDG containers, etc.
- 1.1.14 The CM recalled importing the cargo information into the ship's cargo computer system for stability calculations, referred to as the "Loadstar⁴³". The Loadstar, besides providing ship's stability information also had options to check the stowage of the IMDG containers and their compliance with the Class approved Document of Compliance⁴⁴ "Special Requirement for Ships Carrying Dangerous Goods".
- 1.1.15 If any IMDG containers were found to have been incorrectly planned for stowage, i.e. in breach of the IMDG Code, the CM would inform the planners to re-stow or re-plan before the actual containers were loaded. During MH's port stay in Singapore, the Loadstar did not indicate any stowage abnormalities or conflicts between IMDG containers planned to be loaded and those that were on board.

⁴¹ Bay is an athwart ship block of containers associated with a hatch or hatch cover containing multiple stacks extending longitudinally between two adjacent lashing bridges or lashing stations.

⁴² All containers loaded and discharged from bay 22 were dry containers. There were no dangerous goods (as per IMDG) or reefer containers involved at the port of Singapore.

⁴³ Loadstar is a loading instrument, which was approved by ABS.

⁴⁴ Issued in pursuance of the requirements of Regulation II-2/ 19.4 of the International Convention for the Safety of Life at Sea, 1974, as amended. As per this document, MH was permitted to carry IMDG Class 5.1 under deck as well as on the weather deck (except on deck 8 Forward and 9 Aft). IMDG Code also permits the carriage of IMDG Class 5.1 on the weather deck and under-deck.

- 1.1.16 On the morning of 6 March 2018, the CM commenced the daily routine by keeping a navigation watch from 0400H – 0800H. After breakfast, at about 0830H, the CM carried out a deck inspection. That morning, the CM had tasked the crew to sweep and wash the main deck and the cross-deck area, aft of the accommodation. The CM confirmed that there was no job assigned to the deck crew forward of the accommodation or in the vicinity of no.3 cargo hold.
- 1.1.17 After completing the deck inspection, the CM returned to the ship’s office for routine paperwork and retired to the cabin after lunch.
- 1.1.18 Later in the day, the CM reported to the bridge for keeping the evening navigation watch (1600H – 2000H). At about 1730H, the CM was relieved for dinner by the Third Mate (3M) and returned to the bridge in about 15 minutes. The CM was later joined by the ASD-1 who came to the bridge at about 1800H, to perform the role of a lookout during hours of darkness (as per the ship’s watchkeeping schedule).
- 1.1.19 At about 1945H, when MH was heading 286°True (T) at about 20 knots⁴⁵ and had the wind⁴⁶ about four points⁴⁷ on the starboard bow at 14 knots, no.3 cargo hold smoke alarm⁴⁸ at the “Central Alarm Management System” (CAMS) located on the bridge, sounded.
- 1.1.20 The CM acknowledged the alarm on the panel, switched on the deck lights, and sent the ASD-1⁴⁹ to the main deck to investigate. The CM then reported the nature of this alarm to the Master by the ship’s telephone. While on the phone with Master, a high-level alarm for no.3 LS/ DB WBT⁵⁰ starboard which was empty, sounded. This was then followed by a smoke alarm from no.2 cargo hold.
- 1.1.21 Shortly after, at about 1952H, the ASD-1 reported via walkie-talkie (pre-set at channel 7) that white-coloured fumes (also referred by some crew as smoke) could be seen emanating from centre aft of bay 18. The ASD-1 further added that the smoke was getting thicker. At about the same time, the CM sounded

⁴⁵ Knots is a unit of speed equal to one nautical mile (1.852km) per hour

⁴⁶ The relative wind force and direction recorded from the VDR. This indicated true wind of ENE at about 14 knots. The direction has been converted into points measured from the bow.

⁴⁷ A point is about 11.25 degrees (from centreline of the ship measured from the bow). Fine on the bow, thus, indicated bearings that are less than a point or close to the bow.

⁴⁸ Previously referenced in **footnote 30** and hereafter referred to as a smoke alarm.

⁴⁹ The ASD-1 using the internal stairway to go to the main deck, could smell a chlorine like odour, but later-on recalled dismissing as “*Maybe it’s from the laundry*”.

⁵⁰ No.3 LS/ DB WBT – No.3 Low Side/ Double Bottom Water Ballast Tank.

the general alarm⁵¹.

- 1.1.22 Once the Master arrived on the bridge, the CM went to the muster station which was at the fire control station (FCS). As per the muster list, in the event of a deck fire onboard the ship, the CM would be in-charge of the “Emergency Team” (ET) and besides mustering (including headcount) would oversee the firefighting operation and prepare the crew for boundary cooling.

According to the Chief Engineer (CE)

- 1.1.23 On the morning of 6 March 2018, after breakfast at about 0745H, the CE arrived at the Engine Control Room (ECR) and joined the morning routine toolbox meeting conducted by the Second Engineer (2E). All the Engine Room (ER) crew were present at the meeting.
- 1.1.24 After the meeting, the CE carried out the main engine (ME) performance check as per established procedures, while other ER crew went about doing their assigned tasks.
- 1.1.25 The 2E supervised some crew who had been assigned for cleaning of the sea-chest. The Electrical Engineer (EE) was working on the electrical switch for the emergency fire pump, while the Third Engineer-1 (3E-1) assisted by the Engine Cadet-2 (EC-2) carried out alarm tests for all four diesel generators. There was no work assigned to the ER crew at, or in the vicinity of no.3 cargo hold.
- 1.1.26 By about noon, the CE had completed the performance test of the ME and had returned to the accommodation for lunch. The CE then continued working on the analysis of the ME’s performance test which was completed by the evening. The CE then freshened up, had dinner, and returned to the cabin.
- 1.1.27 At about 1945H, while the CE was resting inside the cabin, a smoke alarm on the CAMS repeater panel in the CE’s cabin sounded. The CE immediately changed into work overalls (hereinafter referred to as boiler suit), took a walkie-talkie (pre-set to channel 7), and went down to the muster station at the FCS. Through the walkie-talkie, the CE overheard the CM telling the ASD-1 about the alarm at no.3 cargo hold. The CE also subsequently heard an announcement on the ship’s PA system about a fire in no.3 cargo hold.
- 1.1.28 At that time, the CE did not recall encountering any smoke or any unusual odour inside the accommodation or in the stairway.

⁵¹ It could not be established why this alarm was raised by the CM (after being informed by the ASD-1 that smoke could be seen from no.3 CH), instead of the fire alarm, as instructed by the Master.

1.1.29 As per the muster list, in the event of a deck fire on board the ship, the CE (assisted by the 3E-1) was to take over the watch in the ER, direct the preparation and operations of fire pumps, and in consultation with the Master, supervise the release of CO₂ for firefighting. On this day, the CE was instructed by the Master to proceed to the FCS.

According to the 2E

1.1.30 On the morning of 6 March 2018 at about 0600H, the 2E carried out rounds inside the ER as per the morning routine. Satisfied that all machinery was in normal operation, the 2E returned to accommodation for breakfast.

1.1.31 At about 0740H, the 2E was joined by the CE in the ECR for the morning routine toolbox meeting and allocation of jobs for the ER crew. The jobs included securing of spares, guarantee claims, purifier maintenance, cleaning of the sea-chest strainer, and general cleaning inside the ER. According to the 2E, there was no job assigned at, or in the vicinity of no.3 cargo hold.

1.1.32 After the meeting, the ER crew proceeded for their tasks. The 2E, being the engineer on duty for the day, in addition to supervising the cleaning of the sea-chest, was also assisting the Fourth Engineer (4E) who was working on the purifier.

1.1.33 At about 1700H, the 2E transferred the ER status to Unmanned Machinery Spaces (UMS), i.e. alarms related to machinery spaces and key equipment such as fire alarm were available for action by the engineer on duty. The 2E returned to the cabin after having dinner.

1.1.34 At about 1853H, when resting inside the cabin, the 2E was alerted⁵² by no.1 heavy fuel oil (HFO) purifier alarm. The 2E put on a boiler suit and went to the ECR via the port side under-deck (passageway) to check on the alarm. Arriving at the ECR, the 2E then headed to the purifier room⁵³ and restarted the purifier.

1.1.35 At about 1945H, while the 2E was monitoring the operation of the purifier, a smoke alarm in the ER's CAMS repeater panel sounded. On returning to the ECR the 2E recalled hearing an announcement on the ship's PA system instructing the crew to proceed for muster station.

1.1.36 As per the muster list, in the event of a deck fire on board the ship, the 2E was to be the leader of the Back-up Team (BT) and was required to assist the ET

⁵² Engineers' cabins were provided with an alarm extension panel, as a part of CAMS.

⁵³ Purifier room was located at the 4th level of the ER. To the port side of the purifier room there was a column with alarm lights (CAMS, CO₂ release, the "dead man" alarm, oil mist alarm, fire, etc.), to the forward centre of the room was the CAMS panel.

for boundary cooling.

According to the 3E-1

- 1.1.37 On the morning of 6 March 2018 at about 0750H, the 3E-1 proceeded to the ECR after breakfast. After attending the toolbox meeting, the 3E-1 proceeded to the auxiliary boiler for the assigned tasks relating to a guarantee claim.
- 1.1.38 On completion of these jobs by about noon, the 3E-1 went for lunch. After lunch, the 3E-1 carried out the routine three-monthly alarm tests which were followed by general checks on the condition of diesel generators. Ending the day in the evening, the 3E-1 had dinner and returned to the cabin to rest.
- 1.1.39 At about 1945H, the 3E-1 was alerted by a smoke alarm on the CAMS repeater panel. The 3E-1 came out of the cabin and saw the ASD-1 going down the stairway.
- 1.1.40 The 3E-1 donned a boiler suit and headed to the ECR using the central stairway to the upper deck and down again to the additional deck. From there to the ECR, seeing the port side passageway (normal route) to be full of white-coloured smoke, the 3E-1 used the starboard side passageway.
- 1.1.41 As per the muster list, in the event of a deck fire on board the ship, the 3E-1 was to assist the CE. Noting that the CE was instructed by Master to proceed to the FCS, the 3E-1 went to the ER to prepare relevant machinery (including the ME) and equipment for firefighting operations.
- 1.2 The Emergency Response
- 1.2.1 The smoke alarm of no.3 cargo hold was activated at about 1945H. A few minutes later, the ship's general alarm of seven short blasts followed by one prolonged blast on the ship's whistle was sounded.
- 1.2.2 After handing over conn to the Master, the CM went down to the FCS to muster the crew and prepare the ET for firefighting. Shortly after, the 2M and ASD-4 came to the bridge for their respective roles of communications and steering as per the muster list. According to the 2M and ASD-4, when they arrived at the bridge, they saw light smoke emanating from the forward part of the accommodation and a strong smell of chlorine/ bleach.
- 1.2.3 At about 1955H, MH was heading about 286°T with the speed at about 20

knots. Noting the apparent⁵⁴ wind about four points on the starboard bow the Master adjusted MH's heading to starboard to minimise the effect of smoke on the accommodation.

1.2.4 The following actions were taken concurrently:

- a. The CM at FCS mustering the crew and carried out a headcount⁵⁵;
- b. The 2E⁵⁶ prepared the ME for manoeuvring and the fire pumps for firefighting; and
- c. All deck lights were switched on and the cargo spotting plan for no.3 cargo hold was reviewed to establish contents in the cargo hold.

1.2.5 The Master instructed the CE to proceed to the FCS where the CO₂ release system was located. After acknowledging, the CE instructed the 3E-1 to go to the ER to assist the 2E in preparing the ME and machinery for firefighting. Thereafter, the CE instructed the 2E to return to the FCS.

1.2.6 By about 2000H, MH was heading 307°T at about 20 knots and having the apparent wind about three to four points on the starboard bow, i.e. the wind was still blowing from the starboard side of the ship towards the accommodation. The Master gave 5° port helm and informed all the crew to remain calm and to keep clear of the smoke (expecting the smoke to change its relative direction with the change in MH's heading).

1.2.7 Meanwhile, at the FCS, the CM assisted by the CE mustered the crew as per the firefighting plan:

- a. Attack Team-1 (AT-1), comprising the 3M and Motorman (MM-1), was donning the fireman's suits and breathing apparatus (BA) taken from the fire locker inside the FCS;
- b. Four crew⁵⁷ were sent to the emergency generator room at the engine casing (located aft) to collect an additional set of fireman's suit and BA set for the second Attack Team (AT-2⁵⁸); and

⁵⁴ The apparent wind is the wind experienced by an observer in motion and is the relative speed of the wind in relation to the observer.

⁵⁵ All persons accounted for.

⁵⁶ The 2E was later joined by 3E.

⁵⁷ The crew (4E, ASD-3, DC-2 and DC-3) reported encountering strong burning smell (like bleach and chlorine).

⁵⁸ AT-2 comprised the 4E (leader) and ASD-3 (member)

- c. The remaining crew⁵⁹ were instructed to rig fire hoses for boundary cooling of no.3 cargo hold from the main deck (port and starboard side).

1.2.8 The CM instructed the AT-1 to shut the natural⁶⁰ ventilator flaps⁶¹ for no.3 cargo hold on the leeward side i.e. the port side, while the CM took some crew⁶² to shut the natural ventilator flaps on the windward side i.e. the starboard side (see **figure 4** showing locations of the ventilator flaps at no.3 cargo hold). It was planned that on completion of these tasks, both teams would then meet at bay 19/ 21 cross-deck to close the two exhaust ventilator flaps for the mechanical⁶³ fan.

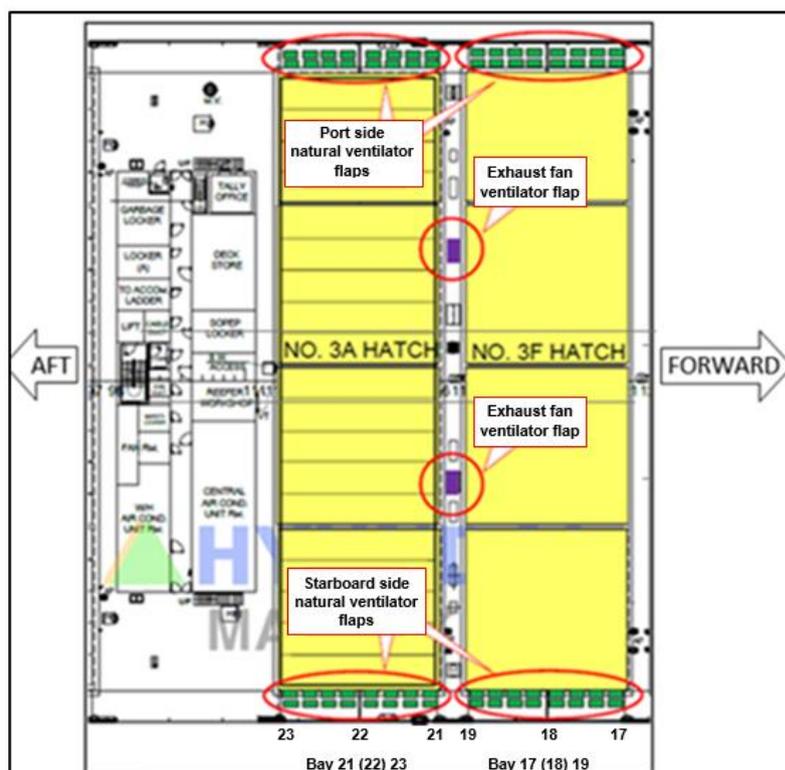


Figure 4 - Plan view showing locations of the natural ventilator flaps and exhaust fan ventilator flaps for no.3 cargo hold (for reference only, annotated by TSIB)

⁵⁹ The crew performing the initial boundary cooling from the main deck comprised the MM-2, Ordinary Seaman (OS), Foreman and Painter.

⁶⁰ Natural ventilation systems refer to the process of supplying or removing air from the space without using mechanical means. It refers to the flow of external air to a space from pressure differences arising from natural forces.

⁶¹ The natural ventilator flaps in this case were 16 in number on each side. They were located at the side of the hatch cover panel. Since it was above the main deck, the crew were required to climb a few steps on a vertical ladder to access the space (below the containers). The AT-1 was not shown the plan at the FCS on the location of the ventilator flaps.

⁶² The ASD-1, ASD-2 and OS.

⁶³ Systems through which exchange of air in a space was carried out either by mechanical supply fans or exhaust fans. MH no.3 cargo hold was fitted with mechanical exhaust fans.

- 1.2.9 Before returning to the FCS as instructed by the CE, following the on board emergency plan, the 2E started no.3 and no.4 diesel generators and disconnected the shaft generator before handing over the ECR duty to the 3E-1.
- 1.2.10 Returning to the FCS, the 2E opened the door leading to the port passageway and encountered a fog-like condition with odourless, white-coloured smoke (with a blue tinge) and reduced visibility of about five to 10 meters. Accordingly, the 2E reported to the Master using the walkie-talkie.
- 1.2.11 Overhearing the conversation, the 3E-1 responded and advised the 2E over the walkie-talkie to use the starboard passageway which was clear of smoke at the time the 3E-1 was going to the ECR. The 2E followed the 3E-1's advice and did not encounter any smoke or unusual smell on the way to the FCS (see **figure 5** showing the locations of the port and starboard natural ventilator flaps⁶⁴ for the passageway).

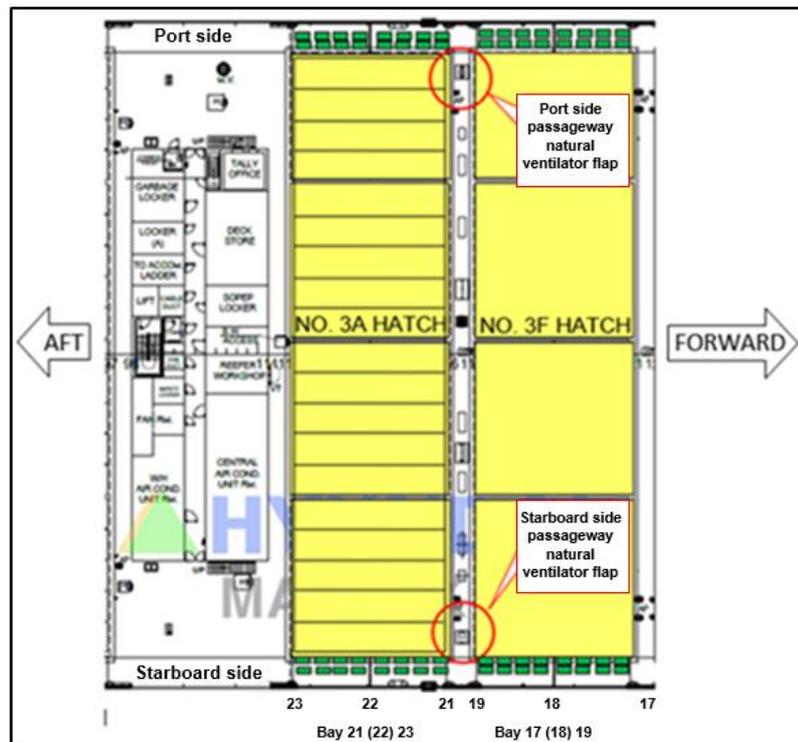


Figure 5 - Plan view showing locations of the natural ventilator flaps for the passageway as marked by the red circle (port and starboard side) annotated by TSIB

- 1.2.12 At about 2002H, upon receiving a report that smoke was getting into the accommodation, the Master announced the activation of the “Emergency

⁶⁴ These flaps were open at the time of the occurrence allowing for a flow of air within the passageway.

Stop⁶⁵ switch C (ES-C). Five minutes later, ES-B too had been activated. The CE heard the accommodation fans stopping and informed the Master accordingly. See **figure 6** showing ES switch panel in the FCS for illustration. A similar set of switches were located on the bridge.



Figure 6 - Emergency Stop Switch box of a sister ship

1.2.13 The Master then instructed the CE to prepare the CO₂ fixed fire extinguishing system for release. The CE broke the glass panel on the front cover of the pilot valve control box and retrieved the key to open the control box for the “Pilot Valve”. Upon opening the control box front cover⁶⁶, an alarm, indicating the CO₂ release box was opened, sounded, as designed. See **figure 7** showing Control Box - Pilot Valve. The CE, in preparation for the CO₂ release, re-affirmed the steps for release.

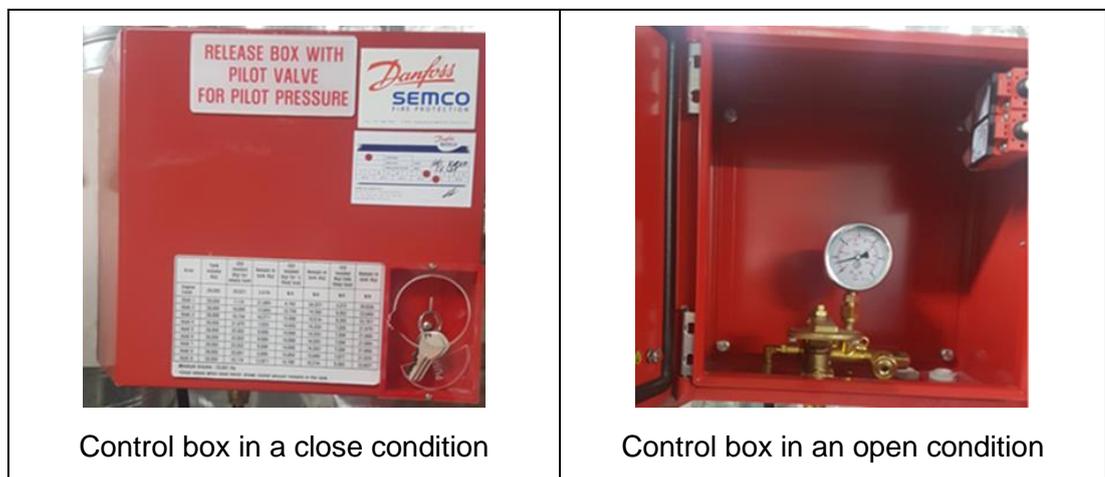


Figure 7 - Control box for Pilot Valve

⁶⁵ ES-B stops all accommodation fans, and ES-C stops fans in the cargo space and other spaces.

⁶⁶ When the CO₂ cargo hold release box was opened, it tripped all mechanical exhaust ventilator fans for all cargo holds (at the time of incident the exhaust ventilator fans of no.3 cargo hold was not running), Bosun’s store and under deck passageway.

- 1.2.14 Meanwhile, the AT-1 had donned their fireman's suits and BA sets, began making their way out from the accommodation's port side to the main deck. No sooner had the team opened the door leading to the main deck, they encountered dense white-coloured smoke with almost zero visibility. Using their torchlight, the team slowly made their way towards no.3 cargo hold by feeling the surrounding structure.
- 1.2.15 By about 2005H, MH on a heading of 295°T and at about 20 knots, had the apparent wind about four points on the starboard bow. The Master after receiving confirmation from the 3E-1 that the ME was ready for use, informed the CM of the intention to slow down the ship.
- 1.2.16 At about that time, the 2M broadcast the urgency signal "*PAN PAN*⁶⁷" on VHF Channel-16, which was followed by an urgency message; "*Latitude 10° 48.2' N, Longitude 065° 49.1'E, MH is on fire and requesting all ships in the vicinity to keep clear*".
- 1.2.17 On the port side main deck, the AT-1 reported on the walkie talkie that due to the smoky conditions, they were unable to locate the natural ventilator flaps for no.3 cargo hold. The 3M recalled, the team had ascended the first vertical ladder (facing outboard) to the cross-deck, identified later as bay 23⁶⁸. The team searched but could not locate any natural ventilator flaps on the cross-deck, and after having walked the intense heat and smoke for about midway across the cargo hold from the port side, the team returned to the FCS.
- 1.2.18 Once at the FCS, the MM-1 removed the face mask and reported of feeling breathlessness, with skin and eye irritation. Leaving the MM-1 at the FCS, the 3M went to the starboard side main deck and reported to the CM in person about the issue with the port side natural ventilator flaps.
- 1.2.19 At about 2010H, the Master called and reported to the Company as follows:
- a. Fire inside no.3 cargo hold, although at that time only smoke was visible;
 - b. All crew had been mustered and accounted for;
 - c. Ship's heading was being continuously adjusted to minimise the effect of smoke on the crew; and
 - d. Master's intention to release CO₂ fixed fire extinguishing system into the cargo hold.

⁶⁷ "*PAN PAN*" is the international urgency signal that is used as a preface to a VHF transmission when the safety of a person or the ship is in serious jeopardy, though no immediate danger exists, but could escalate into a mayday situation.

⁶⁸ This was the cross-deck immediately forward of the accommodation.

- 1.2.20 On the starboard side main deck, the ET comprised the CM and some team members completed closing all the 16 natural ventilator flaps for no.3 cargo hold. The team then ascended the ladder to bay 19/ 21 cross-deck to close the exhaust fan ventilator flaps. They were joined later by the 3M who reported that due to smoke and heat, the AT-1 team could not locate and close the natural ventilator flaps on the port side. The CM then informed the Master that the port side natural ventilator flaps could not be closed due to thick smoke.
- 1.2.21 The Master noting MH's heading about 273°T, speed about 19 knots and the apparent wind about five points on the starboard side, reduced⁶⁹ the speed to "Slow Ahead" with the helm⁷⁰ "Hard to Port". The Master's intention was to reduce and direct the smoke effect away from the port side main deck.
- 1.2.22 At bay 19/ 21 cross-deck, both the ET and 3M began closing the exhaust ventilator flaps for no.3 cargo hold. There, the team reported that the area was less smoky, and they could feel intense heat coming from the hatch cover. While they were closing the flaps, their working area was suddenly engulfed in thick dense smoke. The team retreated to the FCS, reporting about the strong toxic smell (like chlorine) and complaining about the breathlessness with itchy burning sensation.
- 1.2.23 Once at the FCS, the CM again updated Master on the status of no.3 cargo hold ventilator flaps, i.e.:
- a. 16 natural ventilator flaps for the cargo hold on the starboard side hatch cover were closed;
 - b. One exhaust ventilator flap at cross-deck 19/ 21 was closed; and
 - c. 16 natural ventilator flaps for the cargo hold on the port side hatch cover remained open.
- 1.2.24 The Master iterated to the CM that all ventilator flaps at no.3 cargo hold must be closed before the CO₂ being released.
- 1.2.25 The CM and 3M discussed and agreed for the latter to close the port side natural ventilator flaps. However, due to MM-1 been affected by the smoke, the 3M decided to do it alone and later to be assisted by the 4E⁷¹ (a member of the AT-2⁷²).

⁶⁹ VDR data confirmed the ship's speed to start reducing and the heading to change towards port.

⁷⁰ The helm orders were being adjusted accordingly to reduce the smoke effect on the accommodation space.

⁷¹ The 4E was in the process of donning his fireman's suit and BA set.

⁷² The AT-2 comprised the 4E and ASD-3. One crew member alleged that the ASD-3 refused to wear the BA set, but contrary to the allegation, the ASD-3 was asked to pass the BA Set to the 2E, so the latter could use it to go to the CO₂ room.

1.2.26 The CM also instructed the crew doing boundary cooling at the port side main deck to provide a water curtain for aiding the 3M, and later the 4E, to minimise the effects of heat and smoke. Although the 3M reported a slight improvement in the visibility, the area near the port side natural ventilator flaps was still inaccessible due to the intense heat and huge amount of smoke. Unable to close the natural ventilator flaps at the side of the hatch cover, the 3M walked further forward and ascended the second vertical ladder leading to the cross-deck, identified later as bay 19/ 21. The 3M located and successfully closed the no.3 cargo hold exhaust ventilator flap at the port side cross-deck. (See **figure 8** - showing AT-1's track for locating the port side flaps).

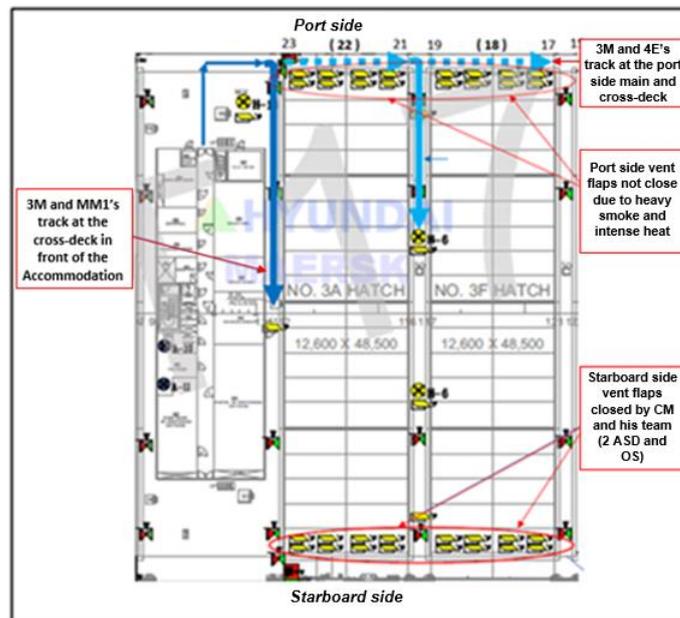


Figure 8 - AT-1's track for closing the ventilator flaps

1.2.27 The 3M descended the vertical ladder to the main deck and was met by the 4E who had arrived from the FCS. Together, they walked further forward to the cross-deck at bay 11/13 and successfully closed the exhaust ventilator flaps for no.2 cargo hold. After closing these ventilator flaps, the 3M informed the 4E of the need for the 3M's BA bottle to be changed before proceeding further. However, the 4E preferred waiting for the 3M's return at the forward part of the ship, which was less smoky while the 3M returned to the FCS alone.

1.2.28 At the FCS, while organising boundary cooling for no.3 cargo hold from the main deck, the CM received the report from the 3M and updated the Master as follows:

- a. Four exhaust ventilator flaps at 11/ 13 and 19/ 21 cross-deck closed: and
- b. 16 numbers of natural ventilator flaps on the port side hatch cover were

still open.

- 1.2.29 Assessing that there was no sign of reduction of smoke, the Master expressed the decision to release CO₂ into no.3 cargo hold, for the safety of the ship and its crew. The Master also instructed the CM to send some crew⁷³ for boundary cooling from the bridge wing, see **figure 9** showing view from the port side bridge wing (Source: Company).



Figure 9 - View from the port side bridge wing

- 1.2.30 After instructing the remaining crew⁷⁴ to continue with boundary cooling of containers, hatch covers and coaming at no.3 cargo hold from the port and starboard main deck, the CM donned the BA set and joined the 3M to rig additional hoses on 'A' and 'B' decks (port side) to aid the boundary cooling from a higher point.
- 1.2.31 By about 2015H, MH's heading about 204°T and speed about 11 knots, the Master noted the volume of smoke appeared to have increased and was now blowing towards the starboard side. The Master gave a port helm and steered on a heading of 165°T to again attempted to minimise the effects of the smoke. A headcount confirmed that all persons were accounted for (including the 4E who by then had gone to the forecastle deck). The Master instructed the CE to release CO₂ into no.3 cargo hold.

- 1.2.32 The CE assisted by the 2E, EE and EC-2, following the CO₂ release

⁷³ Eight crew members were sent and assigned to commence boundary cooling from bridge wing. The team comprised the Third Engineer-2 (3E-2), DC-1, DC-2, DC-3, EC-1, EC-3, CCK and Second Cook (2CK).

⁷⁴ Eight crew members were assigned to continue boundary cooling from the main deck comprising the MM-1, MM-2, ASD-1, ASD-3, ASD-4, OS, Foreman and Painter.

sequence⁷⁵ began opening pilot valve, followed by no.3 cargo hold valve and then the main valve, which released⁷⁶ the CO₂ from the fixed fire extinguishing system into no.3 cargo hold.

- 1.2.33 The CE reported the initial gauge reading for the CO₂ tank was about 28,500kg (about 28.5tons). As per the discharge table plan, a fully filled cargo hold⁷⁷ would require about 6,000kg of CO₂. The CE stopped the release when the gauge indicated⁷⁸ 22,500kg of CO₂ remaining in the tank. (see **figure 10**).

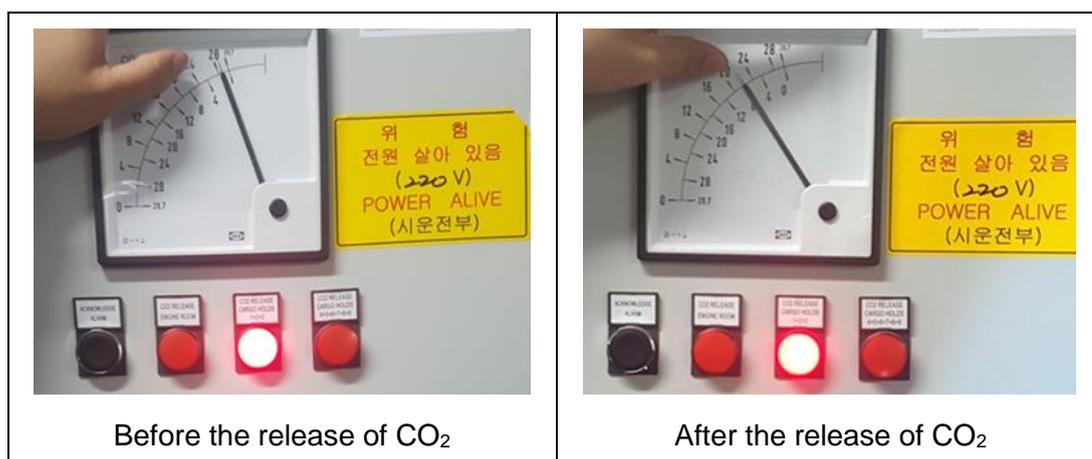


Figure 10 – Photos of CO₂ gauge before and after the discharge

- 1.2.34 The CE then sent the 2E donned with a BA set to the CO₂ room (one deck below the upper deck) to verify the gauge reading at the CO₂ tank. The 2E returned moments later stating that the CO₂ room could not be accessed as the whole upper deck was full of thick white smoke.
- 1.2.35 At about 2021H, while directing the boundary cooling from the bridge wing, the Master noticed an increase in the smoke (with an orange glow) from no.3 cargo hold. The Master continued adjusting the ship's course and speed (a combination of increase/ decrease) to minimise the effect of smoke on the accommodation and to see whether it would be clear to get to the lifeboats.
- 1.2.36 By about 2025H, MH's heading 164°T and speed about 14 knots⁷⁹ with the apparent wind about five points on the port bow. The Master informed the Company that partial CO₂ had been released into no.3 cargo hold. Though uncertain, the Master indicated to the Company that IMDG containers inside no.3 cargo hold might have caused the fire.

⁷⁵ Instructions posted on the inside cover of CO₂ release box.

⁷⁶ It was reported that the first CO₂ release at about 2023H.

⁷⁷ MH no.3 cargo hold was full of containers.

⁷⁸ Photos were taken by the crew of MH as evidence at the time of release.

⁷⁹ According to the Master the speed was increased when the smoke started to circulate around the accommodation.

- 1.2.37 As time progressed, the deck crew who were tasked to carry out boundary cooling from the Main, A and B decks, were continuously shooting copious amounts of seawater towards the containers and hatch covers at bay 23. The teams indicated that they could feel intense heat and smoke from no.3 cargo hold, but no flames were sighted.
- 1.2.38 At about 2030H, MH maintaining a heading of 164°T and doing about 15 knots, the Master noted that the smoke was blowing over to the starboard side. The 2M who was on the bridge assisting in navigation was continuously monitoring and responding to VHF communication with other ships/ stations in the vicinity.
- 1.2.39 By about 2035H, the Master noting that the CO₂ had not had the desired effect, announced for all the crew to muster on the bridge, while continuously assuring the crew not to panic. The Master also called the 4E at the forward station to return to the bridge but did not receive any reply from 4E.
- 1.2.40 The 3E-1 overhearing the Master's call relayed the message on the walkie-talkie to 4E (in local Bisaya dialect). The 4E responded that the main deck was full of smoke and that the passageway door at the forecastle store was padlocked⁸⁰. As per the ship's fire plan, the forecastle had a fire locker that contained chemical protective clothing and a BA set with spare bottles. The Master then instructed the 4E through the 3E-1, to seek shelter from smoke and heat.
- 1.2.41 At about 2045H, i.e. one hour from the time the first alarm sounded, the Master carried out another headcount⁸¹ (before releasing CO₂ for the second time) and instructed all the crew to muster⁸² on the bridge.
- 1.2.42 On arriving at the bridge, the CM saw that most of the crew were already mustered and reported to the Master that they were not able to do anything more on deck. From the bridge, a thick plume of smoke was sighted but there was still no sight of fire. The CM recalled that on the way up to the bridge, the

⁸⁰ The forecastle store was padlocked from the outside at the time of the incident. The padlock had a butterfly-nut arrangement which could allow a person inside the forecastle store to exit by opening the butterfly-nut. This arrangement was reportedly due to security reasons as the ship's transit would take her through high-risk areas of piracy. The 4E recalled asking the 3E-1 to come forward via the under-deck passage to open the butterfly-nut. It was made known to the investigators that before abandoning ship, the 3E-1 attempted to reach the forecastle using the main deck passage to help the 4E but could not do so, due to smoke. According to the 4E the remaining air in the BA bottle was about 50 bars and that the air was insufficient to go aft. Shortly after that the BA bottle ran out of air, the 4E removed the BA set and fireman's suit, donned the immersion suit and lifejacket (located at the upper deck starboard side near the life raft) and waited there.

⁸¹ All personnel had been accounted for, including the 4E at the forecastle deck.

⁸² The 2M made an announcement on the PA system. According the Master, this was done with the intention to ensure that the crew on board were at a relatively safer location at that time.

central stairway was clear of smoke⁸³. The 3M arrived a few minutes later at the bridge for the headcount and saw thick smoke entering the bridge from the wing door on the windward side (with a smell of burnt paint thinner).

- 1.2.43 At the ECR, the 3E-1 reported to the CE that several alarms⁸⁴ had sounded from the CAMS. The 3E-1 was instructed by the CE to acknowledge the alarms and change the setting on the “Power Management System” from two to four diesel generators, which automatically started the two additional standby diesel generators. At about 2052H, the 3E-1 reported on the walkie-talkie that the ER water mist sprinkler system had auto-activated.
- 1.2.44 After acknowledging the alarms, the 3E-1 opened the ECR door to inspect the diesel generator room and saw the ER space filled with smoke. The 3E-1 reported the condition to the CE (adding that ECR was also filling up with smoke) and was subsequently told by Master to come to the bridge.
- 1.2.45 The 3E-1 left the ECR via the port side door to the workshop, then up to the duty lounge area and onto the aft upper deck. Arriving at this location, the 3E-1 saw a smoke-like fog with a smell of burning plastic which had covered the deck area forward of the engine casing towards the forward superstructure. The 3E-1 also noticed that the skylight for the ER was open and proceeded to close it.
- 1.2.46 While closing the skylight, the 3E-1 was joined and assisted by the MM-1 and Ordinary Seaman (OS) who had retreated aft due to the smoke. After the skylight was closed, the 3E-1 reported to the Master and was again instructed to come to the bridge.
- 1.2.47 En route to the bridge by the port side main deck, the trio used a fire hose to provide a water curtain to shield themselves from smoke and heat. However, when they reached no.4 cargo hold (just behind the accommodation block), they were forced to retreat to the engine casing after suffering breathlessness. They reported this to the Master.
- 1.2.48 At about 2055H, assessing the options, the Master instructed the 2M to send the distress alert (which was activated⁸⁵ soon after). The Master again referred to the IMDG spotting plan, this time with the CM, and discussed the possibility

⁸³ A possible indication that the magnetic fire doors were closed by now.

⁸⁴ At about 2045H, the following alarms were noted – in particular, ER fire alarm & others, Cargo Hold Exhaust fail, Local Fire Fighting System (L.F.F.S) water release (No.3&4), etc.

⁸⁵ Using distress button on digital selective calling (DSC), which is a standard for sending pre-defined digital messages via the medium-frequency (MF), high-frequency (HF) and very-high-frequency (VHF) maritime radio systems and the Inmarsat-C. The distress signal was received by ALS at about 2110H.

of IMDG container(s) inside no.3 cargo hold on fire and the follow-up response to be made, including the full discharge of CO₂ inside the cargo hold. The Master then instructed the CM to update the Company.

- 1.2.49 At about 2100H, MH's heading was 162°T at about 15 knots and the apparent wind was about five points on the port bow. The Master ascertained that all the crew were accounted for by another headcount (**see figure 11**) and after discussion with the officers, instructed the CE to carry out a full release of CO₂ inside no.3 cargo hold.

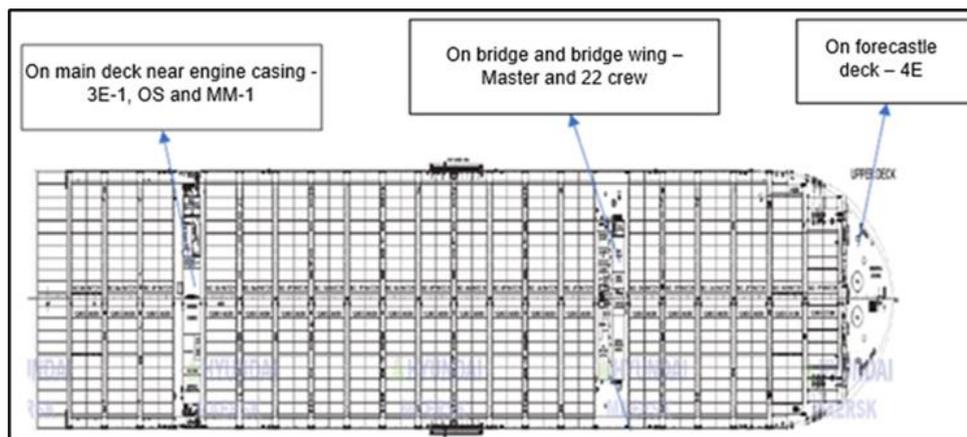


Figure 11 - Location of all the crew before the second CO₂ release

- 1.2.50 At about 2110H, the CE sent the 2E and EE down from the bridge to the FCS to carry out the full release of CO₂. On arrival at the FCS, the 2E and EE, lined up the valves as per the release sequence, and carried out the full release of CO₂ into no.3 cargo hold. Confirming that the remaining quantity of CO₂ was reducing and on completion of the release until the tank was empty, the 2E and EE returned to the bridge.
- 1.2.51 Following the complete discharge of CO₂ into no.3 cargo hold, witness accounts confirmed that several loud explosions were heard which was followed by large plumes of smoke rising from no.3 cargo hold, engulfing the forward part of the accommodation, up till the bridge wings (port and starboard). The Master called the crew doing boundary cooling from the bridge wings to leave their fire hoses behind and go inside the bridge for shelter.
- 1.2.52 The CM who had just completed updating the Company, saw very thick smoke entering the bridge as it followed the crew through the open bridge side door. At the same time, smoke could also be seen entering the bridge from the deckhead vents. Soon the entire bridge was filled-up with smoke and the crew began coughing, some feeling breathless. The crew got into a panic⁸⁶ state

⁸⁶ As heard from the VDR audio.

and scrambled down from the bridge using the central stairway.

- 1.2.53 At this time, the Master and 2M were left on the bridge with the ASD-4 on the steering wheel. Taking over the helm, the Master instructed the ASD-4 to go down from the bridge. The Master stopped the ship's engines in preparation for abandoning ship⁸⁷.
- 1.2.54 At about 2120H, various alarm from the CAMS sounded. The Master noted that MH's heading about 285°T at about six knots and having the smoke blowing towards the port side, looked around and after confirming that there were no crew on the bridge, activated the ES-A⁸⁸ and evacuated the bridge soon after.
- 1.2.55 The activation of the ES-A caused the ship to black-out and resulted in the emergency generator to come on-line automatically.

1.3 Evacuation

- 1.3.1 After the bridge was vacated, the investigators noted that the panicked crew found themselves separated, dispersed and divided into four main groups⁸⁹.

Group 1

- 1.3.2 After activating the ES-A and seeing nobody else at the bridge, the Master and the 2M left the bridge. But once at the central stairways, the Master, looked behind but did not see the 2M, headed towards the Master's office at the H-deck (one deck below the bridge). At the H deck alleyway, the Master met the CE, 2E, Deck Cadet-3 (DC-3), ASD-2, ASD-3, and Chief Cook (CCK). With the assistance of the crew, the Master collected the ship's documents, crew passports, and mobile phone from the Master's office.
- 1.3.3 This group, (seven persons) used the central stairway, planned to make their way down from the H-deck to the upper deck, then to the passageway towards the engine casing. On the way down, the group encountered thick smoke at the C-deck, triggering continuous coughing and breathlessness amongst them. The group was forced to return to the E-deck where the smoke was lighter, and they took shelter in one of the cabins⁹⁰ on the port side.
- 1.3.4 At about 2144H, the Master using the mobile phone managed to call the

⁸⁷ There was no announcement made on the PA system or radio for abandon ship.

⁸⁸ Emergency Stop-A switch when activated, among others, stops the ER fans, and is the emergency stop for all fuel pumps, purifiers, coolers, etc.

⁸⁹ Not listed in any order.

⁹⁰ It was reported that Group 1 took shelter in cabin 'O' to assess their situation.

Company to report of their situation on board the ship. The other members of the group called the remaining crew on walkie-talkie channel 7 and other working channels but received no response. Noting the radio silence, the Master feared that the only survivors left on board were in their group.

- 1.3.5 While the group⁹¹ was assessing and discussing their options, they heard crackling and buckling sounds outside. Looking out from the cabin window, the group saw orange-coloured light glowing with embers falling to the sea. At that time, the deck lights were still operational, and the Master conveyed to the group of the intention to abandon ship.
- 1.3.6 The group then made their way across to the starboard alleyway and opened the accommodation door leading outside. Although encountering thick dense smoke, the group forced their way and reached the starboard lifeboat on the B-deck where they saw the Foreman lying unconscious.
- 1.3.7 At about 2215H, the group carried the Foreman and boarded the starboard lifeboat (now comprising eight persons). The lifeboat was lowered to water level and once waterborne was cast off from the ship. The Master steered the lifeboat away but stayed in close vicinity of the ship to look out for other crew who could still be on MH's main deck.
- 1.3.8 The Master then saw and steered the lifeboat towards the life raft floating close on the ship's starboard quarter (near the engine casing). Thereafter, the Master successfully retrieved 15 crew (14 from the life raft on the starboard side and the Painter from the sea on the port side). Finding no other crew in the vicinity, the Master steered the lifeboat towards the first ship to arrive on the scene, identified as ALS Ceres (ALS).
- 1.3.9 On 7 March 2018, at about 0130H, out of the total of 27 crew members of MH, 23 crew were taken on board ALS, while four others were reported missing⁹². Of the 23 survivors, one crew member (Painter) later succumbed to injuries, while on the way for shore medical treatment.

Group 2

- 1.3.10 When the bridge filled-up with smoke, the CM and some crew ran down the central stairway to the FCS. Arriving at the entrance to the FCS, the CM noticed that some crew were already waiting along the alleyway.

⁹¹ Varying witness accounts mentioned the fear of the worst-case scenario, seeing some crew coughing and slumped, breaking down while waiting for orders and them possibly being the only survivors.

⁹² Missing were 3E-2, EC-1, EC-3 and 2CK.

- 1.3.11 This group (10 persons) comprising the CM, 3M, EE, DC-1, DC-2, EC-2, MM-2, Painter, ASD-1 and ASD-4 made their way to the ship's infirmary (located on the port side of the same deck) to take shelter from the smoke and to assess their options. The CM called the Master on walkie-talkie channel 7 and other working channels but received no response.
- 1.3.12 Due to presence of thick smoke inside the accommodation and surrounding the main deck area, the group decided to go to the engine casing via the passageway. When the group arrived at the passageway, they saw that both passageways were full of smoke.
- 1.3.13 Braving the smoke, the group walked, crawled at cabling level, along the port passageway to the aft mooring station. Once at this location, the CM again called the other crew members on walkie-talkie channel 7 and other working channels but received no response.
- 1.3.14 As the group comprised 10 crew, they planned to launch two (6-man) life raft, located on either side of the engine casing to abandon ship. When the group went to the starboard side, they saw that the starboard life raft was already waterborne. On deck, they met four other crew members, i.e. three from Group 4 (the 3E-1, MM-1, and OS) and one from Group 3 (the 2M who was injured).
- 1.3.15 The CM further divided the crew (now 14 in number) into two teams. The first team was tasked to lower the starboard side embarkation ladder to the life raft, while the second team was tasked to launch the port side life raft and lower the embarkation ladder.
- 1.3.16 The second team went to the port side and lowered the embarkation ladder to the water level. On completion, the team proceeded to the life raft location but discovered that the life raft area was covered with smoke. The team decided to wait for the smoke to clear and while waiting, the MM-2 recalled seeing the Painter with a lifebuoy (around the waist), hurriedly climbing down the ladder.
- 1.3.17 While waiting, the team heard sound of lifeboat engine on the starboard side. The team hurried to the side railing and saw a lifeboat approaching towards their ship. The team shouted and called for the lifeboat's attention, while at the same time directing the boat towards the life raft on the starboard quarter. Seeing that the lifeboat was heading towards the stern, the team on the port side joined the rest of the crew at the starboard side life raft embarkation area.
- 1.3.18 The lifeboat was tied alongside the life raft (attached to the bottom rung of the ladder) to facilitate the crew to board the lifeboat. In all, 15 crew boarded the

lifeboat with 14⁹³ crew from the starboard life raft while the Painter was retrieved from the sea at the port side.

Group 3

- 1.3.19 After the ES-A was activated, the 2M and Master left the bridge⁹⁴. When they were in the central stairways, the 2M returned to the bridge to collect the portable GMDSS equipment (radio, SART⁹⁵, and EPIRB⁹⁶) that had been kept aside earlier for fast retrieval. Returning to the bridge, the 2M recalled that the central stairways space was fast filling up with smoke.
- 1.3.20 After collecting the equipment, the 2M tried, but could not exit via the central stairway, as the smoke had filled up to the bridge deck level. The 2M abandoned his plan through the central stairways, entered the converter room (located inside the bridge) and discovered that the EC-1 and Foreman were taking shelter from the smoke. The 2M then called the 3E-1 by walkie-talkie channel 7 and was advised to use the starboard side main deck to the engine casing which was less smoky.
- 1.3.21 The group (three persons) made their way outside the accommodation, via the starboard side external stairways, down from the bridge to the main deck. However, when they reached the D-deck, they encountered thick smoke that caused them to separate. The 2M recalled falling on deck and losing consciousness momentarily.
- 1.3.22 Shortly after, regaining consciousness, the 2M not knowing the whereabouts of the Foreman or EC-1, slowly descended to the main deck. Arrived at the main deck, the 2M threw two lifebuoys into the sea, as a precautionary measure in case there was a need to jump overboard. The 2M recalled seeing the coaming lights were still on. With much effort, the 2M staggered to the engine casing and met the 3E-1 before collapsing again. After regaining consciousness, the 2M, with the assistance of the 3M and DC-1 (from group 2), climbed down the embarkation ladder and into the life raft.
- 1.3.23 The investigation team further learnt that the Foreman had also lost consciousness after separating from the 2M. On regaining consciousness, the Foreman had made it to the starboard side lifeboat at A-deck before collapsing again. The Foreman was later discovered and rescued by group 1.

⁹³ The 4E joined this group after being called by the 3E-1 which brought the number of crew from 14 to 15.

⁹⁴ 2M had suggested to the Master earlier to seek shelter at the aft station.

⁹⁵ Search and Rescue Radar Transponder.

⁹⁶ Emergency Position Indicating Radio Beacon.

1.3.24 The whereabouts of EC-1 could not be established after they were separated at the D-deck.

Group 4

1.3.25 The group (three persons) comprised the 3E-1, MM-1, and OS, retreated aft to engine casing due to smoke. On receiving a walkie-talkie call from the 2M, asking for the best possible route (less smoky) to the engine casing, the 3E-1 advised the 2M to use the starboard side main deck but did not receive any acknowledgment. The 3E-1 called the Master and other crew members on walkie-talkie channel 7 and other working channels but received no response.

1.3.26 The group then launched the starboard side 6-man life raft located in-way of the engine casing. Before boarding the life raft, the group decided to collect bottles of drinking water from the ER. The group entered the ER, donned the EEBD obtained from the ECR, and collected bottles of drinking water before returning to the starboard life raft. At the life raft boarding area, the group saw the 2M staggering from forward. A few minutes later, they were joined by members of group 2 which was led by the CM, coming from aft mooring deck.

1.3.27 The 3E-1 handed over the care of the injured 2M to the CM, and together with the MM-1 and OS, went forward to the accommodation block to collect more lifejackets for the crew. On the way forward, they heard sound of lifeboat engine being started. They looked over the side and saw that the starboard lifeboat was waterborne. The group shouted and directed the boat towards the life raft at the starboard quarter, where other crew members had assembled.

1.3.28 The trio continued forward, climbed up to the starboard side lifeboat deck and collected lifejackets from the storage bins. While the MM-1 and OS were collecting the lifejackets, the 3E-1 recalled looking and shouting for any other crew members that might have been left behind but did not receive any response.

1.3.29 After collecting the lifejackets, the group called the 4E (on the walkie-talkie channel 7), who was still at the forecastle deck, to go down to the starboard side main deck. The group met the 4E near the vicinity of no.2 cargo hold on the main deck, and together, they proceeded aft to the life raft boarding area.

1.3.30 According to the 3E-1, who was at the starboard side main deck in-way of no.2 cargo hold, smoke could be seen coming out from no.2 and no.3 cargo hold but with no flame. However, looking up at the D-deck level of the accommodation towards the port side (nearer to the centreline), some containers were seen to be on fire and the flames could be seen spreading

towards the starboard side.

- 1.3.31 According to the 4E, looking from the forecastle deck, thick black smoke and flames were seen coming out from about the fifth tier between no.2 and no.3 cargo hold. Recalling further, the 4E mentioned that orange-coloured flames with burning were seen coming out from the top of the containers. The debris could also be seen being blown to the port side and into the sea (see **figure 12** showing fire and its aftermath on board MH).



Figure 12 - Images of fire and its aftermath onboard MH

1.4 Initial consequences⁹⁷

1.4.1 The fire on board MH resulted in, amongst others, the following:

- a. Four fatalities and one crew unaccounted for⁹⁸;
- b. Material damage to the ship as indicated by the post incident inspection, (please see para 1.5.15 - figure 16 showing images of the damage);
- c. Damage to cargo forward of the accommodation and the potential for damage to cargo on other parts of MH; and
- d. Potential for severe damage to the environment brought about by the fire occurrence and its resultant firefighting efforts.

⁹⁷ The ship was abandoned and subsequently towed to the United Arab Emirates (UAE). The ship returned to service on 7 August 2019 after undergoing repairs.

⁹⁸ 3E-2, EC-3 and 2CK – Were assisting in the boundary cooling from the port side bridge wing. The EC-1 became a part of group 3 (together with 2M and Foreman) and the Painter became a part of group 2 (together with CM and some crew).

1.5 Rescue and salvage operations

By ALS⁹⁹

- 1.5.1 On the evening of 6 March 2018, while the Marshall Islands-registered container ship, ALS was on a routine voyage in the Arabian Sea, a “PAN PAN” alert with an urgency message of MH in “*Latitude 10° 48.2' N, Longitude 065° 49.1'E, on fire and requesting all ships in the vicinity to keep clear*”. The Master of ALS established radio communication on VHF channel 16 with MH and altered the vessel’s course towards MH to render assistance.
- 1.5.2 While en route to the location, at about 2120H, the Master of ALS received a distress alert through MF/ HF DSC about “*Fire and Explosion*” on board MH at *Latitude 10°34.49’N, Longitude 065° 49.6’E*. The Master of ALS established radio communication with the Maritime Rescue Coordination Centre (MRCC¹⁰⁰) Mumbai, India.
- 1.5.3 By about 2230H, ALS arrived on scene and updated MRCC Mumbai.
- 1.5.4 Subsequently, the Master of ALS updated MRCC Mumbai that on 7 March 2018 at about 0130H, 23 crew members from MH had been recovered on board ALS and that four persons were unaccounted for. SAR operations of the nearby sea area to look out for the four missing persons continued with the assistance of several vessels. See **figures 13 and 14** - fire on board MH.



Figure 13 - Fire onboard the MH

⁹⁹ ALS was the initial on-scene coordinator (OSC) and was later replaced by Edith Maersk. Various ships (AL Jasrah, Gerd Maersk, Navigator Centauri, Seaspan Zambezi and Daedalus Centaur) aided with SAR operations. The Indian Coast Guard aided in the firefighting as well as SAR operations which was coordinated by MRCC Mumbai.

¹⁰⁰ MRCC Mumbai – responsible for coordinating air-sea rescue in Mumbai and an extensive area of the Arabian Sea.



Figure 14 - Aerial view of MH during the day (Source - Tradewinds)

- 1.5.5 On 7 March 2018 at about 0630H, ALS proceeded towards Colombo¹⁰¹, Sri Lanka to disembark the 23 crew members rescued from MH after been released on scene by Edith Maersk from OSC duties (see **footnote 99**).
- 1.5.6 According to the Master of ALS, all 23 crew were suffering from throat pain, irritation to the eyes and skin due to smoke inhalation and exposure. Two of the rescued crew displayed serious symptoms and received medical first aid and treatment on board ALS in consultation and coordination with Medico Cuxhaven¹⁰². One of the two was the Painter who later passed away.
- 1.5.7 In consultation with ALS's Company as well as that of MH, and advice from the Indian Coast Guard (ICG), three MH crew¹⁰³ were evacuated to the ICG's ship on 8 March 2018 at about 1326H off Thiruvananthapuram, India. Thereafter, in consultation with ALS's Company and that of MH, it was decided for ALS to proceed to Cochin instead of Colombo to disembark the remaining crew of MH for medical care and attention.

By other assisting ships

- 1.5.8 MH's fire resulted in SAR operations involving several ships after MH sent out a distress signal on 6 March. Several ships deviated from their route to assist. Subsequently, the Company engaged SMIT Salvage BV and Ardent Global for firefighting and salvage operations.

¹⁰¹ ETA to Colombo on the 8 March 2018 at about midnight.

¹⁰² Medico Cuxhaven - The tele-medical maritime assistance service (TMAS) Germany (Medico Cuxhaven) supports and gives advice to seafarers in case of sickness, accidents, maritime emergencies, and other incidents on board that require medical advice. The TMAS is an essential part of the health protection of seafarers.

¹⁰³ The Foreman, 2M and ASD-2.

- 1.5.9 On 8 March 2018, the ICG's ship (Shoor) commenced firefighting operations. Thereafter, the ICG Shoor was joined by other ships engaged by the Company for the firefighting operations. See **figure 15** - firefighting operation.



Figure 15 - Firefighting operation

- 1.5.10 On 10 March 2018, with continuous firefighting and boundary cooling being carried out by various firefighting crafts for three days, the salvage team boarded MH, and began their search for the missing crew on board.

By salvage ships

- 1.5.11 On 11 March 2018, with craft from the salvage team in better control of the firefighting and boundary cooling operations, the ICG Shoor was released from site. On the same day, the remains¹⁰⁴ of three crew were discovered by the salvors while one remained unaccounted for.
- 1.5.12 On 12 March 2018, though the fire was under control, several smouldering hotspots remained inside no.1, 2, and 3 cargo holds but with much reduced smoke. The search for the missing crew continued on board¹⁰⁵.
- 1.5.13 After assessing the situation on board MH and consulting the various port authorities in the area, the Company decided to tow MH to the port of Jebel Ali, UAE, being the most suitable to accommodate the ship in that condition.
- 1.5.14 On 24 April 2018, MH arrived under tow and waited at Jebel Ali port anchorage for the hot spots in the affected areas to be completely extinguished before the ship could be berthed. It was further anticipated that the remaining cargo on MH could take 4-5 weeks to be discharged.

¹⁰⁴ Remains of two of the crew were discovered on the port side bridge wing while the other crew was located below the port side lifeboat at the A-deck. The three remains were then sent to Mumbai, India, for a positive identification.

¹⁰⁵ The Company subsequently informed the NOK that the missing person (EC-3) was likely lost at sea as a result of the incident.

1.5.15 Post-incident inspection photographs¹⁰⁶ (see figure 16)

<p>View from sea level showing:</p> <p>Ship's starboard bow with burnt damages at ship's side and forward section of the accommodation</p>	
<p>View from the bow facing aft, indicating the extent of damage at the forward section that included:</p> <ul style="list-style-type: none"> • Collapsed containers • No.1, 2 and 3 cargo hold structure and outfitting • Burnt damages at the forward of the accommodation 	
<p>Forward view from the bridge showing the ship's damaged section, which included:</p> <ul style="list-style-type: none"> • Collapsed containers¹⁰⁷ • No.1, 2 and 3 cargo hold structures and outfitting 	

¹⁰⁶ Some of these were taken by TSIB's investigators, while others were provided by the Company.

¹⁰⁷ According to the Company, excavation of containers revealed that they were completely burnt internally, some of them indicating signs of high energetic decomposition resulting from hot gas blowing the doors open.

<p>View of the inside of the bridge and mess room (swept by salvors for access) showing burnt equipment, fittings, and structure</p>	
<p>View of the inside of the CO₂ room (swept by salvors for access) and the E-deck alleyway</p>	
<p>The boiler suit indicated gross discolouration (caused by bleaching) to a near white colour from the original pale blue.</p> <p><i>Source</i> – Fire Forensic Expert</p>	
<p>The inner lining of the fireman's jacket shows gross discoloration.</p> <p><i>Source</i> – Fire Forensic Expert</p>	

<p>Photographs obtained by the investigation team:</p> <ul style="list-style-type: none"> - Fire locker inside the Bosun store (forward) contains: <ul style="list-style-type: none"> • one BA set with two spare bottles • one complete set of chemical suits - Fire suit, BA set, and two sets of walkie-talkies found outside the forward store 	
<p>Showing one set of walkie talkie bearing the 2M's tag (annotated no.3 by TSIB) was found at 3rd level lashing bridge forward of the accommodation.</p> <p>Additionally – Four sets of walkie-talkies tagged¹⁰⁸ with various ranks were discovered</p> <ul style="list-style-type: none"> • One in the ECR • Two inside the ER; and • One in the accommodation 	

Figure 16 – Post incident inspection

1.6 Records of alarms and events

- 1.6.1 A screen shot of the CAMS console (see **figure 17**) showing the graphical representation of some of the key alarms that occurred during the incident indicating the onset of the smoke alarm, the release of CO₂ and the blackout.

¹⁰⁸ It is possible for walkie-talkies to get swapped in an emergency. A walkie-talkie thus tagged and found in a location may not imply the person was in that location.

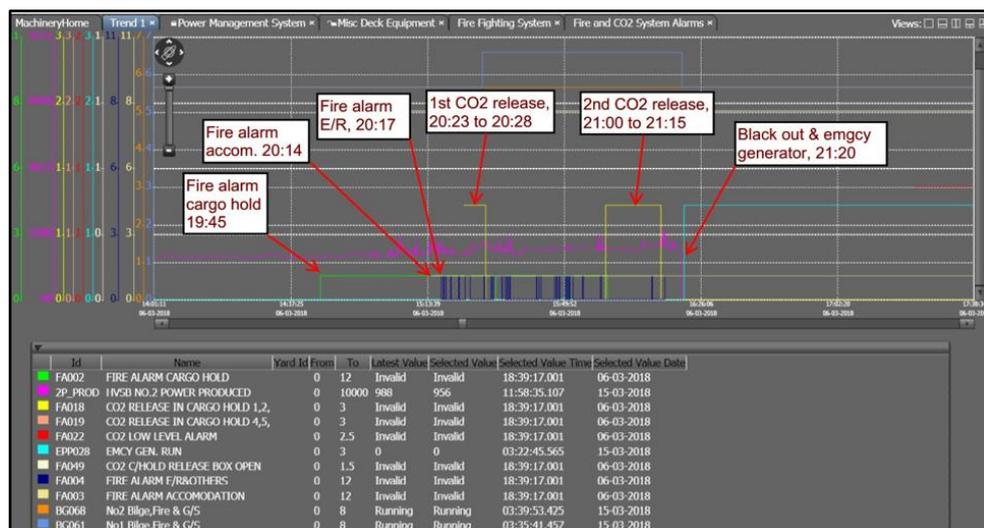


Figure 17 - CAMS data showing the alarms and events during the incident (Source – Annotated by the Fire Forensic Expert)

1.6.2 Relevant additional alarms recorded by the CAMS during the incident are summarised¹⁰⁹ in the table below:

Time	Event
1945	First activation of the smoke detection system in no.3 cargo hold
1947	No.3 LS/ DB WBT (S) high level alarm
1950	No.3 cargo hold lighting ON
1951	Earthing fault on the 220V emergency switchboard
1952	Disruption to the low voltage (220V) switchboard
2100	No.3 LS/ DB WBT (P) high level alarm
2120	ES-A - blackout

Table 2

1.7 Ship's crew

1.7.1 The ship was manned¹¹⁰ by 27 crew with two of the crew members who were

¹⁰⁹ Source: The Fire Forensic Expert.

¹¹⁰ According to the Minimum Safe Manning Document (MSMD) issued by the flag Administration, a ship is considered to be safely manned if, when she proceeds to sea, carries not less than the number and grades/ capacities of personnel as stipulated (total:13 officers and crew).

a part of the stock team as tabulated from MH muster list below:

No.	Rank Nationality	Age Yrs	Experience		Joined	Duty as per Muster list for fire on deck	Remarks
			In-rank	MH			
1	Master Indian	43	3 yrs 6 mths	4 mths Second contract	Feb 2018	Takes over the watch In charge of all operations	Joined 'H' class newbuilding team in Jan 2017 Joined MH and delivered from yard Sep 2017
2	CM Romanian	36	2 yrs. 5 mths	5 mths Second contract	Feb 2018	In charge of ET for deck fire Prepare for boundary cooling	Joined 'H' class newbuilding team in Jan 2017 Joined MH and delivered from yard Sep 2017
3	2M Filipino	33	1 yr 5 mths	2 mths	Jan 2018	Assist as per the Master's orders Conduct radio communication	
4	3M British	23	10 mths	2 mths	Jan 2018	Leader of AT-1 for deck fire	
5	ASD-2 Indian	34	4 yrs 3 mths	2 mths	Jan 2018	Prepare fire hose AT and boundary cooling Assist as instructed by Team Leader	
6	ASD-4 Indian	28	5 yrs. 2 mths	6 mths Second contract	Feb 2018	Helmsman Assist as instructed by Master	
7	ASD-1	34	2 yrs.	2 mths	Jan	Assist as	

No.	Rank Nationality	Age Yrs	Experience		Joined	Duty as per Muster list for fire on deck	Remarks
			In-rank	MH			
	Indian		3 mths		2018	required	
8	ASD-3 Indian	32	7 days	7 days	Feb 2018	Member of AT-2	
9	OS Indian	31	2 yrs 4 mths	7 mths	Aug 2017	Timekeeper, prepare fire hose for AT and as instructed by Team Leader	
10	DC-3 Indian	23	1 yr 1 mth	6 mths	Aug 2017	Assist as required	
11	DC-1 Filipino	22	1 yr	5 mths	Sep 2017	Assist as required	
12	DC-2 Indian	22	1 yr 1 mth	1 mth	Feb 2018	Assist as required	
13	CE Indian	41	3 yrs 6 mths	5 mths Second contract	Feb 2018	In charge of ER watch Direct preparation & operations of fire pumps, CO ₂	Joined 'H' class newbuilding team in Jan 2017 Joined MH and delivered from yard Mid-2017
14	2E Filipino	47	6 yrs 10 mths	6 mths Second contract	Feb 2018	Back-up Team for deck fire Prepare for boundary cooling	Joined 'H' class newbuilding team in Jan 2017 Joined MH in the yard in Sep 2017
15	3E-1 Filipino	27	2 yrs 1 mth	2 mths	Jan 2018	Delegated to take over ER watch as instructed by CE	

No.	Rank Nationality	Age Yrs	Experience		Joined	Duty as per Muster list for fire on deck	Remarks
			In-rank	MH			
16	4E Filipino	27	6 mths	2 mths	Jan 2018	Leader of AT-2 for deck fire	
17	EE Indian	33	4 yrs 2 mths	3 mths	Dec 2017	Cut off fuel, electrical & forced ventilation as required Run main/ emergency fire pumps	
18	MM-1 Indian	40	3 yrs 7 mths	6 mths Second contract	Feb 2018	Member of AT-1	
19	EC-1 Filipino	22	1 yr	5 mths	Sep 2017	Assist as required	Loss of life on board
20	EC-2 Filipino	22	1 yr	5 mths	Sep 2017	Assist as required	
21	EC-3 Filipino	22	1 yr	1 mth	Feb 2018	Assist as required	Missing
22	CCK Indian	32	1 yr 11 mths	1 mth	Feb 2018	Collect First Aid kit, resuscitator, stretcher, and blankets	
23	2CK Indian	25	18 days	18 days	Feb 2018	Collect First Aid kit, resuscitator, stretcher, and blankets	Loss of life on board
24	Foreman Thai	36	6 yrs 10 mths	5 mths Second contract	Mar 2018	Assist as required	
25	Painter Thai	28	11 mths	6 mths Second	Mar 2018	Assist as required	Succumbed to injuries

No.	Rank Nationality	Age Yrs	Experience		Joined	Duty as per Muster list for fire on deck	Remarks
			In-rank	MH			
				contract			
26	3E-2 Stock Team ¹¹¹ South Africa	54	2 yrs 7 mths	1 mth	Jan 2018	Proceed to bridge Assist as required	Loss of life on board
27	MM-2 Stock Team Filipino	53	5 mths	1 mth	Jan 2018	Proceed to bridge Assist as required	

Table 3

1.7.2 The statutory certificates for all the crew were valid at the time of occurrence.

1.7.3 The records of hours of rest and work documented by the officers were as per the Company's SMS and indicated that the rest hours followed the 'Hours of rest' requirements¹¹².

1.8 Ship's design

General

1.8.1 MH was one of the 11 ships from a series of H-Class ultra-large container ships (ULCS) built at Hyundai Heavy Industries shipyard, South Korea. The ship's design, construction requirement for structure, subdivision and stability, machinery, and electrical installations were following SOLAS, 1974, as amended.

1.8.2 The ship was a gearless container ship with a twin-island configuration i.e. the accommodation block¹¹³ was immediately aft of no.3 cargo hold, and the engine casing and funnel assembly were immediately aft of no.8 cargo hold.

¹¹¹ Stock Team (ST) is not part of the ship's operational crew. As the ship was newly delivered, the duties of the ST on board, among others, were to take inventory of all items and equipment and update into shipboard database system.

¹¹² Maritime Labour Convention (MLC) 2006 provides guidelines on minimum number of hours of rest required for seafarers on merchant ships. Similar requirements for watchkeeping personnel are contained in the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, as amended (STCW Convention).

¹¹³ Navigation bridge located at the forward accommodation, besides maximizing cargo carrying capacity of the ship, also provides better visibility ahead.

See **figure 18** showing the ship's design comprising the forward section (from the bow, bay 01 to 23), accommodation (wheelhouse/ bridge, living quarters, etc.), middle section (parallel body from bay 25 to 67), engine casing and aft section (bay 69 to 82).

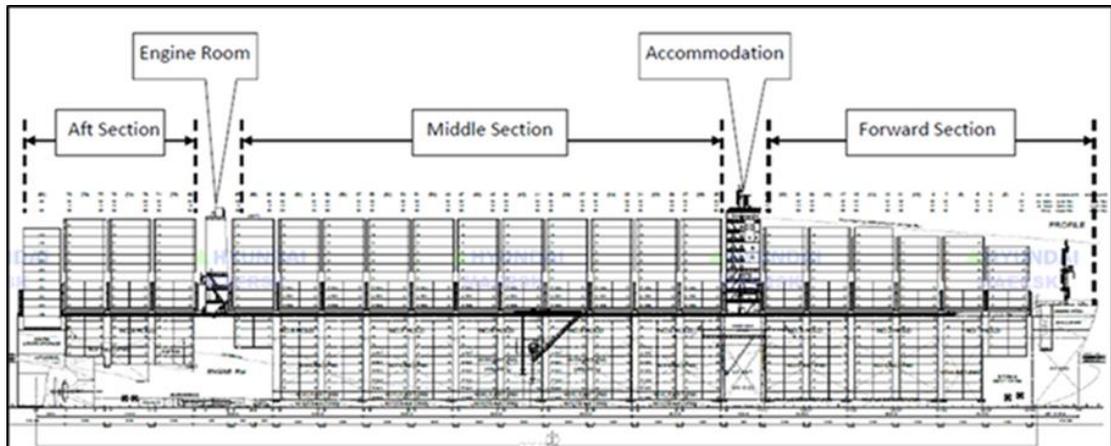


Figure 18 - Side view of MH indicating the various sections

- 1.8.3 The design of the ship was dependent on various factors, which amongst others, included:
- IMO visibility criterion¹¹⁴ that requires that the water surface minimum 500m forward of the bow must be visible from the bridge;
 - Increased carrying capacity of TEU, as the accommodation was fitted forward, thus resulting in a larger cargo carrying capacity in the parallel body area; and
 - Crew comfort, away from engine/ propeller vibrations and noise.

Accommodation block

- 1.8.4 The accommodation block (see **figure 3** showing the various deck levels) comprised nine decks of living quarters, public spaces, offices, etc. as indicated from the upper deck up to the bridge. Each deck was connected by an internal stairway which could be segregated by magnetic fire doors on each individual deck (with automatic closure capability – connected to the main fire alarm). Each deck was also provided with sets of external staircases outside the accommodation on both sides (port and starboard).
- 1.8.5 The ship was fitted with two separate sets of air-conditioning units/ systems. One was the central air conditioning unit that served the common spaces (for crew comfort) in the accommodation and the other was a wheel-house air

¹¹⁴ SOLAS Chapter V, Regulation 22, Navigation bridge visibility

conditioning unit (for navigational equipment). Both systems could be switched-off by the activation of the ES-B.

- 1.8.6 There were four fire (smoke) dampers inside the accommodation (two at the upper deck alleyway and another two at the B-deck). These smoke dampers were capable of being activated remotely¹¹⁵ using switches located inside the FCS and the bridge or manually at the location¹¹⁶ itself. When closed, they were designed to restrict/ prevent the entry of smoke or gases into the accommodation and prevent them from spreading (see **figure 19**).

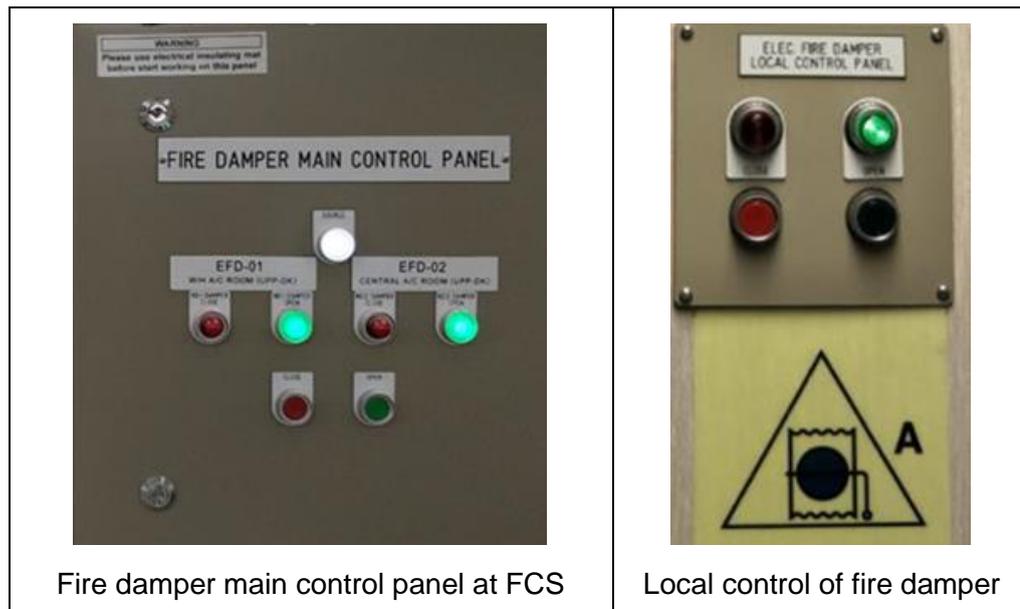


Figure 19 – Switches for the fire damper

- 1.8.7 In addition to the fire dampers, the accommodation block was also fitted with a total of 27 manually operated ventilation closing appliance¹¹⁷ (hereinafter referred to as exterior ventilation vents). These exterior ventilation vents were meant for exchanging of fresh air with exterior environment when opened and for preventing entry of smoke or gases into the accommodation when closed.
- 1.8.8 The investigation team was able to access and check the condition of the exterior ventilation vents for the accommodation. Most of these were found¹¹⁸ in an open position (see **figure 20** on ventilation closing appliance of cover type and mushroom type).

¹¹⁵ Remotely operated smoke damper can be closed by the crew through a control located at a distance away from the controlled damper.

¹¹⁶ Two dampers at Upper-deck located at the alleyway and B-deck dampers located at galley and duty mess room.

¹¹⁷ The different types of ventilation closing appliance, among others, includes, vent with cover, vent with flaps, screw-down type mushroom vent, etc.

¹¹⁸ The salvors confirmed that the condition had not been changed since they boarded.



Figure 20 - Ventilation covers and mushroom ventilators for the accommodation

Bunker tanks

1.8.9 The ship had six HFO bunker tanks (namely 1, 2, and 3 port and starboard) located immediately aft of no.3 cargo hold (see **figure 21**).

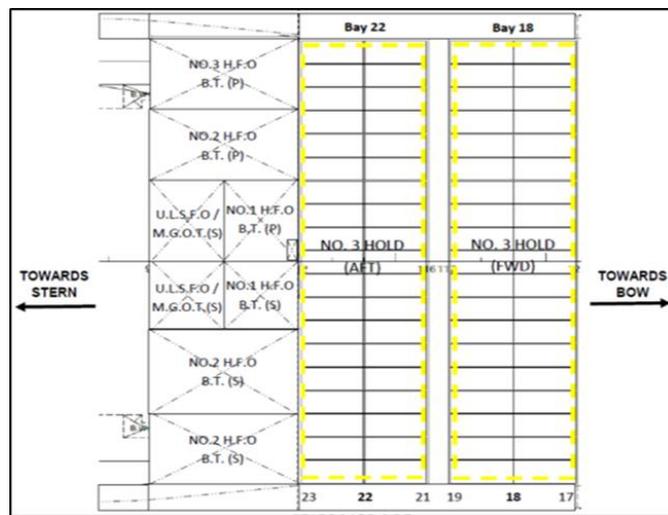


Figure 21 - Position of bunker tanks (adjacent to and aft of no.3 cargo hold)

1.8.10 Typically, as per normal practice, before consuming the fuel from the bunker tanks, the HFO in the tanks would be pre-heated by steam coils (about 40°C) from the exhaust gas boiler. The high-temperature alarm was set at 45°C. At the time of the incident, bunker tank no.1 starboard was in use and according to the 3E-1, the last temperature of the tank checked was about 43°C.

1.8.11 There was no record of leaking steam coils on board. An inspection of the HFO tanks by the salvors indicated that they were intact and that there was no significant change from the last known quantity.

1.8.12 After the occurrence, the Company undertook a temperature monitoring exercise on one of the sister ships which was on the same route to determine whether the heating of one or more of the HFO tanks on a typical ship of this class had any noticeable effect on the temperatures experienced in no.3 cargo hold. The conditions at the time of monitoring the temperature were as close

as practicable¹¹⁹ to those on MH and temperature data were collected for 10 days. The exercise revealed that the temperature in the cargo hold fluctuated generally between 24°C and 31°C and there were no obvious changes to these temperatures as changes in fuel tank temperatures were carried out.

Cargo holds¹²⁰

- 1.8.13 MH had nine cargo holds, of which three were in the forward section i.e. forward of the accommodation, while the remaining were located aft of the accommodation.
- 1.8.14 MH’s cargo holds were fitted with non-weather tight hatch cover¹²¹ panels. These panels had gaps of about 35 +/- 10mm between them which were Class Approved and were of an industry standard widely used on container ships to ease handling of panels for access to containers in cargo hold. The gap was to ensure that natural air would escape the cargo hold in case of CO₂ release and ensure that the cargo hold was saturated with CO₂. (CO₂ is heavier than air and would sink to the bottom of cargo hold and displace the air through the top of the cargo hold). (See **figures 22 and 23** – annotated by TSIB).



Figure 22 - Forward section of the ship (annotated by TSIB with yellow markings)

¹¹⁹ Ventilation and cargo arrangement in the cargo hold were similar i.e. no reefer containers.

¹²⁰ The fire occurrence on board the ship was first detected (as a smoke alarm) and observed to have originated from bay 18 (aft) in-way of no.3 cargo hold, subsequently affecting cargo holds no.1 and 2.

¹²¹ No.1 Forward (Hatch cover) Size: 12.60 x 27.98m, Quantity: 3 panels

No.1 Aft (Hatch cover) Size: 12.60 x 43.10m, Quantity: 4 panels

No.2 Forward to 9 Aft (Hatch cover) Size: 12.60 x 48.50m, Quantity: 4 panels

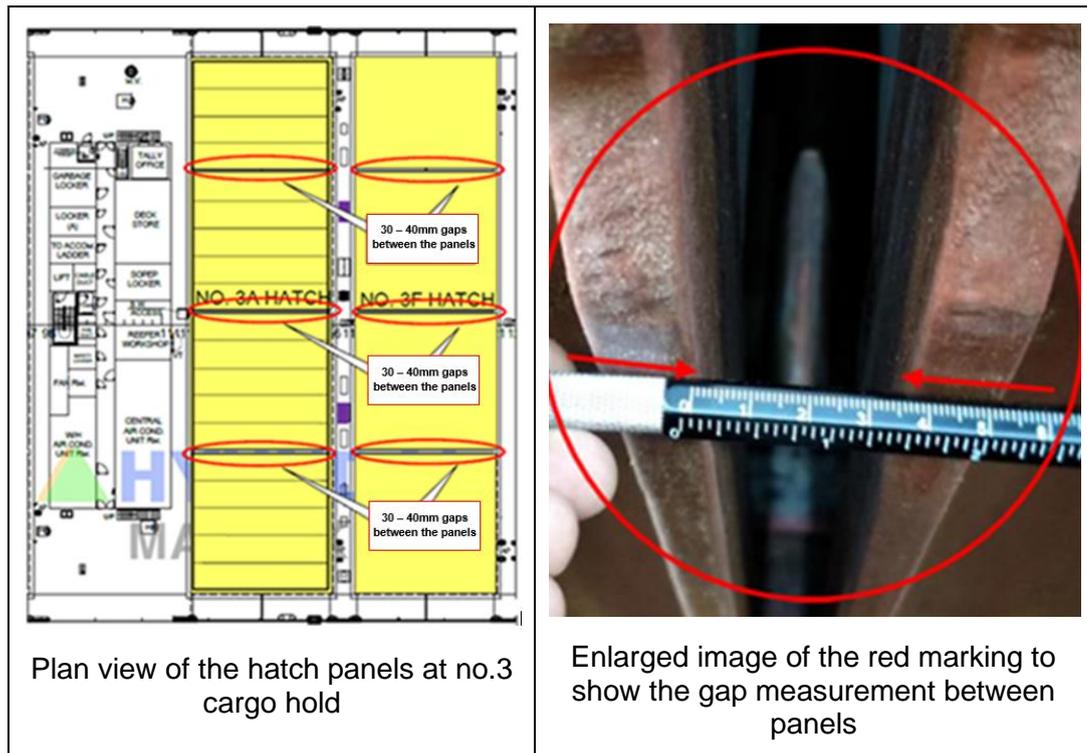


Figure 23 – Gaps between the hatch cover panels (annotated by TSIB with red markings)

1.8.15 MH’s design requirements for coaming height and hatch covers followed the International Association of Classification Societies (IACS) Unified Interpretation (UI) of Load Line 1966 (LL66) and to the approval of the flag Administration¹²² by Regulations 2(5)¹²³ and 14(2)¹²⁴ of the Load Line Convention.

1.8.16 All the cargo holds were designed to carry IMDG cargo as specified by the Class Approved Document of Compliance “Special Requirement for Ships Carrying Dangerous Goods”. This document stated the ship was fit for purpose

¹²² Flag Administration’s condition for approval among others, includes:

- “...limited to use on container ships”
- “...hatchway coamings should be not less than 600 mm in height”
- “...non-weather tight gaps between hatch cover panels should be considered as unprotected openings with respect to the requirements of intact and damage stability calculations. They should be as small as possible commensurate with the capacity of the bilge system and expected water ingress, and the capacity and operational effectiveness of the firefighting system and, generally, should not exceed 50 mm” and
- Bilge alarms should be provided in each hold fitted with non-weather tight covers.

¹²³ Reg 2(5) states that, “...Relaxations from these requirements may be granted to a ship to which a greater than minimum freeboard is assigned on condition that the Administration is satisfied with the safety conditions provided”.

¹²⁴ Reg 14(2) states that, “Coamings and hatchway covers to exposed hatchways on decks above the superstructure deck shall comply with the requirements of the Administration”.

to carry IMDG Class 5.1¹²⁵ and 9¹²⁶ under-deck and on the weather deck.

1.8.17 The ship was provided with supply¹²⁷ and exhaust¹²⁸ fans with the ventilator flaps located at the cross-deck between the forward and aft panels (as previously indicated in **figure 4**).

1.8.18 A remote switch was available on the bridge and FCS for starting/ stopping the exhaust fans. After stopping the exhaust fans, the exhaust fan ventilator flaps would need to be manually shut using a spindle wheel key located at the site. See **figure 24** showing the ventilator flap arrangement at the cross deck.

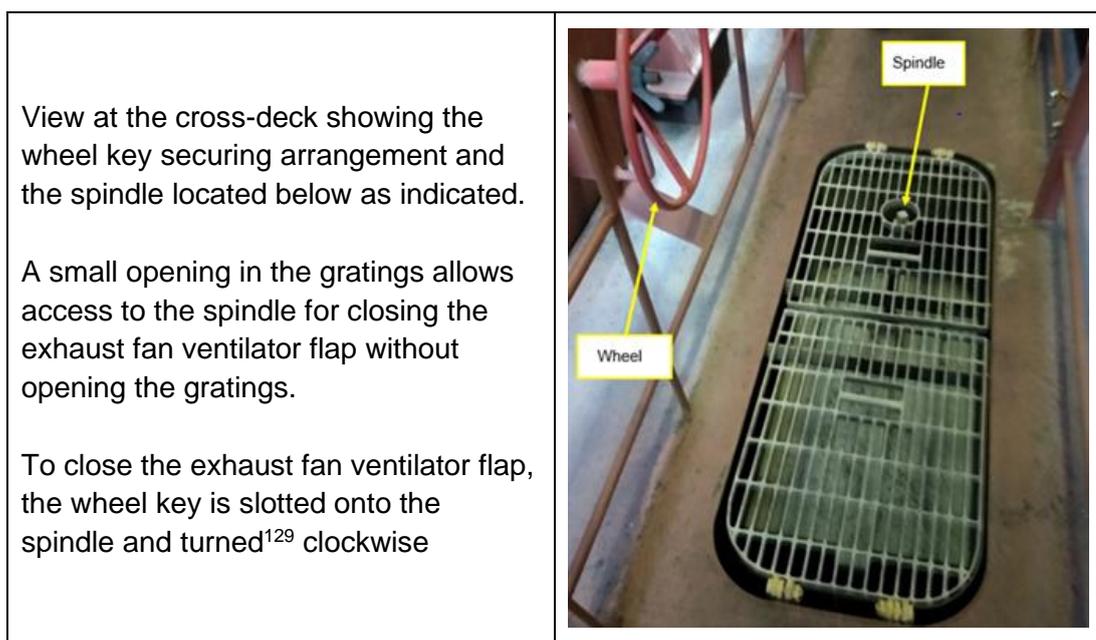


Figure 24 – Showing the ventilator flap below the grating

Reefer cargo holds and related ventilator flaps

1.8.19 In addition to the exhaust fan ventilator flaps, no.3 and no.8 cargo holds, were also fitted with natural ventilator flaps (32 nos./ cargo hold on the side of the hatch cover panels) in preparation for the future carriage of reefer¹³⁰ containers in these holds for additional natural ventilation. (See **figures 4 and 25**)

¹²⁵ Class 5.1 – Oxidising substances

¹²⁶ Class 9 - Miscellaneous dangerous substances and articles, and environmentally hazardous substances

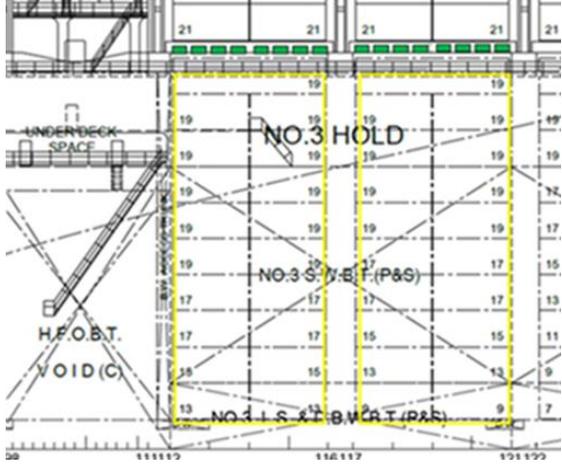
¹²⁷ Total 16 nos. of supply fans only for cargo holds no.4 to no.7

¹²⁸ Total 26 nos. of exhaust fans for cargo holds no.1 to no.9

¹²⁹ Requires about 39 turns (about two minutes) to close the ventilator flap from full open to full close.

¹³⁰ A refrigerated container for the transportation of temperature-sensitive cargo. Onboard MH no.3 and no.8 was planned to carry reefer containers.

1.8.20 These natural ventilator flaps were required to be kept open¹³¹ when carrying reefer containers. At the time of the occurrence, there was no reefer container loaded inside no.3 and no.8 cargo holds, as there were no connections to supply power for reefer containers.

<ul style="list-style-type: none"> • Side view of no.3 cargo hold (forward and aft part) indicated by yellow markings. • The illustration shows the location of the 16 natural ventilator flaps, annotated by TSIB in green, on the hatch cover (in this case the starboard side is depicted) 	
<ul style="list-style-type: none"> • The image shows the natural ventilator flaps of a sister ship in close position, located on the side of the hatch cover panel. • These flaps are located at a height of about 1.95m above the main deck. To access these flaps, the crew must either use a portable ladder on the main deck to reach the flaps or climb on to the hatch coaming and squat under the container. 	
<ul style="list-style-type: none"> • The image shows the flap in the process of being opened (with two hands) and then hooked in an open position. • To close the flap, it must be first lifted in the upward direction to release the “locking hook” before closing and securing with a wing nut 	

¹³¹ It was noted that the natural ventilator flaps for no.3 cargo hold (total 32nos.) were in open position.

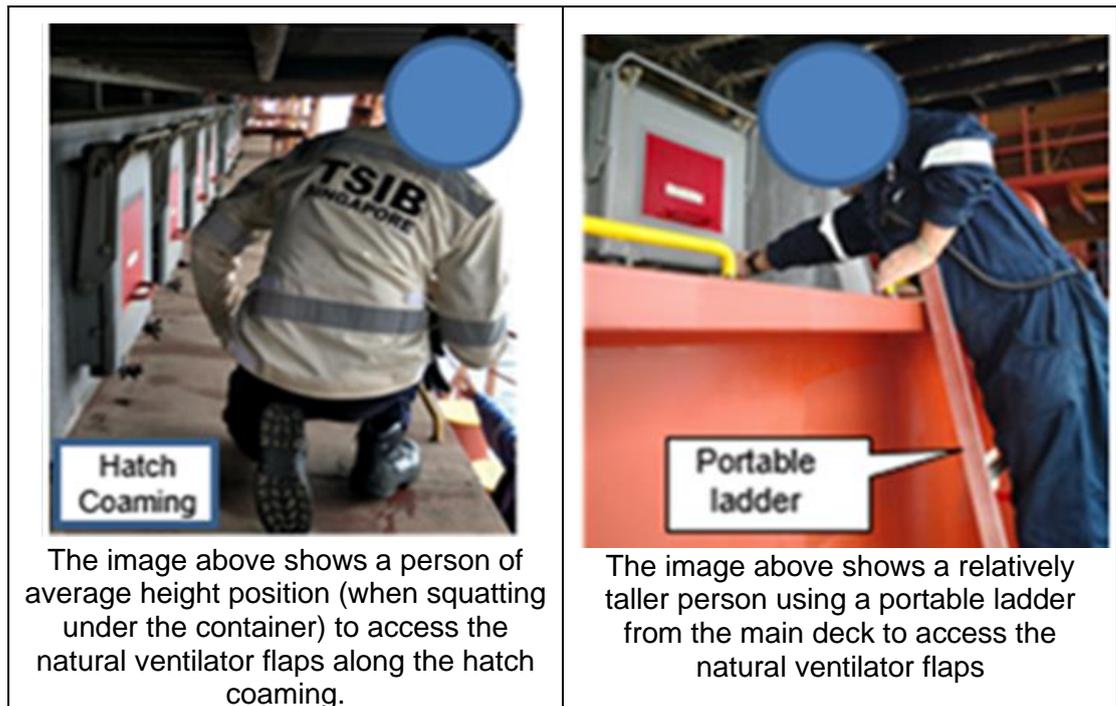


Figure 25 – Natural ventilator flaps

1.8.21 The investigation team was able to confirm the account of the crew by an inspection of the ship post-incident, that the starboard side natural ventilator flaps were closed while those on the port side were open (see **figure 26**).

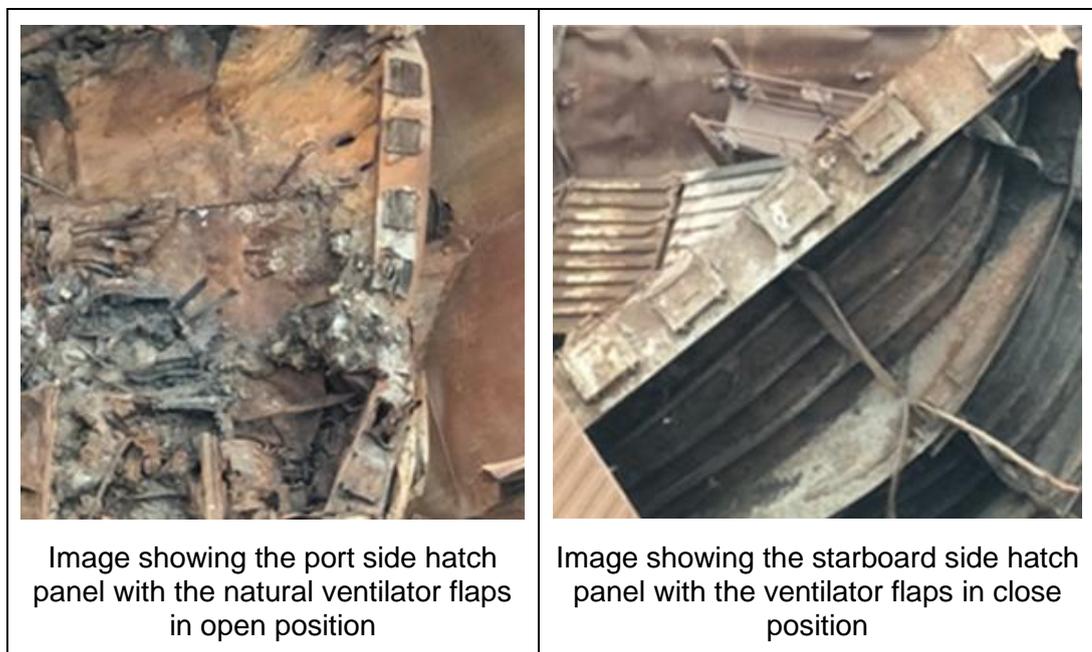


Figure 26 – Shows the condition of hatch panels during post inspection

1.9 Layout of no.3 cargo hold¹³²

Cargo hold bays and electrical fittings

1.9.1 No.3 cargo hold comprised two 40' bays, i.e. bay 17(18)19 in the forward section, and bay 21(22)23 in the aft, which were separated by a non-watertight bulkhead (hereinafter referred to as the intermediate gallery), at frames 116 and 117 (see **figure 27**). The hold was enclosed at the forward and aft, by watertight bulkheads (at frames 121 and 112 respectively).

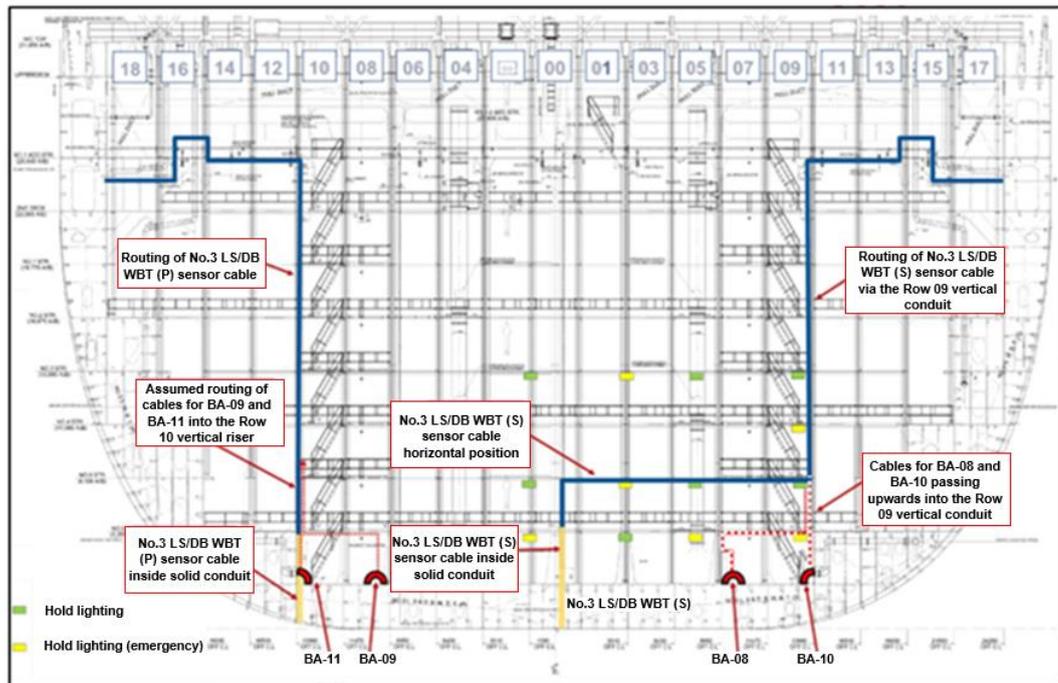


Figure 27 - Layout of no.3 cargo hold and the intermediate gallery at frame 116 ~ 117

1.9.2 Personnel access to the hold was via the intermediate gallery between the two 40' bays. There were two sets of ladders (at row nine and row ten) that provided access to a series of full width galleried landings.

1.9.3 The ladders and the full width galleried landings were illuminated by fluorescent lamps in steel fittings, which were mounted to the deckheads of the landings or other steel support. There were two sets of light, both of which could be illuminated from a single switch control.

1.9.4 The cabling for all systems in the hold was distributed via two conduits mounted adjacent to the ladders referred to as the vertical conduits. Cables to the individual light fittings on each galleried landing extended horizontally from these vertical conduits.

¹³² Relevant extract obtained from the Fire Forensic Expert.

Hydrostatic sensors in ballast tanks

1.9.5 Housed inside the vertical conduits were hydrostatic sensors and control cables associated with the water ballast tanks and hydraulic valves¹³³ in way of no.3 cargo hold. There were four water ballast tanks: two side tanks, outboard of each longitudinal bulkhead on either side of the ship, and two “low side & double bottom” tanks which extended from the bottom of the side tanks beneath the tank top. The nomenclature of the tanks and their full names is provided as follows:

Tank ID on the drawing	Tank name
No.3 SWBT (P)	No.3 Side Water Ballast Tank (Port)
No.3 SWBT (S)	No.3 Side Water Ballast Tank (Starboard)
No.3 LS/ DB WBT (P)	No.3 Low Side & Double Bottom Water Ballast Tank (Port)
No.3 LS/ DB WBT (S)	No.3 Low Side & Double Bottom Water Ballast Tank (Starboard)

Table 4

1.9.6 Each ballast tank incorporated a 24V submersible hydrostatic sensor, mounted close to the bottom of each tank, that measured the water level. The water level information was transmitted through cable to the ER. This data was then fed to the CAMS.

1.9.7 The starboard side hydrostatic sensor was mounted close to the centreline (i.e. on the far port side of that tank). The cable for this sensor passed vertically to no.5 stringer level before turning and passing horizontally across to row 9, where it joined other cables passing up through the vertical conduit. Around the level of no.1 additional stringer, the cable then passed horizontally in an outboard direction to the starboard side passageway.

1.9.8 The port side hydrostatic sensor was mounted in line with row 10¹³⁴ and the cable for this sensor passed vertically from where it exited the tank-top directly into the vertical conduit, before passing horizontally at no.1 additional stringer level into the port side passageway. The solid steel conduit in which the tank sensors were housed are shown with the yellow lines in **figure 27**.

¹³³ BA08~BA11 – Hydraulic valves for water ballast tanks in figure 27.

¹³⁴ An error by the Fire Forensic Expert mis-identified No.3 LS/ DBT WBT (P) as No.3 LS/ DBT WBT (S) has been amended to read correctly in figure 27.

- 1.10 The Company and its Safety Management System (SMS)
- 1.10.1 A DOC certificate was issued to the Company by LR on 24 October 2017 based on the verification completed on 5 September 2017 and it was valid until 3 November 2022.
- 1.10.2 A SMC was issued by ABS to MH on 13 January 2018 and was valid until 12 January 2023. During the initial audit the auditor had verified emergency response requirements as per the ISM code including drill plans. There was no emergency drill¹³⁵ conducted during the initial audit.
- 1.10.3 MH held relevant certificates for compliance with the ISM Code and a functional SMS, which amongst others, included organisational policies, procedures, manuals, checklist, etc. The Company had a Drug and Alcohol policy that prohibits its employees to be under the influence or in possession of any alcohol, illegal drugs, or narcotics while on board the ship.
- 1.10.4 MH was provided with detailed instructions and procedures to ensure the safe operation of the ship, which included, Training Manual and Maintenance Instructions for Life-Saving Appliances¹³⁶, Training Manual and Maintenance Instructions for Fire Safety Operational Booklet¹³⁷, and an Emergency Response Manual¹³⁸.
- 1.10.5 The SMS also contained Emergency Checklists and Procedures with guidelines to identify and respond to various potential emergency shipboard situations to ensure appropriate reporting of emergencies to all parties concerned, as required by the local, national/ international regulations and the Company. The Company also established programs for drills¹³⁹ and exercises to prepare for emergencies by providing measures for shipboard personnel to respond to hazards, accidents, and emergencies involving its ships.
- 1.10.6 The ship's 'Emergency Response Manual' (ERM) in the SMS contained the following information that was displayed on the bridge in the form of flow charts (see **table 5**) regarding actions to be taken in the event of a fire on board the

¹³⁵ It was not mandatory requirement for a drill to be carried out during an audit for Singapore flagged vessels and is left to the prudent judgement of the attending auditor to verify emergency preparedness. Some flag Administrations specify that a drill must be conducted during the audit.

¹³⁶ Training Manual and Maintenance Instructions for Life-Saving Appliances with reference to SOLAS Chapter III Regulation 35 and 36.

¹³⁷ Training Manual and Fire Safety Operational Booklet with reference to Chapter II-2 Regulation 14 (Operational readiness and maintenance), 15 (Onboard training and drills) & 16 (Operation) of the 1974 SOLAS Convention and the 2000 amendments.

¹³⁸ Emergency preparedness – Emergency Response Procedure dated 01 May 2017.

¹³⁹ It was common industry practice for emergency drills to be carried out pre-announced and pre-arranged, and usually during daylight hours.

ship. According to these procedures, a fire alarm was to be sounded as one of the first actions. Subsequently, the flow charts were split up into respective actions to be carried out for fire at different locations, e.g. Fire (on-deck), Fire (under-deck).

Flow Chart 05 Fire (On Deck)	Flow Chart 06 Fire (Under-deck)	Flow Chart 07 Fire (Accommodation)	Flow Chart 08 Fire (E/R - General)
Immediate Actions (Common)			
<ul style="list-style-type: none"> • Sound Fire Alarm and announce the location of the fire on PA System • Manoeuvre the ship to minimise the effects of the fire • Stop all ballast, internal transfer, bunker, and cargo operations 			
Bridge Actions			
<ul style="list-style-type: none"> • Start fire pumps • Close any open valves on fire-line • Isolate any damaged part of fire-line • Steer away from traffic, coast or shallow depths prior stopping ME • Turn on deck lights • Start an event log, including communication 	<ul style="list-style-type: none"> • Start fire pumps • Close any open valves on fire-line • Isolate any damaged part of fire-line • Steer away from traffic, coast or shallow depths prior stopping ME • Turn on deck lights • Start an event log, including communication 	<ul style="list-style-type: none"> • Start fire pumps • Steer away from traffic, coast or shallow depths prior stopping ME • Turn on deck lights • Start an event log, including communication 	<ul style="list-style-type: none"> • Start fire pumps • Close any open valves on fire-line • Isolate any damaged part of fire-line • Steer away from traffic, coast or shallow depths prior stopping ME • Start an event log, including communication
Engine Room Actions			
<ul style="list-style-type: none"> • Manned ER • Put ME on standby • Start an Emergency Generator 	<ul style="list-style-type: none"> • Manned ER • Put ME on standby • Start an Emergency Generator • Ensure all fire 	<ul style="list-style-type: none"> • Manned ER • Put ME on standby • Start an Emergency Generator • Ensure all fire pumps working 	<ul style="list-style-type: none"> • Manned ER • Put ME on standby • Start emergency generator • Ensure all fire pumps working

<ul style="list-style-type: none"> • Ensure all fire pumps working • Isolate electrical power to the area • Stop ventilation in the area 	<p>pumps working</p> <ul style="list-style-type: none"> • Isolate electrical power to the area • Stop ventilation in the area 	<ul style="list-style-type: none"> • Isolate electrical power to the area • Stop ventilation in the area 	<ul style="list-style-type: none"> • Isolate electrical power to the area • Stop ER ventilation
Fire Fighting Actions			
<ul style="list-style-type: none"> • Prepare fire teams • Prepare container firefighting gear • Check for IMDG and reefer cargo near the fire • Close cargo holds fire flaps • Start boundary cooling • Check for any flammable material that can be removed. 	<ul style="list-style-type: none"> • Close cargo holds fire flaps • Prepare fire teams • Prepare container firefighting gear • Check for IMDG and reefer cargo near the fire • Start boundary cooling 	<ul style="list-style-type: none"> • Close manual fire flaps and doors in accommodation • Close any open valves on the fire-line • Isolate any damaged part of fire-line • Prepare fire teams • Remove hospital equipment to a safe area (if required) • Start boundary cooling • Check for IMDG and reefer cargo near the accommodation • Check for any flammable material that can be removed 	<ul style="list-style-type: none"> • Prepare fire teams • Check for IMDG and reefer cargo near ER • Start boundary cooling • Close funnel flaps, fire doors, skylights and all other openings • Evaluate shutting off fuel pumps and quick closing valves
For the release of CO₂ to follow the Emergency Flowchart 11			
Master's action	Sealing Actions	CO₂ Release Actions	
<ul style="list-style-type: none"> • Ship management agrees to CO₂ release 	<ul style="list-style-type: none"> • Ventilation STOPPED • Fire flaps, doors and all other opening CLOSED 	<ul style="list-style-type: none"> • Crew mustered and recounted • Two Senior Officers appointed in charge of CO₂ release • Amount of CO₂ to be released determined • Valves lined up correctly 	

Table 5 – Consolidated by TSIB for the report

1.10.7 The SMS in the form of a muster list and a flow chart provided guidance and steps to be taken for abandon ship. According to these procedures, the decision to abandon ship would require the sounding of the general alarm, followed by an announcement by the Master or the substitute on the PA or radio¹⁴⁰. Before MH was abandoned, neither the general alarm was sounded, nor an announcement was made on the PA system or the radio.

1.10.8 The investigation team gathered from the interaction with the Company and survivors that all the crew had undergone familiarisation¹⁴¹ with their respective duties in the event of a fire occurrence and abandon ship scenario.

1.11 Smoke and Fire Detection System¹⁴²

Smoke (cargo hold) detection system¹⁴³

1.11.1 The smoke detection system panel was located inside the CO₂ room, while a repeater panel was located at the bridge and the FCS. These repeater panels mirrored and displayed all alarms, indicated on the main panel in the CO₂ room, and extended to alarm call panels in the officers' cabins.

1.11.2 At about 1945H, the bridge team was alerted by the smoke alarm on the bridge repeater panel indicating smoke being detected in the mid-section of no.3 cargo hold. See **figure 28** showing the repeater panel.



Figure 28 - Cargo hold smoke detection repeater panel on the bridge

¹⁴⁰ The Company's rationale for having this requirement specified in the muster list was to ensure that all the crew members were able to directly hear the order for abandon ship. The Company opined that while it was difficult to predict the evolution of an incident, radios would be expected to be available with the respective teams and they would collectively be able to hear the order for abandon ship.

¹⁴¹ The Company provided the investigation team with drill records which were maintained electronically on completion of the drill and resided on the Company's server.

¹⁴² The equipment and installations were in accordance with MSC.292(87) which provides adoption of fire safety system amendments to the International Fire Safety Systems (FSS) Code, among others, includes, "...Engineering Specification – General requirement, Component requirement, Installation requirement, System control requirement". Monthly safety checks were carried out as per the ship's planned maintenance system.

¹⁴³ The smoke detection system in the cargo hold comprised two smoke detection units - one was the air sampling unit to monitor the cargo hold atmosphere, and the other monitored the air in the exhaust vent trunking of the cargo holds.

1.11.3 The smoke detection system for MH's cargo holds consisted of the 'Smoke Detection System' (SDS-48) with 'Addressable Fire Detection System' (Synchro ASM¹⁴⁴) provided by "Safetec". Each cargo hold had sample lines connected to sensors in a detector unit housed in the CO₂ room. A fan unit would draw air from the cargo hold through the system while the detector monitored the air. Each cargo holds exhaust ventilation ducts were also fitted with individual smoke detectors. See **figure 29** – showing intermediate bay of no.3 cargo hold at frames 116 -117.

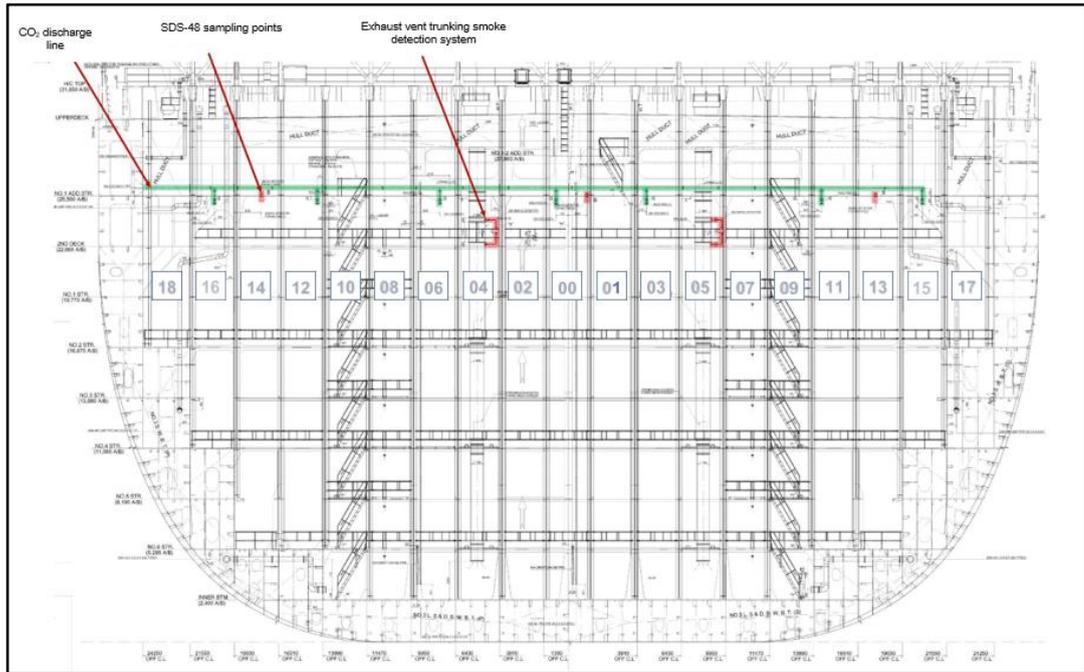


Figure 29 - Showing intermediate bay of no.3 cargo hold at frames 116-117¹⁴⁵

1.11.4 The smoke detection system was independent of and separate from the fire detection system (by Consilium) which covered other areas, such as accommodation, machinery spaces, etc. The ship's crew were aware that smoke alarm from a cargo hold requires to be treated as though it was a fire in the cargo hold.

Fire detection system

1.11.5 The Consilium fire detection system was connected to the magnetic fire doors.

¹⁴⁴ The alarm panel gives readout for smoke detected in either the air sampling unit or the vent trunking and gives an audible alarm in addition to an LED light (indicating FIRE) being activated. The Company was aware and confirmed, although the 'Fire' light on the panel was activated, the repeater panel had detected the presence of smoke inside the cargo holds.

¹⁴⁵ Plan by Fire Forensic Expert annotated by TSIB.

In the event of any detector being activated (and was not reset within three minutes), the main fire alarm (a two-tone alarm) would sound on the entire ship, and the magnetic fire doors would close automatically¹⁴⁶.

1.11.6 On the day of the event, the two-tone alarm was heard on the VDR audio at about 2033H¹⁴⁷. Prior to this main fire alarm, a series of fire alarms (in zones) were activated on the fire detection system.

1.12 Fixed Fire Extinguishing System

Low-Pressure¹⁴⁸ CO₂¹⁴⁹

1.12.1 CO₂ is a colourless, odourless gas that normally exists at a concentration of about 0.04% in the air. CO₂ does not support life and in a concentration¹⁵⁰ above 3%, has dangerous effects. The concentration poses a risk of asphyxiation/ suffocation to anyone in areas where CO₂ is present.

1.12.2 CO₂ does not support combustion, and it is about 50% heavier than air. When used as an extinguishing agent, it forms a blanket over the fire and extinguishes it (starving the oxygen).

1.12.3 Each cargo hold on board MH was protected by CO₂ fire suppression system by means of multiple discharge heads located at high level across the intermediate gallery of each hold (also shown on **figure 29**). As CO₂ enters¹⁵¹ the space and mixes with the atmosphere, the percentage of oxygen in the atmosphere is reduced (space is inert) and results in extinguishing the fire. The enclosed space must be sealed as reasonably tight as possible to maintain the concentration of CO₂ and the reduction in oxygen. Spaces must be kept filled with CO₂ until it has been established that the fire has been extinguished and reduction of hot spots is verified.

¹⁴⁶ To close the magnetic fire doors remotely (without the fire detection system), requires the activation of a push button fire alarm (manual call points). The Company carried out tests on a sister ship to confirm these connections.

¹⁴⁷ The magnetic fire doors likely closed at this time.

¹⁴⁸ One kilo of CO₂ will develop about 0.546m³ of gas (21°C), capable of extinguishing fire in concentration of 30% and more. By compression, large quantities of CO₂ stored in the tank which is kept cooled (about -18°C) by refrigerating machinery at an operating pressure inside the tank of 20 Bar.

¹⁴⁹ The guidance on board MH was provided in a manual by Danfoss Semco.

¹⁵⁰ At 1% CO₂ concentration will cause shortness of breath.

At 3% CO₂ concentration will increase breathing and pulse rates.

At 4% CO₂ concentration will result in IDLH (Immediate Danger to Life and Health).

¹⁵¹ The discharge of a CO₂ flooding system is likely to be violent and frightening to those in the vicinity and the pressure pulse will blow out any incompetent blockage of holes made in the cell walls for the transit of cables, etc. The sudden drop of cell temperature causes dense misting of the atmosphere to take place, obscuring any remaining vision through cell windows.

- 1.12.4 The quantity of CO₂ for extinguishing the fire in a cargo hold is generally based on developing a concentration of 30% within 900 seconds. However, the cargo in the hold can be of such a nature that further CO₂ may be needed to ensure the fire is extinguished or the very least controlled. The possibility of a fire to break out again if fresh air is allowed into space, i.e. when there is access for fresh air into the cargo hold, must always be taken into consideration.
- 1.12.5 CO₂ as extinguishing agents is most effective for various types of fire, among others, includes:
- flammable liquids like oils, paints, and fats;
 - gases; and
 - electrical¹⁵² equipment

**Caution¹⁵³: Fire in nitrates or chlorates cannot be extinguished by CO₂ due to the oxygen contained in these chemicals.*

- 1.12.6 MH was fitted with an approved low-pressure CO₂ fixed fire extinguishing system, manufactured by “Danfoss Semco”. The main components of the system were fitted at the under-deck space below the accommodation and were protected by fire-resisting Division ‘A’ as annotated by TSIB with a red colour (see **figure 30** as annotated by TSIB).

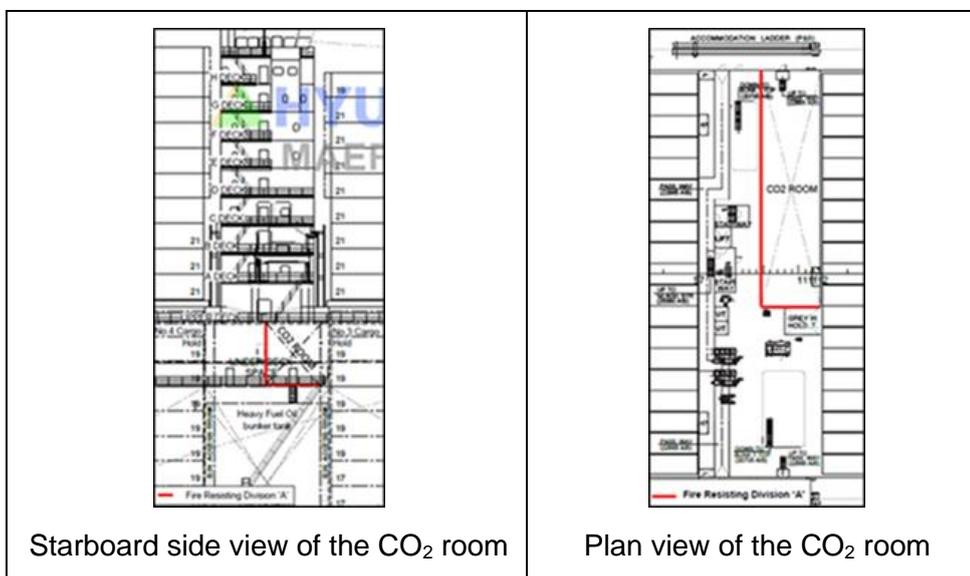


Figure 30 - CO₂ room boundary (annotated by TSIB with red marking)

¹⁵² CO₂ is a non-conductor of electricity.

¹⁵³ Substances of Class 5.1 in certain circumstances directly or indirectly evolve oxygen. For this reason, oxidising substances increase the risk and intensity of fire in combustible material with which they come into contact.

1.12.7 CO₂ release procedures¹⁵⁴ (English) inside FCS (see **figure 31**)

1. Make sure that nobody is in the area in question.
2. Make sure the fire dampers are closed in the area in question.
3. Stop fuel pumps, close fuel valves, and close all openings.
4. Take the hammer and break glass on key box, collect the key.
5. Remove padlock on the control box marked 1 PCS. Pilot valve.
6. Open the cabinet cover marked control box marked 1 PCS. Pilot valve and pull the handle.
7. Unlock the padlock and open the cabinet cover marked cargo holds. This will activate the alarm.
8. Pull down the handle for the hold in question 1 to 9. This will open the diverter valve placed in the passageway, together with one of the distribution valves. Diverter valve no. 1 to 3 will open the distribution valve marked FWD. Diverter valve 4 to 9 opens the one marked AFT. The distribution valve will activate the ventilation stop.
9. Check for failure signals.
10. Pull down the handle marked by MAIN. This will open main valve (8) after the pneumatic time delay.
11. When step 1 to 10 is completed, the system will release CO₂ to the cargo hold in question, starting within a MAX. 90 sec. If failed, follow 'Emergency Release'.
12. Close main valve handle after the calculated release time 15 min, this will close main valve. Check CO₂ liquid content meter and reopen the main valves by use of handle, if the required amount of CO₂ is not reached.
13. After completed release, close main valve handle, this will close main valve. Wait for 1 min then close handle for area in question, this will close the diverter valve.
14. Close Pilot valve handle
15. Go to CO₂ room and activate all manual relief valves, start with the one marked cargo hold DISP. Valves. This will close distribution valve and depressurize Pilot piping.

¹⁵⁴ A copy of the procedures was posted at the operating location of the FCS as well as contained in the Fire Safety Operational Booklet. The description of the procedures in the FCS were detailed and cluttered.

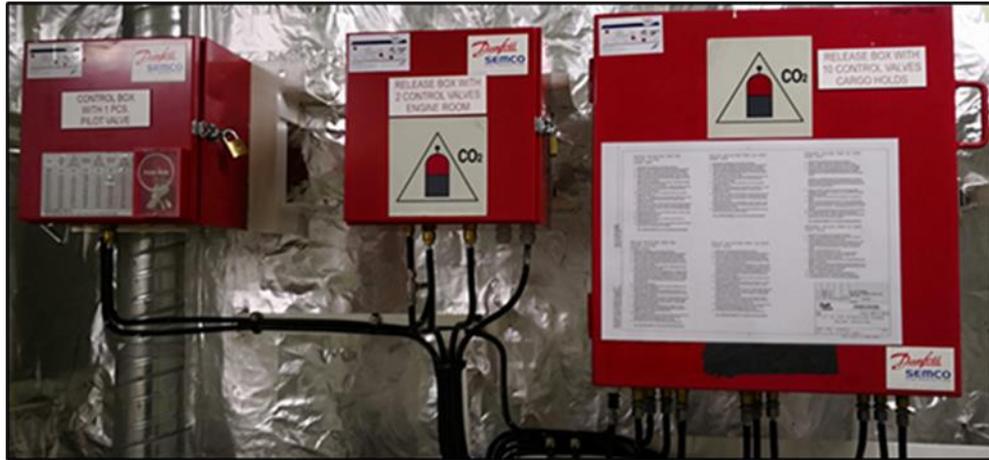


Figure 31 - Control cabinet for the CO₂ system with detailed and cluttered instructions

1.13 Additional firefighting equipment

1.13.1 MH was also provided with portable firefighting equipment that included eight Mobile Water Monitors (MWM)¹⁵⁵ with flexible fire hoses (see **figure 32**).

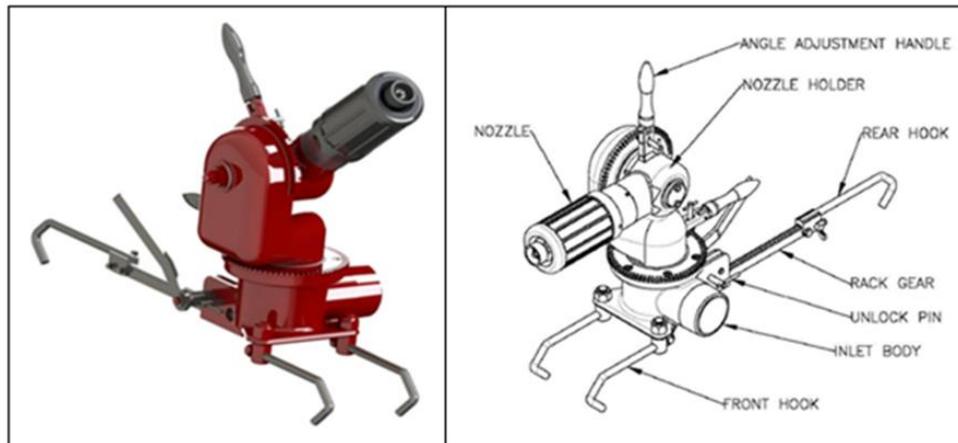


Figure 32 - Mobile Water Monitor

1.13.2 Operation of the MWM¹⁵⁶

- a. Two personnel were required to prepare the MWM for use;
- b. The first person would carry the MWM in the bag and proceed to the

¹⁵⁵ The MWM was tested and approved by the RO on behalf of the Administration based on ABS' FOC (firefighting on-deck container) notation. The MWM is primarily used for container fires on deck. When properly fitted, the MWM provides an unattended water curtain to contain the fire to one bay/ tier and prevent the fire from spreading on deck by spraying on the adjacent bay/ tier and not the bay on fire. When properly fitted it also minimises risk of smoke/ toxic gases/ heat exposure to the crew.

¹⁵⁶ MWM weighed about 13kg, comprised an Aluminium alloy body and capable of providing dual-purpose (Jet/ Spray).

location (e.g. the top of the lashing bridge or its side on the deck (the monitor could be mounted either on the railings or ladders);

- c. Once the MWM was in position (i.e. nozzle pointed toward fire area and locked), the first person would then raise the fire hose by a rope to connect the hose to the monitor; and
- d. The second person would connect the loose end of the hose to the hydrant, open the hydrant valve, and operate the fire pump.

1.13.3 This additional firefighting equipment was stowed inside the storage cabinet at the upper deck storeroom as per the fire control plan.

1.13.4 At the time of the occurrence and until MH was abandoned, the MWM was not utilised¹⁵⁷ by the crew.

1.14 MH's port of call

1.14.1 MH's complete ports of call (refer table 4 below) before the occurrence:

Port	Country	Arrival	Departure
Singapore	Singapore (Westbound)	13 Dec 2017	14 Dec 2017
Suez Canal	Egypt	24 Dec 2017	25 Dec 2017
Marsaxlokk	Malta	27 Dec 2017	29 Dec 2017
Barcelona	Spain	30 Dec 2017	02 Jan 2018
Valencia	Spain	03 Jan 2018	04 Jan 2018
La Spezia	Italy	06 Jan 2018	07 Jan 2018
Gioia Tauro	Italy	08 Jan 2018	10 Jan 2018
Port Said	Egypt	12 Jan 2018	14 Jan 2018
Suez Canal	Egypt	14 Jan 2018	14 Jan 2018
King Abdullah	Saudi Arabia	16 Jan 2018	16 Jan 2018
Jebel Ali	United Arab Emirates	22 Jan 2018	23 Jan 2018
Singapore	Singapore (Eastbound)	31 Jan 2018	01 Feb 2018
Shekou	China	06 Feb 2018	07 Feb 2018
Xiamen	China	09 Feb 2018	10 Feb 2018

¹⁵⁷ The smoke was emanating from the cargo hold. From the interaction with the crew, the investigation team became aware that the use of this equipment, which was essentially for deck container fire, was not considered (in hindsight) due to the unknown nature of the smoke and fire being encountered.

Qingdao	China	12 Feb 2018	13 Feb 2018
Busan	Republic of Korea	14 Feb 2018	15 Feb 2018
Ningbo	China	20 Feb 2018	21 Feb 2018
Shanghai	China	21 Feb 2018	22 Feb 2018
Xiamen	China	23 Feb 2018	23 Feb 2018
Nansha	China	24 Feb 2018	25 Feb 2018
Singapore	Singapore (Westbound)	28 Feb 2018	01 Mar 2018

Table 6 – Port of calls for MH

1.15 The cargo booking process and stowage

1.15.1 The cargo booking process for the Company was similar to that used by most container carriers. Typically, once a customer made the booking request for the carriage of cargo in a container from the port of origin to destination, a validation of the cargo documentation would take place on the carrier’s side to ensure that the cargo was acceptable for carriage and could be transported safely on the selected route considering relevant restrictions on ships and in ports.

1.15.2 The cargo information would then be sent to Cargo Stowage Coordinators to plan the position of the stowage on board the ship. In between, a detailed screening process by the booking team would follow to check the cargo declaration. This process would check for compliance with IMDG rules and validate if there were conflicting information in the booking documentation.

1.15.3 The Company’s dangerous goods approvers would approve the dangerous goods booking according to IMDG Code and restrictions¹⁵⁸ at national, port and terminal level.

1.15.4 When IMDG cargo booking was received, and IMDG stowage requirements were met, the cargo was planned for loading on board a ship and the stowage layout would be sent to the ship as well as the port of loading¹⁵⁹. Any changes in case of downfall, i.e. cargo not arriving on time, would result in a re-stow¹⁶⁰.

¹⁵⁸ This check may include electronic verification of the IMDG Class, UN No. and proper shipping name. A manual screening would only be carried out if the above criteria indicate some discrepancies.

¹⁵⁹ A similar process to integrate data from the carrier to the port’s system would follow which again relies on the documentation submitted by the shipper. Ports may introduce random checks on IMDG cargo from the perspective of checking proper placards according to the documentation as declared.

¹⁶⁰ Re-stow - moving a container from one position on a ship to the other

1.15.5 This entire process of booking would largely depend on the first entry into the booking system received from the customer¹⁶¹. If the shipper's declaration made during the booking did not raise any flags within the carriage requirements, the process of checking for IMDG compliance would flow through.

1.15.6 A shipper would declare IMDG cargo using a Multimodal Dangerous Goods Form¹⁶² (IMDG Code Chapter 5.4.5) comprising 22 fields. Field 14 of this form was a free text box and required the shipper to provide shipping marks, number and kind of packages, description of goods, gross mass (kg), net mass (kg) and cube (m³) information on the IMDG cargo being carried (see **figure 33** as a sample of such a declaration). The top image showed detailed declaration (by one shipper) and the bottom image gave basic information (by another shipper).

14. Shipment information Number and kind of packages; description of goods (*see bottom)				
GWT:	5212.00 (kg)	NET WEIGHT:	4800.00 (kg)	
UN NO:	3077	Technical name:	Adipic dihydrazide	
Proper shipping name:	ENVIRONMENTALLY HAZARDOUS SUBSTANCE, SOLID, N.O.S.		Imo class:	9
Sub risk:	N	N	Packing group	III
Limited QTY:	N	\BoilG Pt:	Marine pollutant (p,pp or no):	Y
Flash point :		Quantity of Package quantity :	4G	240
Inner Description			Inner QTY	
14. Shipping marks		*Number and kind of packages;description of goods		Gross mass
435DRUMS				Net mass (kg)
				Cube
				11,962.50
				10005
				34.8
UN 3077,ENVIRONMENTALLY HAZARDOUS SUBSTANCE ,SOLID, N.O.S.(N-Methyl-1,2-phenylenediamine)				
Class 9, PG III, FPN/M ,MP YES EMS:F-A,S-F				

Figure 33 – Sample of shipper's declaration for reference

1.15.7 A similar process would be in place for accepting a booking from another Company under a sharing agreement¹⁶³. The initial screening of the IMDG booking would be done by the partner carrier and go through the approval process through IMDG approvers of the Company.

1.15.8 According to the Company, packing and securing of the container was the

¹⁶¹ Cargo exporters and importers typically book their freight with a shipping line of their convenience or any related freight forwarder. Based on the commodity to be shipped, a container is dispatched to the shipper's premises where it was packed and if required, labelled. This back-end process did not involve the carrier and was not normally aware of the contents inside a container. There was no manifest issued for all the containers on board the ship.

¹⁶² One of the primary requirements of a transport document for Dangerous Goods was to convey the fundamental information relative to the hazards of the goods. It is was therefore necessary to include certain basic information on the documents for a consignment of Dangerous Goods unless otherwise exempted or required in the IMDG Code. Ref: Chapter 5.4 of the IMDG Code.

¹⁶³ A Ship Sharing Agreement was the sharing of a ship between carriers on a service, i.e. two or three or more carriers supply ships to operate on a service and share the capacity on board the ships on the service according to the agreed joint working procedures.

shipper's responsibility to ensure that the cargo was stuffed and packed correctly. This was a globally accepted norm according to the general terms and conditions that all carriers used.

- 1.15.9 From its interaction with the industry¹⁶⁴, the investigation team noted that if the declaration by a shipper had indicated the cargo to be a Class 9, with the proper shipping name as per the Dangerous Goods List, i.e. Environmentally Hazardous Substance (N.O.S), the dangerous goods approvers would not know whether the product indeed belonged to that class, especially if the booking documents¹⁶⁵ stated that it was a Class 9 without secondary hazards such as oxidising properties.
- 1.15.10 The investigation team examined the material safety data sheets (MSDS) provided on board MH and noted that most of the MSDS was scanned pages and could not be "searched" for keywords. From the MSDS, it would not be possible to electronically identify whether the cargo declared as Class 9 was indeed a Class 9 cargo or any other types of IMDG cargo having secondary hazards such as oxidising properties. MSDS was not a mandatory document for cargo booking.
- 1.15.11 As per the cargo spotting plan, there were 269 containers inside no.3 cargo hold (Forward) in-way of bay 17 (18) 19. The breakup of numbers and type of containers stowed as a block stowage¹⁶⁶ (see **figure 34**) were as follows:

	Nos. of Containers	Type	Remarks
a.	74 x 40'	Dry general cargo	
b.	129 x 20'	Dry general cargo	
c.	11 x 20'	IMDG Class 5.1 ¹⁶⁷	
d.	50 x 20'	IMDG Class 9 ¹⁶⁸	All 50 SDID
e.	5 x 40'	IMDG Class 9	4 containers SDID and 1 container miscellaneous.

¹⁶⁴ Freight rates for carriage of goods declared as IMDG are known to be higher than the rates for non-IMDG cargo.

¹⁶⁵ The dangerous goods were planned for positioning on the ship in accordance with the details mentioned and approved based on the booking details in the booking system.

¹⁶⁶ A method whereby cargo containers packed with Dangerous Goods of the same IMDG Class were stowed in the same bay and adjacent to each other.

¹⁶⁷ Consisted of nine containers of Potassium Nitrate (UN No. 1486) and two containers of Sodium Carbonate Peroxyhydrate (UN No.3378).

¹⁶⁸ These containers were declared to be Sodium Dichloroisocyanurate Dihydrate (SDID) (UN No.3077).

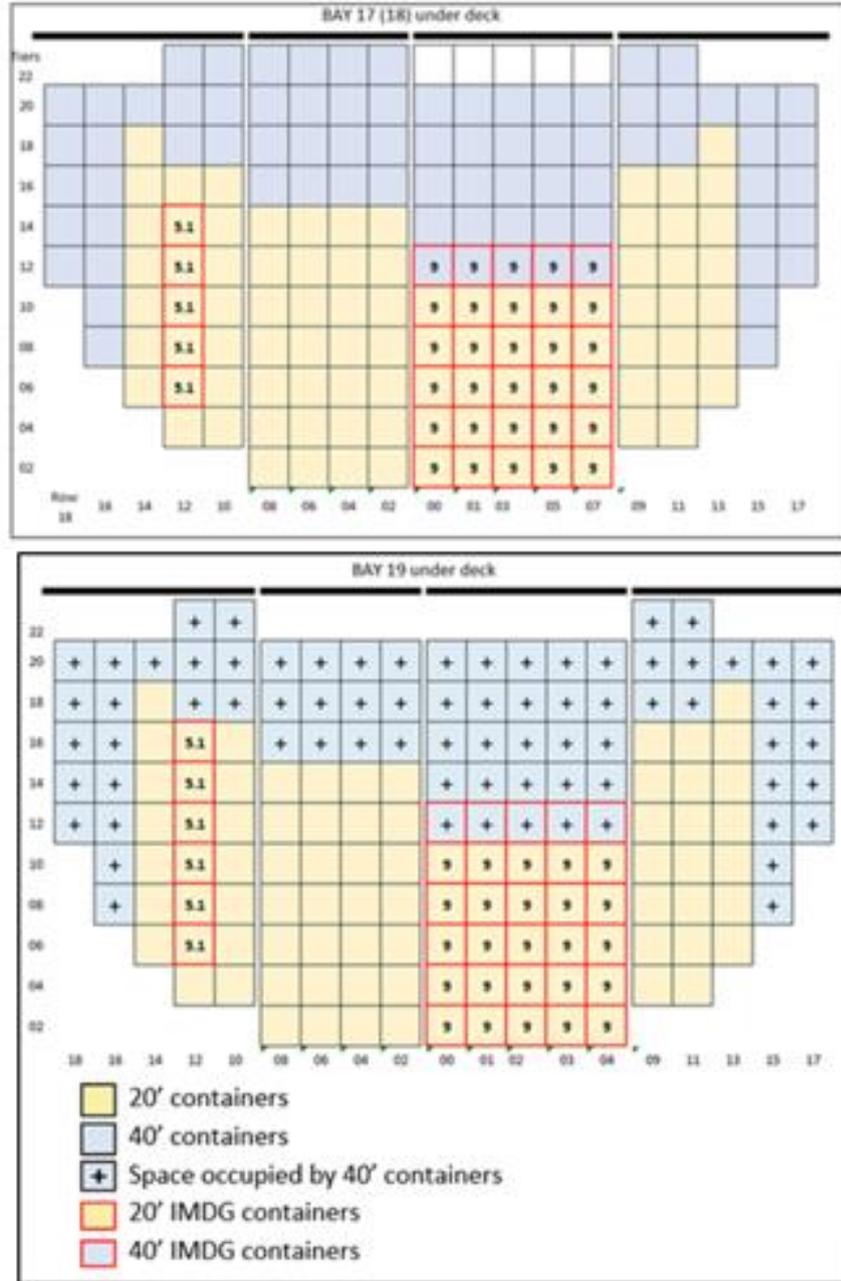


Figure 34 – Showing containers at bay 17 (18) 19

1.15.12 Similarly, there were 294 containers inside no.3 cargo hold (Aft) in-way of bay 21 (22) 23. The breakup of the numbers and type of containers (see **figure 35**) were as follows:

	Nos. of Containers	Type	Remarks
a.	88 x 40'	Dry general cargo	

b.	202 x 20	Dry general cargo	
c.	4 x 20'	IMDG Class 9	Miscellaneous

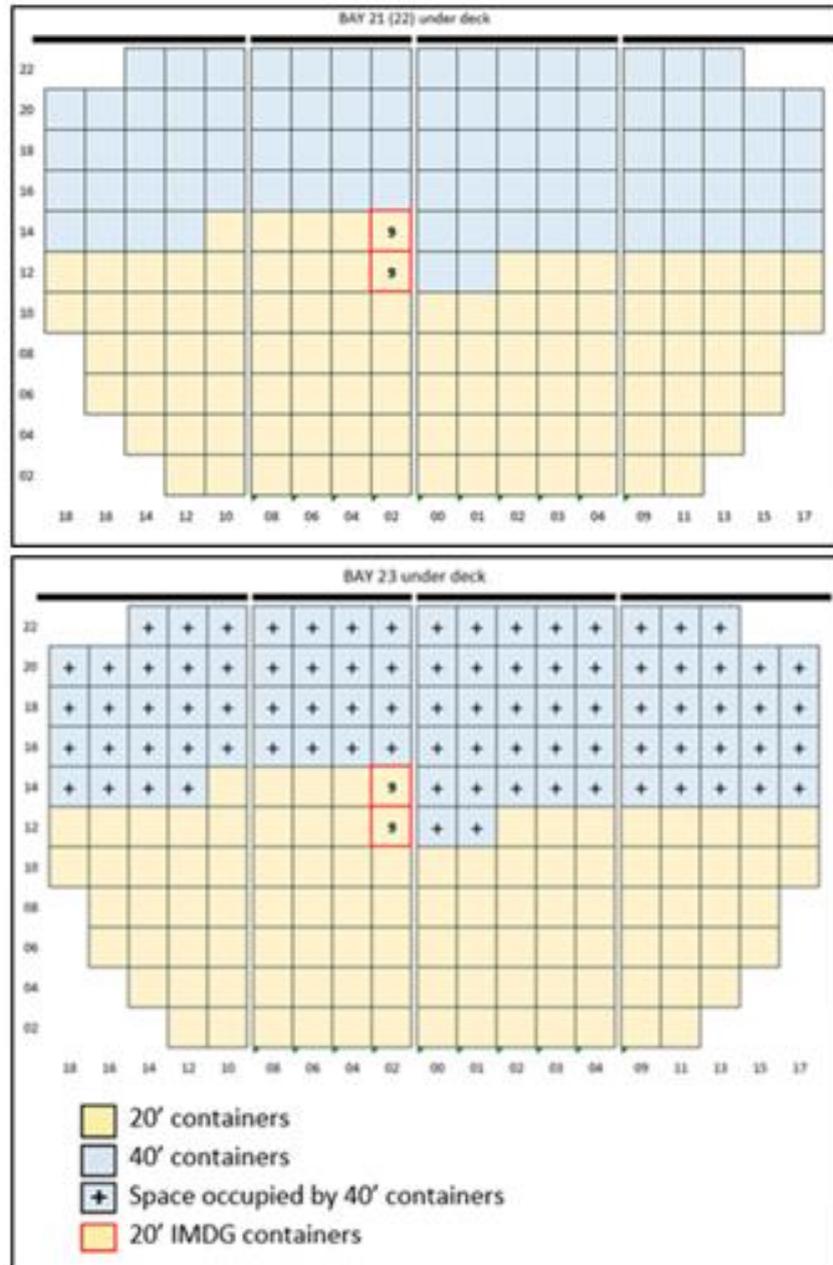


Figure 35 - Showing containers at bay 21 (22) 23 – annotated by TSIB

1.15.13 Section view of no.3 cargo hold superimposed with the routing of water ballast tank hydrostatic sensor cabling, the position of lighting, and the approximate outline of the 54-container block stow of SDID in **figure 36**.

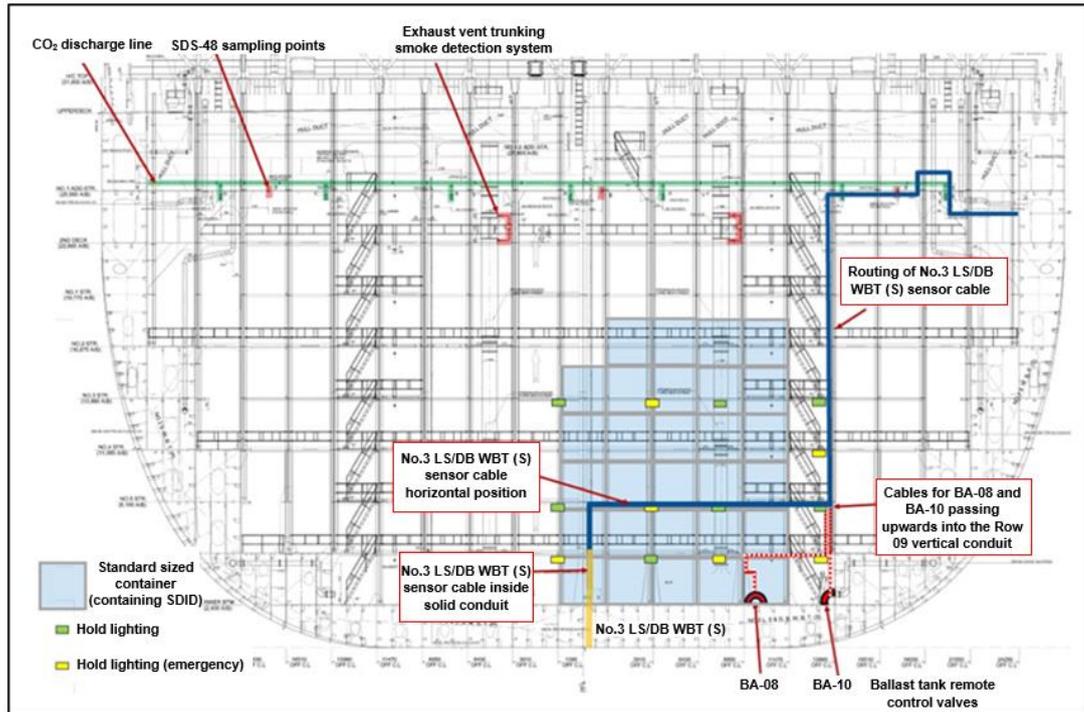


Figure 36 - Cross-section of no.3 cargo hold showing the routing of water ballast tank hydrostatic sensor cabling, the position of lighting, and the approximate outline of the 54-container block stow of SDID – Source: The Fire Forensic Expert

1.16 IMDG cargo inside no.3 cargo hold

Class 5.1 – Oxidising substances

1.16.1 Oxidising substances are substances which, while in themselves are not necessarily combustible, may, generally by yielding oxygen, cause, or contribute to, the combustion of other material. For this reason, oxidising substances increase the risk and intensity of the fire in combustible material with which they come into contact.



1.16.2 Mixtures of oxidising substances with combustible material and even with material such as sugar, flour, edible oils, mineral oils, etc., are dangerous. These mixtures are readily ignited, in some cases by friction or impact. They may burn violently and may lead to an explosion.

1.16.3 There will be a violent reaction between most oxidising substances and liquid acids, evolving toxic gases. Toxic gases may evolve when certain oxidising substances are on fire.

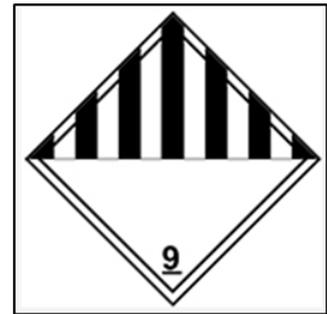
1.16.4 The above properties are, in general, common to all substances in this class.

Additionally, specific properties for some substances are provided in the IMDG cargo list which is to be considered in transport.

- 1.16.5 The Emergency Schedules (EmS) Guide of the IMDG Code states that fires in which these substances are present, are difficult to extinguish, and the ship's firefighting installation may not be effective. The guide further states that everything possible should be done to prevent the spread of fire to containers containing these IMDG cargo. However, if the fire reaches the cargo, personnel should be withdrawn immediately to a well-protected position.
- 1.16.6 The EmS further indicates that if a fixed gas fire extinguishing system is used for incidents under-deck, all hatches and vent dampers should be closed and ventilation shut-off before the system is activated. If the fire is under-deck, consideration should be given to the stability of the ship when flooding the hold with water. Although EmS also states that if smoke is seen coming from around the hatches, the leaks should be sealed with any suitable material available, this is applicable¹⁶⁹ to general cargo ship when carrying IMDG cargo.

Class 9¹⁷⁰ - Miscellaneous dangerous substances and articles, and environmentally hazardous substances

- 1.16.7 These miscellaneous dangerous substances and articles are substances which, during transport, present a danger not covered by other classes.



- 1.16.8 Goods under Class 9 includes, among other things-
- Substances and articles not covered by other classes which experience has shown, or may show, to be of such a dangerous character that the provisions of part A¹⁷¹ of chapter VII¹⁷² of SOLAS, as amended, shall apply.
 - Substances not subject to the provisions of part A of chapter VII of SOLAS, as amended, but to which the provisions of Annex III¹⁷³ of MARPOL 73/ 78

¹⁶⁹ Typically, on container ships the gaps between hatch pontoons, which is an approved design, cannot be sealed as it is permitted to carry containers on hatch pontoons.

¹⁷⁰ Note 1: For the purposes of this (IMDG) Code, the environmentally hazardous substances (aquatic environment) criteria contained in this chapter apply to the classification of marine pollutants.

Note 2: Although the environmentally hazardous substances (aquatic environment) criteria apply to all hazard classes, except for Class 7 (see paragraphs 2.10.2.3, 2.10.2.5 and 2.10.3.2), the criteria have been included in this chapter.

¹⁷¹ Part A – Carriage of Dangerous Goods in Package Form

¹⁷² SOLAS 2001-2003 Amend/ Chapter VII/ Reg.1 – Carriage of Dangerous Goods.

¹⁷³ MARPOL Annex III – Reg for the prevention of pollution by harmful substances carried by sea in package form.

of MARPOL, as amended, apply.

- c. Substances that are transported or offered for transport at temperatures equal to, or exceeding 100°C, in a liquid state, and solids that are transported or offered for transport at temperatures equal to or exceeding 240°C.
- d. Genetically micro-organisms (GMOs¹⁷⁴) and genetically modified micro-organisms (GMMOs) not meeting the definition of infectious substances¹⁷⁵, but which are capable of altering animals, plants, or microbiological substances in a way not normally the result of natural reproduction.

1.16.9 Correlating the account of the crew, the investigation team attempted to identify whether any of the Class 5.1 or 9 were likely to have been involved in the events leading to the fire in no.3 cargo hold. Both the Class 5.1 cargo declared in no.3 cargo hold, i.e. UN No.1486 Potassium Nitrate and UN No.3378 (Sodium Carbonate Peroxyhydrate), did not contain chlorine as an active ingredient.

1.16.10 However, cargo declared as UN No.3077¹⁷⁶ - SDID - under Class 9, is an active ingredient in dry bleaches, dishwashing compounds, scouring powder, detergent sanitizers, swimming pool disinfectants, water, and sewage treatment. SDID contains a chlorine content of 56% as compared to Dichloroisocyanuric acid¹⁷⁷ which contains a chlorine content of 62%.

1.16.11 Seven separate MSDS (by different manufacturers) for SDID provided to MH by the shipper were reviewed by the investigation team. The criteria to test this cargo for qualifying as an oxidiser¹⁷⁸ was not stated in the MSDS. A summary

¹⁷⁴ GMO or GMMO are not subject to the provisions of this Code when authorised for use by the competent authorities of the countries of origin, transit and destination.

¹⁷⁵ See IMDG Code para 2.6.3, Class 6.2 – Infectious substances

¹⁷⁶ According to the IMDG Code, entries of 3077 are used for substances and mixtures which are dangerous to the aquatic environment (marine pollutant) that do not meet the criteria of any other class or another substance within Class 9. The criteria for substances which are hazardous to the aquatic environment are given in section 2.9.3 of the IMDG Code.

¹⁷⁷ IMDG Code Dangerous Goods list states that Dichloroisocyanuric acid is to be classed as Class 5.1 and bears the UN no.2465. IMDG Code further states under Special Provisions (SP) 135 that SDID (the dehydrated salt) does not meet the criteria for inclusion in Class 5.1 and is not subject to the provisions of this Code unless meeting the criteria for inclusion in another class or division. According to the Fire Forensic Expert, this exemption (referring to SP 135) likely dates back to a decision made by the UN DG Advisory Council, in 1980, and that the common industry approach appears to be that SDID is carried under UN no.3077, Environmentally Hazardous Substance, Solid, N.O.S., as part of Class 9 of the IMDG Code, Miscellaneous Dangerous Substances and Articles.

¹⁷⁸ According to a MSDS by Chemwatch, obtained by TSIB, the proper shipping name for Sodium Dichloroisocyanurate is Dichloroisocyanuric Acid, Dry or Dichloroisocyanuric Acid Salts which has been assigned a UN No.2465. It is an active ingredient in dry bleaches, dishwashing compounds, scouring powders, detergent sanitizers, swimming pool disinfectants, water and sewage treatment, replacement for Calcium Hypochlorite (in usage) and is an oxidiser.

of the information extracted from the MSDS is tabulated in **table 7**.

Manufacturer	M-1	M-2	M-3	M-4	M-5	M-6	M-7
Proper Shipping Name	SDID						
UN No.	3077	3077	3077	3077	3077	3077	3077
IMDG Class	Class 9						
Packing Group	PG III						

Fire Fighting means	Water Spray	Plenty of water	Plenty of water	Water [Fog stream and flooding for large fires]	Water to cool containers	Flood with water	Flood with water	
	ABC CO ₂	Do not use Dry chemical, CO ₂ or halogenated extinguishing agents	Do not use ABC or nitrogen based extinguishing agents	Do not use Dry chemical, CO ₂ or halogenated extinguishing agents		Do not use Dry chemical, CO ₂ or halogenated extinguishing agents	Do not use Dry chemical, CO ₂ or halogenated extinguishing agents	Do not use Dry chemical, CO ₂ or halogenated extinguishing agents
	Chemical							

Oxidiser	Not mentioned	Yes	Not mentioned	Yes	May cause oxidisable materials to explode	Oxidiser Special Warning	Yes [Strong]
Decomposition	230° C	240°-250° C	240° C [First molecule of water given off at 60° C]	240°-250° C [First molecule of water given off at 50° C]	240° C	240°-250° C [First molecule of water given off at 50° C]	230°-250° C

Table 7

- 1.16.12 As noted above table, most manufacturers documented their product to be an oxidiser and recommended that the suitable firefighting means for SDID was to flood with plenty of water, and not to use dry chemicals, CO₂, or halogenated extinguishing agents. This recommendation is similar to that stated in the MSDS for Class 5.1 cargo.
- 1.16.13 SDID is extremely corrosive, causes severe eyes and skin burns, and if inhaled would cause irritation to the respiratory tract. If in contact with combustible material it may cause a fire. While it has a negligible fire hazard, it may undergo self-sustaining decomposition with the evolution of heat and dense toxic gases.
- 1.16.14 SDID is required to be stored in a dry place, not to be exposed to temperatures exceeding 50°C and not to be stored in metal or wooden containers or drums for storage.
- 1.16.15 According to the Fire Forensic Expert, "...citing a single container incident containing chlorinated isocyanurates", SDID is known to spontaneously decompose and explode due to ingress of moisture. Plumes of white smoke have known to be emitted as a result. It is also noted that such materials in

bulk can have a different (lower) decomposition temperature¹⁷⁹ as compared to the same material tested under laboratory conditions.

1.16.16 The investigation team noted that SDID has similar end uses as cargo by the PSN of calcium hypochlorite¹⁸⁰, though both cargoes have a different chemical composition.

1.16.17 The investigation team was also aware that CINS¹⁸¹ had issued a guidance paper on the shipment of calcium hypochlorite which recommends that before carriage, carriers should satisfy themselves that the cargo has been packed¹⁸² and secured with a method that allows adequate airflow within the container. There is no specific guidance for the industry for the carriage of SDID.

1.17 Excavation post occurrence

1.17.1 A post event excavation was undertaken under the supervision of the Fire Forensic Expert. The condition of the cargo hold, and its remnants, including the conduct of various tests to determine composition of materials and electrical sources¹⁸³ was done by the Fire Forensic Expert. A picture summary of this process relevant to the investigation as shown below (see **figure 37**).

¹⁷⁹ Typical MSDS from SDID manufacturers list decomposition temperatures ranging from 230 to 252 °C, indicating that the substance is susceptible to decomposition at elevated temperatures in this range, with the evolution of gases (including chlorine) and heat. Decomposition can also be initiated when the substance is heated or moistened or if it stored in the presence of impurities/ inclusions. According to a MSDS produced by Johnson Diversy, decomposition of such cargo can occur at temperatures as low as 35-40°C. This low temperature onset could be a reference to the temperature of the first molecule of water being driven off. The temperature at which the thermal decomposition of SDID becomes self-accelerating is quoted as being substantially below 100°C, irrespective of the technique used to determine the onset temperature. The prospect exists, therefore, that the self-accelerating decomposition temperatures (SADT) in larger commercial consignments could be depressed to dangerously low levels (as a direct result of the insulating properties of the larger package size) - *Source* – The Fire Forensic Expert.

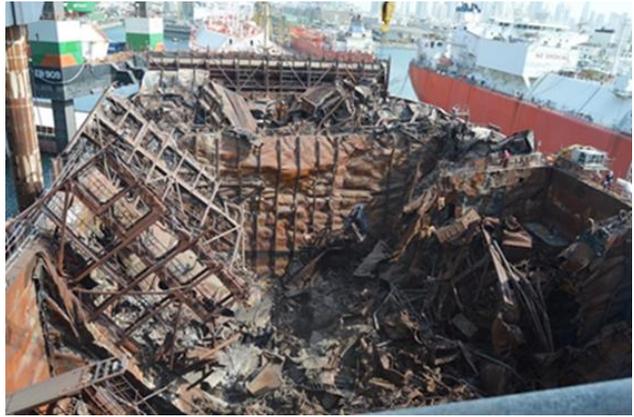
¹⁸⁰ Calcium hypochlorite is an oxidising agent and is designated a Class 5.1 oxidiser in the IMDG Code. Special Provision 314, under Part 3, Chapter 3.3, of the IMDG Code applies to calcium hypochlorite and states that these substances are liable to exothermic decomposition at elevated temperatures. Decomposition can be initiated by heat and can be accelerated by contamination with organic materials (such as oil), inorganic materials (such as metals) or moisture. Calcium hypochlorite tends to be shipped on a full container load basis, is to be stowed on deck only (for cargo ships) and during the course of transport, these substances shall be shaded from direct sunlight and all sources of heat and be placed in adequately ventilated areas and are recommended to be stowed where they are accessible.

¹⁸¹ Cargo Incident Notification System (CINS), a shipping line initiative, launched in September 2011, to increase safety in the supply chain, reduce the number of cargo incidents on board ships and on land, highlight the risks caused by certain cargo and/ or packing failures, and the International group of P&I Clubs, issues various guidelines. Membership of CINS comprises over 65 percent of the world's container slot capacity. The Company of MH was one of the founding members of CINS.

¹⁸² The packaging and quantity can have an impact on self-accelerating decomposition – *Source* CINS *circa* January 2018.

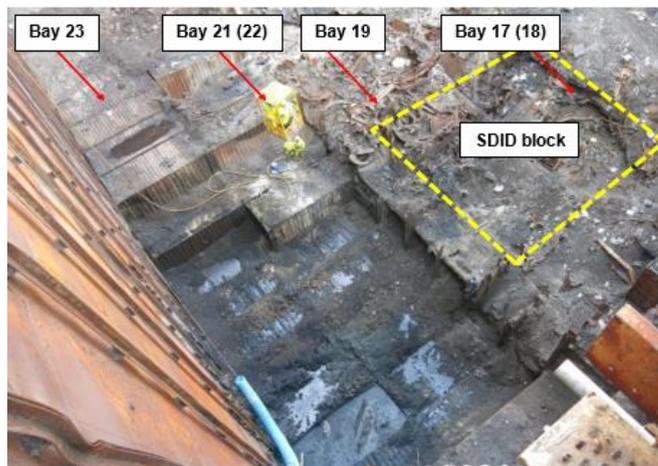
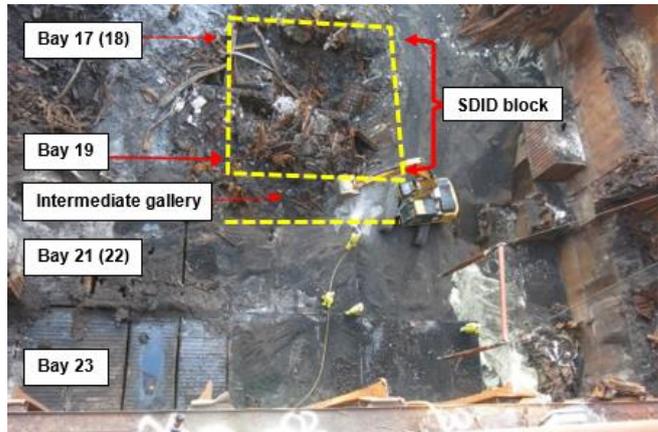
¹⁸³ No signs of electrical distress were noted to the remains of the light fittings or associated cabling. *Source* – Fire Forensic Expert

Before the excavation



Highlighting the SDID block in no.3 cargo hold at bay 17 (18) 19 as viewed from different angles.

(Source - The Fire Forensic Expert)



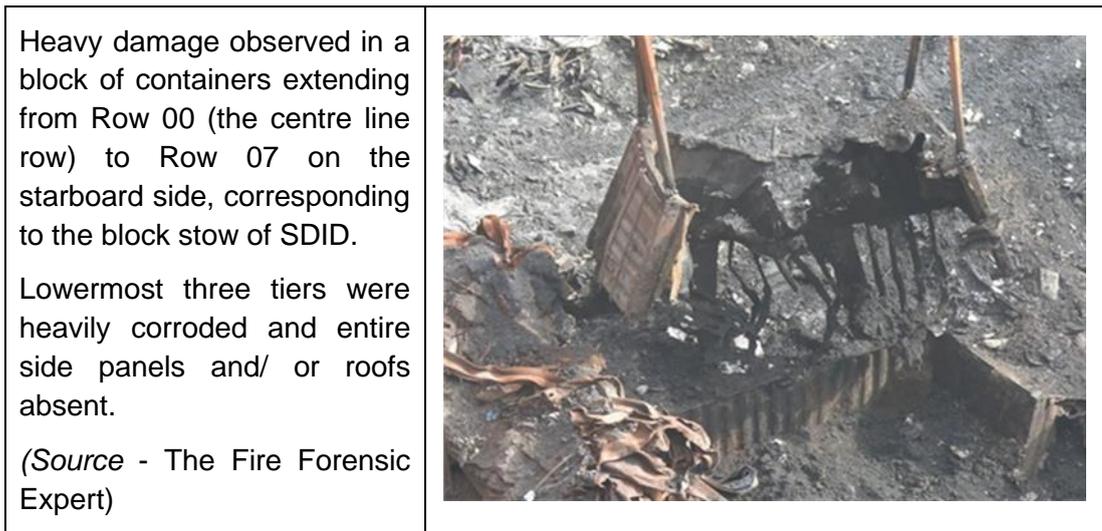


Figure 37 – Condition during excavation

1.18 Notable incidents and related developments

1.18.1 The investigation team noted that numerous container ship fires had occurred in the recent past, especially preceding this occurrence. These included but not limited to MSC Flaminia¹⁸⁴ (2012), CCNI Arauco (2016), MSC Daniela (2017). According to Allianz Global, major container ship fires are among the largest hazards for the global shipping industry. This has also been recognised in a document submitted to the IMO¹⁸⁵. The document also notes that the potential of fire incidents increases in correlation to the growing number of containers per ship. The firefighting challenges and issues faced by the crew with the increasing size of container ships have not been taken into consideration nor have new mitigation measures been incorporated into the existing regulatory framework for the fire protection, detection and extinction on board container ships¹⁸⁶.

1.18.2 After the occurrence, the Company embarked on a detailed physical verification exercise of random containers to establish whether any IMDG cargo shipped by the same shippers (as those on MH) had been mis-declared. According to the Company, there was no evidence to suggest so.

1.18.3 The investigation team also noted that the matter related to container cargo

¹⁸⁴ Investigation report produced by the BSU, Germany.

¹⁸⁵ MSC 102/ 21/ 7 jointly submitted by Bahamas, Germany, International Union of Marine Insurers (IUMI), Baltic and International Maritime Council (BIMCO) and Community of European Shipyards' Association (CESA), expressing the need for amendments to regulations in SOLAS II-2, regarding enhanced provisions for early fire detection and effective control of fires in containerized cargoes stowed on and under deck of container ships.

¹⁸⁶ Source MSC 102/ 21/ 3.

declaration had been raised at various platforms such as at the Container Ship Safety Forum¹⁸⁷ (CSSF) and had gained the attention of various stakeholders such as BIMCO, IUMI, P&I Clubs who have issued their respective guidance for managing risks related to container ship fires. The Company is a member of CSSF along with others¹⁸⁸.

- 1.18.4 At the 6th session of the CCC¹⁸⁹ Sub-committee, a correspondence group was established to review the Special Provisions of the IMDG Code from 900 onwards.
- 1.18.5 In October 2019, ABS published a **Guide for Firefighting Systems for Cargo Areas of Container Carriers** with optional notations to cover fire protection for below deck containers and cargo hold flooding. A similar guide and additional notation were also published by DNV-GL¹⁹⁰ in July 2020, to reduce the possibility and consequences of a container fire in holds for detecting, containing and extinguishing fires in accommodation, machinery, deck and cargo areas, supplementary to those given in SOLAS II-2.

¹⁸⁷ CSFF was launched in 2014 to improve safety performance and management practices in the container shipping industry.

¹⁸⁸ www.cssf.global.

¹⁸⁹ Carriage of Cargoes and Containers.

¹⁹⁰ MPA's approved RO.

2 ANALYSIS

2.1 Likely cause of the smoke alarm

2.1.1 IMDG Code has general provisions¹⁹¹ that set out measures for dangerous goods stowage. The evidence available to the investigation team showed that the cargo stowed on board MH followed the relevant rules of stowage and segregation as per the IMDG code, considering that there were no conflicts raised during the ship's stay in Singapore.

2.1.2 The smoke alarm sounded from no.3 cargo hold at about 1945H, which was followed by the crew reporting seeing "white-coloured smoke from bay 18 centre aft". According to MH's cargo spotting list, no.3 cargo hold had a total of 59 containers of IMDG Class 9 cargo, of which 54 contained SDID.

2.1.3 As most of the evidence in the vicinity of no.3 cargo had been badly damaged by fire, the investigation team made use of the information obtained from the survivors, recordings from the VDR and CAMS, information obtained from the Fire Forensic Expert, as well as cargo manifest to consider the following possibilities which would have triggered the smoke alarm in no.3 cargo hold–

- a. Mis-declared¹⁹² consignment - The Company did not find any evidence (after occurrence) during its physical verification exercise of a mis-declaration. The Fire Forensic Expert could not obtain any evidence of mis-declared cargo during the excavation of the hold. This was based on an examination of the inert unreactive dry goods in the vicinity of the SDID block, which would not have heated (or have undergone another type of adverse reaction) spontaneously. Recalling that there was no smell of combustion, or the sighting of grey/ black smoke or flames noted by the crew in the initial stages of the development, the investigation team deemed that the probability of heat being initiated from other sources was low and thus opined that mis-declaration could be ruled out.
- b. Electrical source - Correlating the sequence of events (see **figure 17 and table 2**) and the examination and tests carried out on the electrical remnants by the Fire Forensic Expert, seems to suggest that an electrical

¹⁹¹ Provisions in the IMDG Code indicate that: (X) means 'Segregation, if any, is shown in the IMDG list', (1) means 'Away from', (2) means 'Separated from', (3) means 'Separated by a complete compartment or hold from' and (4) means 'Separated longitudinally by an intervening complete compartment or hold from'.

¹⁹² If indeed a mis-declared consignment was in the container(s) stowed near to these 54 SDID containers, it might have caught fire and thus initiated the trigger to raise the temperatures of the container(s) and that of other IMDG containers (containing oxidisers) in the vicinity. As noted in the MSDS, decomposition of an oxidiser may occur at temperatures above 50°C with a full decomposition occurring at 240°C.

source was not the initial cause of the occurrence.

- c. Bunker tanks – Considering the temperature monitoring exercise conducted on the sister ship which did not indicate obvious changes to the temperatures in the cargo holds as changes in fuel tank temperatures were carried out, the Fire Forensic Expert ruled out tank heating to be a likely factor.
- d. Other cargo in the vicinity, i.e. Class 5.1 and Class 9 – Owing to the extensive damage within the holds forward of the accommodation, the Fire Forensic Expert was unable to identify the precise point of origin of the initial event from the physical remains of the container shells. Noting the chemical properties (e.g. non-chlorine or inability to decompose) of the other Class 5.1 and Class 9 cargo, the possibility of these being the initial source was extremely low.
- e. Self- decomposition of SDID - noting that SDID may decompose at lower temperatures (as low as 50°C or even lower) as a direct result of the insulating properties of the larger package size as mentioned in **footnote 179**, decomposition exothermic reaction could have been possible (discussed separately).

2.1.4 As evident from the post-accident excavation process (see **figure 37**), and correlating that the crew had reported encountering smoke with the smell of chlorine initially and the severe bleaching of boiler suits, it is likely that the integrity of SDID container(s) in no.3 cargo hold (stowed as a block stowage from centreline towards the starboard side) had been compromised at the onset of the event, which resulted in heat being generated within no.3 cargo hold.

2.1.5 The compromised SDID had resulted in the release of toxic gases from no.3 cargo hold, triggering the smoke alarm and also noted by the ship's crew to smell like chlorine or bleach, but was initially considered as possibly coming from the laundry by the crew.

2.1.6 When the increase in temperature in the cargo hold cannot be promptly

detected¹⁹³ and effectively lowered¹⁹⁴, it can be detrimental and result in the situation to deteriorate quickly. Hence, the investigation team opined that an early detection of the increase in temperature in no.3 cargo hold would give the crew more time to react to a situation. As such, temperature sensors in the cargo holds and connected to the ship's fixed fire detection system would be useful in providing early warning¹⁹⁵ of an impending situation.

2.1.7 Similarly, it would be desirable for individual containers, designated for carriage of IMDG cargo, to be fitted with individual and appropriate firefighting means¹⁹⁶ (for specific IMDG Class) when the temperature within the container exceeds the pre-set range. The investigation team noted that having such a provision has its advantages such as:

- a. Preventing the spread of heat or fire as each container would act as a buffer zone within the cargo hold before the heat can spread to other containers within the hold; and
- b. Lessening the reliance on ship's fixed firefighting system or crew involvement (which is the last line of defence).

2.1.8 The investigation team also notes, that such means would have to be properly fitted, surveyed, and maintained to be effective. Inspection and maintenance would not be within the purview of the statutory requirements of the carrier and needed to be addressed within the approval processes of the Administration (the Government of a Contracting Party) in which the containers are

¹⁹³ A detection system utilising optical or thermal imaging, laser beam detection and/ or other fire safety technology capable of continuously monitoring and detecting both smoke as well as elevated levels of heat within the container holds - *Source: ABS guide for Firefighting Systems for Cargo Areas of Container Carriers*. According to *DNV-GL notation* - Thermal sensors shall be permanently installed at transverse bulkheads allowing continuous monitoring of the temperature of all containers in holds.

¹⁹⁴ A fixed water spray system capable of uniformly distributing the quantity of water underdeck structure immediately above the container bay, underside surfaces of the portions of the hatch covers immediately above the container bay and the tops of all container stacks in the container bay- *Source: ABS guide for Firefighting Systems for Cargo Areas of Container Carriers*. According to *DNV-GL notation* - cooling system in all holds for containers and hold boundaries reducing the risk that an emerging fire is further developing in the hold and or spreading to adjacent holds or through the hatch cover, consisting of water spray nozzles, fixed supply piping system and remotely operated stop valves, able to distribute water uniformly bulkhead plating itself, pouring down the bulkhead.

¹⁹⁵ Fires evolve in two phases: the heating phase and after ignition, the burning phase. Early fire detection is of utmost importance. Advanced technology may achieve this and combine fire detection, localisation and immediate risk assessment to enable an appropriate response. *Source: MSC 102/ 21/ 7*.

¹⁹⁶ Fires in their heating phase could be detected early by temperature monitoring of containers. Such early detection at ambient temperature and before the occurrence of smoke would allow the situation to be kept under control, maintain the personnel in safety, protect the adjacent containers by water cooling and take efficient fire-fighting measures. *Source: MSC 102/ 21/ 7*.

approved¹⁹⁷.

2.2 Classification and stowage of SDID

2.2.1 As discussed earlier, SP 135 allows for SDID to be declared under Class 9 (UN no.3077)¹⁹⁸. It is possible that the lower chlorine levels and lower oxidising properties (6% lesser than those in UN 2465) may have been historically deemed as less risky. However, it must be recognised that SDID presents primary and secondary hazards that are not captured in the current provisions of the IMDG Code and may undergo chemical decomposition at lower temperatures, which could be readily experienced on a ship.

2.2.2 The 54 containers of the SDID block formed a single cuboid block and extended over Bays 17 and 19, from rows 00, 01, 03, 05 and 07, and tiers 02, 04, 06, 08 and 10. In addition, there were 4 x 40' boxes stowed directly on top in tier 12, rows 01, 03, 05 and 07 (see paragraphs 1.15.11 and 1.15.13). According to the Fire Forensic Expert, a decomposition of cargo in this general area would thus be expected to manifest itself in the general area where the smoke was first observed by the crew.

2.2.3 The Fire Forensic Expert commented that the test results for SDID had been derived for relatively small package sizes, adding that a typical 20' container could hold 20 x 1MT jumbo bags, which when stacked in a single container might be considered as a single 20MT (400 times larger than the typical 50kg drum of SDID package), effectively a cuboid comprising over 1000MT of SDID stored in 54 containers stowed over bays 17 to 19.

2.2.4 The Fire Forensic Expert also indicated that the onset temperature of a runaway decomposition reaction may be substantially lower than 100 °C and in certain circumstances (particularly involving larger masses) could be depressed as low as temperatures that might be experienced in a ship's hold. The Fire Forensic Expert further opined¹⁹⁹ that the presence of excess moisture (arising from a humid environment, accidental wetting or some complex mechanism of free water or hydrolysis products migrating through the stow) could lead not only to the depression of the self-accelerating decomposition temperatures (SADT), but a localised elevation in temperature that in conjunction with the depressed SADT could then create conditions for

¹⁹⁷ International Convention for Safe Carriage of Containers, 1972, as amended. The convention has been ratified by 84 contracting States, representing about 66% of the world tonnage.

¹⁹⁸ The declaration of SDID cargo under Class 9 (miscellaneous dangerous goods) is something of an industry norm, due to the fact that SDID presents an alternative hazard as an aquatic toxin. Source – Fire Forensic Expert.

¹⁹⁹ There is scope for further detailed research in this area.

the onset of a runaway reaction even in mild environmental conditions.

- 2.2.5 The Fire Forensic Expert also expressed the possibility of incompatible impurities or moisture could be introduced at the time of manufacture, or afterwards during handling, packing or container stuffing, and that as a result a decomposition reaction could be initiated, slowly at first but accelerating during the sea passage.
- 2.2.6 As such, the investigation team deems that there is merit for the SP 135 to be reviewed for the carriage of SDID and its secondary hazard to be addressed in such a review.
- 2.2.7 The investigation team notes that the correspondence group tasked intersession to 7th session of the Carriage of Cargoes and Containers sub-committee (CCC 7) for reviewing the SP 900 onwards would not be able to review this SP. Relevant submission to the next session of the CCC should be considered to include this review at the earliest.
- 2.2.8 Shippers must take reasonable steps to ensure produced SDID is stable and is packaged correctly according to IMDG requirements. Notwithstanding, carriers must also take reasonable steps to ensure SDID are packed properly i.e. by adopting similar requirements as those for calcium hypochlorite as recommended by CINS (see paragraph 1.16.17) and to consider stowing such cargo on the weather deck, away from direct sunlight, so that the existing water-based firefighting equipment can provide a better response with a lesser risk for the safety of the crew.

2.3 Emergency response for the fire

Sounding of emergency alarm

- 2.3.1 When the smoke alarm sounded at the cargo hold smoke detection system on the bridge panel, the CM's actions to immediately inform the Master was considered appropriate. However, it could not be established as to why the CM sounded the general alarm instead of the two-tone fire alarm, as stated in the muster list and instructed by the Master, especially after getting confirmation from the ASD-1 about the presence of smoke at no.3 cargo hold.
- 2.3.2 Similarly, when the Master arrived at the bridge, the fire alarm²⁰⁰ was also not sounded by using the manual push-button²⁰¹. The Master took over conn from

²⁰⁰ The actions by both Senior Officers, reflected the existence of systemic failure rather than a single person error.

²⁰¹ Doing so would have closed the magnetic fire doors of the accommodation in the early stages of the development and delayed the entry of smoke in the stairway.

the CM and announced the emergency on the PA system. The mustering of the crew on MH was prompt and achieved the intent of established emergency response procedures.

Pre-assigning duties in the muster list to all the crew on board

- 2.3.3 The execution of duties for the emergency on board MH followed the muster list, except that of the 2E. The investigation team noted that 11 of the 27 crew on board were assigned duties as “Assist-as-required” (refer to **table 3**). This might have resulted in the crew without an assigned duty to wait for instructions to be given, i.e. passive response.
- 2.3.4 The accommodation block was the control station and safety centre for firefighting on board the ship. It was thus, extremely important for such a space to be adequately protected from the ingress of heat, smoke, and toxic gases by ensuring all exterior ventilation vents were closed promptly.
- 2.3.5 Although, it is possible that a ship may have persons more than those stipulated in the MSMD, they are nevertheless assets on board to be utilised appropriately during an emergency. Considering that all seafarers (including cadets) engaged on board undergo basic safety training which includes firefighting, the muster list on MH could have taken this into account and assigned these additional personnel with duties such as ensuring that the vents, fire doors and watertight doors etc. are closed during an emergency.
- 2.3.6 The ship’s crew would have reacted better to the situation if, for e.g. the roles of closing these vents had been assigned (within the muster list) to those without any specific duties. This might have thus improved the chances of these 27 exterior ventilation vents (see paragraph 1.8.7) of the accommodation block and the engine casing being closed.
- 2.3.7 The investigation team opined that the pre-assigning of duties would ensure expeditious response and at the same time would help to relieve the Master, or other senior officers, from having to allocate these tasks during emergency.

Issues relating to the execution of the muster list duties

- 2.3.8 Based on the muster list, the 2E as the leader of the Back-up Team (BT), should have assisted the ET in ensuring boundary cooling was provided rather than assisting the CE (who was already being assisted by the EE) in the FCS for the planned release of CO₂.
- 2.3.9 The ship’s ‘Emergency Response’ flow chart 06 *Fire (under-deck)* and 05 *Fire (on-deck)* required actions by the firefighting teams to “close cargo hold fire

flaps” only. Similarly, flow chart 07 *Fire (accommodation)* identified closing of the ventilator flaps, and flow chart 08 *Fire (ER-general)* identified closing of the funnel dampers/ skylight for the ER and accommodation fire damper as one of the tasks to be carried out. The design of the flow charts suggests that the relevant actions were only needed to be taken for fire at the respective locations, i.e. appeared to be read individually as a response. From this occurrence, it shows that it is equally important to close the ventilator flaps/dampers in the accommodation and machinery spaces for the protection of the crew even for an under-deck fire.

- 2.3.10 The non-closure of these had, as a result, caused entry of smoke and toxic gases into the safe area²⁰² (e.g. engine room), the control station²⁰³ (e.g. FCS) and safety centre²⁰⁴ (e.g. bridge), due to the close proximity of the accommodation block to the location of the fire. The timely closure of the ventilator flaps/ dampers in the accommodation and machinery spaces could have provided additional time and opportunity for comfort of the crew and for the Master to re-think the options for effective command and control.
- 2.3.11 It is recognised that the smoke and intense heat near no.3 cargo hold had increased the challenges for the AT-1 to identify the correct location of the 16 natural ventilator flaps²⁰⁵. The AT-1 was not searching at the correct location and had not been provided with specific instructions by referencing the numbers and location of the ventilator flaps from the plan. Had AT-1 been given specific instructions, it could have saved some time to search the location of those flaps.
- 2.3.12 The investigation team noted that members of the second AT-1 (comprising the 3M and 4E) split at some point halfway during the emergency, because the 4E chose to stay forward (where there was lesser smoke) whereas the 3M had to retreat alone to the FCS to replace the BA bottle. The 4E’s decision to stay forward could have been influenced by a fear of getting stuck halfway on the way back with smoke in the vicinity and an empty bottle. Nevertheless, the 4E should have returned with the 3M instead of proceeding forward and getting isolated from the rest of the crew (until being assisted by the 3E-1 at the time

²⁰² Safe area in the context of a casualty is, from the perspective of habitability, any area(s) which is not flooded, or which is outside the main vertical zone(s) in which a fire has occurred such that it can safely accommodate all persons on board to protect them from hazards to life or health and provide them with basic services.

²⁰³ Control stations are those spaces in which the ship's radio or main navigating equipment, or the emergency source of power is located or where the fire recording or fire control equipment is centralised. Spaces where the fire recording or fire control equipment is centralised are also considered to be a fire control station.

²⁰⁴ Safety centre is a control station dedicated to the management of emergency situations. Safety systems' operation, control and/ or monitoring is an integral part of the safety centre.

²⁰⁵ The limitations and practical challenges will be discussed under a separate section under ship's design.

of abandoning the ship). It must be emphasised that team members should make every effort to stay together, especially when they are a part of a firefighting/ response team.

2.3.13 The 4E could not access the BA bottles located in the forecastle fire locker, because the passageway was padlocked due to security measures in place for transiting high-risk areas of piracy. It could not be established why the 4E could not break the padlock with the fire axe (part of fireman's suit) or any other means. Notwithstanding the 4E's inability to break the padlock, while both security and safety are important on a ship, consideration should be made in the design of the padlock (e.g. using a combination lock known to the ship's crew) for it to be opened in an emergency.

2.3.14 Though the ME on MH was ready for Master's subsequent action as per SMS to "steer away from traffic, coast or shallow depths prior stopping ME", MH's speed was about 15 knots up to about 2115H²⁰⁶ and the engine was stopped at 2130H. For almost two hours, the Master had attempted to reduce the effect of smoke on MH's crew engaged in firefighting but maintained headway²⁰⁷. It could not be established why the ME was not stopped earlier (despite the telegraph being moved to Slow Ahead as early as 2005H). The thrusters (bow and stern)²⁰⁸ could have been used to assist in maintaining the ship's heading to minimise the effect of smoke on the accommodation. The use of thrusters for maintaining the ship's heading without making headway to serve as a reminder to the Master²⁰⁹ could be considered in the ship's ERM.

2.4 Firefighting efforts and related issues

2.4.1 Faced with not knowing²¹⁰ the cause and source of the smoke (emanating from gaps between hatch cover panels as well as the open natural ventilator flaps), the Master's decision in releasing the CO₂ into the cargo hold i.e. to err on the side of caution was understandable. Unfortunately, the injection of CO₂ into a cargo hold containing oxidising substances (Class 9) and which was partially unsealed (open natural ventilator flaps on the port side) had little effect.

²⁰⁶ VDR at about 2025H, MH's heading 334.1°T at about 4 knots.

²⁰⁷ The ship would lie broadside to the effect of the prevailing winds if it lost speed and subsequent steerage. However, the headway of the ship also likely "fanned" the spread of smoke with the introduction of "air" across the bow of the ship.

²⁰⁸ Thrusters are typically effective at slower speeds, generally around 4-5 knots.

²⁰⁹ This would minimise the effect of fanning on the fire.

²¹⁰ SDID, being an oxidiser also requires a response, similar to that required for a Class 5.1 cargo. It must be noted however, that the cargo hold contained other non-IMDG containers which would likely make decision making a difficult task.

- 2.4.2 The investigation team noted that the dangerous goods were classed, in the IMDG Code, based on the primary hazard and not secondary hazard. The 54 containers inside no.3 cargo hold carrying SDID, though exempted to be classed as Class 5.1 (under SP 135), were classed as Class 9 and contained a secondary hazard of chemical decomposition/ instability which was not recognised in the current provisions of the IMDG Code.
- 2.4.3 Even if the SDID was declared as Class 5.1, for it to have been tackled by the crew appropriately, i.e. flooding the cargo hold with water, there were practical challenges to do so. Firefighting response for an oxidised substance requires the use of abundant water, as recommended in the EmS, which under the current statutory requirements, could only be met by cutting out holes in the hatch cover for inserting the fire hoses. This response would, however, require additional tools and time to carry out (especially in the hours of darkness), as well as putting the crew at risk of being in the vicinity, which would have been contrary to the recommendation contained in the EmS of moving people away to a safe place when dealing with SDID.
- 2.4.4 It is also noted that the MWM was relatively heavy equipment (weighing 13kg) to be carried from the storage cabinet (located on the upper deck) for it to be rigged. The extreme heat, toxic smoke, rapid deterioration of the situation and practical difficulties to do so could be possible contributing factors for its non-usage during the occurrence.
- 2.4.5 The crew exposed to the smoke and heat showed courage and endurance to perform boundary cooling and to shoot copious amount of water jets from the lower decks and the bridge wing towards no.3 cargo hold, to try and minimise the effects of heat and smoke.
- 2.4.6 Notwithstanding the efforts by the crew, the investigation team is aware that there are no statutory requirements for cargo holds to be fitted with fixed water-flooding systems (especially if they could be activated remotely²¹¹). The investigation team noted the calls by various industry stakeholders for SOLAS requirements for firefighting measures to be reviewed²¹².
- 2.4.7 As such, it would be desirable for standards/ guidance like those prepared by ABS and DNV-GL (after the accident) to be adopted across the industry, as a risk-mitigating measure, especially considering that the industry has

²¹¹ A remote means of closure is to be provided for ventilation arrangements if they are not able to be closed locally due to the possibility of heat or smoke from a fire within a container bay. *Source: ABS guide for Firefighting Systems for Cargo Areas of Container Carriers.*

²¹² Fire protection provisions for container ships need to be revised in view of the safety objectives in SOLAS regulation II-2/ 2 and the need for a contemporary level of protection. *Source: MSC 102/ 21/ 7.*

recognised that the growth of the size of container carriers in the recent years has been steadily increasing and has outshone the statutory requirements. It must be recognised, however, that operational risks should be addressed properly, before advancements can be made, over and beyond statutory requirements.

2.4.8 The ship's DOC for IMDG allowed for Class 5.1 and Class 9 cargo to be stowed both on the weather deck and under-deck. Given the challenge of not being able to flood the cargo hold effectively with water, till the statutory requirements are amended, it would be desirable to load dangerous goods with oxidising properties (and those with secondary hazard of chemical decomposition) on-deck, away from direct sunlight, where water could be used more effectively. Similar recommendations have already been made by CINS in the document containing safety considerations for ship operators related to risk-based stowage of dangerous goods on container ships, issued in November 2019.

2.5 Evolution of the emergency and response to abandon ship

2.5.1 The transition from an on board fire to an abandon ship may not be readily apparent (for it to be included in an SMS) especially in an emergency of the magnitude that occurred on MH. Situations on board may change (some rapidly as was in this case) and require a review of the strategy during the emergency.

2.5.2 Even though it could not be positively ascertained at what stage the fire in no.3 cargo hold became uncontrollable, as discussed earlier, the first injection of CO₂ may not have had the effect (as anticipated) on no.3 cargo hold from a firefighting perspective.

2.5.3 Before the second release of CO₂, the Master's decision to call all the crew to the bridge was for their own safety, while concurrently attempting to fight the fire. Although, the Master was considering options to abandon ship, as evident from attempts to keep the smoke away from the accommodation and the lifeboats (in the event that the crew were required to access the lifeboats), and the subsequent instructions to send the distress alert, this was not made known to the crew. The investigation team held the view that, since the time the first alarm sounded till the MH was abandoned, certain triggers, if recognised timely by the Master, may have been able to allow for allocation of resources to prepare for abandon ship, such as the launching of lifeboat and life rafts, while attempting to fight the fire.

2.5.4 Some of these triggers include the inability of the AT-1 to close the ventilator flaps on the port side while experiencing excessive heat and smoke, the

ineffectiveness of the first injection of the CO₂, the limitation of the boundary cooling, the ingress of smoke and activation of the water mist sprinkler system in the ER.

- 2.5.5 When the second and final injection of CO₂ was done at no.3 cargo hold, the CO₂ likely reacted with the developments already inside (explosions were heard, which are common during injection, refer **footnote 151**). Without no.3 cargo hold completely sealed, the CO₂ displaced heat, smoke and toxic gases emanating from the hold upwards, which found its way through openings in the accommodation and into the bridge.
- 2.5.6 At this stage when toxic gases entered the bridge, chaos started to develop causing the formation of different groups. Unknown to the Master's group which took shelter inside cabin 'O' before proceeding to the lifeboat, the other three groups assembled aft in-way of the engine casing.
- 2.5.7 It could be reasonably established that by the time the crew of MH had been split, the tremendous heat emanating from no.3 cargo hold had caused the containers on deck to catch fire.
- 2.5.8 After the crew had dispersed into several groups, the Master called the others on the walkie-talkie but received no response. Likewise, the other crew members also recalled trying to establish communications but did not receive any response²¹³.
- 2.5.9 The investigation team then attempted to rationalise, whether, in the absence of a booster, what could be the chances of the Master's call to crewmates not being heard. The radio silence could be attributed to factors which cannot be positively identified, but can't be ruled out either, such as, ambient noise of fire in the vicinity and walkie-talkies not being within listening range (kept on the side for performing various functions) during the emergency.
- 2.5.10 While SOLAS does not specify how the abandon ship order is to be given, the way the order is given should be specified in the muster list. The muster list stated that the abandon ship was verbal order by the Master, which is a common and widely accepted practice for the industry. The Company's muster list further stipulated that this order was to be given by the Master either in

²¹³ Based on the Company's own investigation after the occurrence, it became apparent that though the booster units were supposed to be connected to the emergency power on all H-class ships, on some ships, this was missed out, which included the MH.

person or by radio²¹⁴.

2.5.11 On the day of the occurrence, there was no formal order given to any crew member to abandon ship by the Master, except for discussions within group 1 while inside cabin 'O', fearing the worse. Although the PA system was connected to the emergency power source, the nearest PA system to the Master's location was on the bridge which had been evacuated.

2.5.12 The ship's telephones were connected to the emergency power source and had a paging facility. Though it was possible to use the phone to make an abandon ship announcement (last-minute attempt to announce for abandon ship), it was evident that by this time, inside cabin 'O' there was a lot of fear set amongst the members of group 1. This ranged from the crew breaking down to imagining the worst-case scenario. It would be reasonable to expect a mental overload for the Master who had the duty to care for the safety of the crew within the cabin. Under these circumstances, the Master's action to abandon ship with group 1, after making reasonable attempts to reach out to the other crew on walkie-talkie was considered plausible. It would be desirable for the Company to include the use of the ship's telephones for making an announcement for abandon ship in the muster list to remind its crew, particularly in a situation of high workload and stress.

2.5.13 When the crew were separated, no one could anticipate the presence (or absence) of other crew, in groups or otherwise. It was a situation where the crew had to find ways to seek shelter at the engine casing or abandon ship for their safety. This was evident from the actions of the Painter at the aft who jumped into the water using a lifebuoy. The efforts of many crew members to save others are considered commendable under the circumstances.

2.5.14 The Master's actions to manoeuvre the lifeboat in the vicinity of MH to rescue any crew were noteworthy and in line with the ordinary practice of seamen.

2.6 Ship's design

2.6.1 The twin-island design²¹⁵ of positioning the bridge and accommodation block towards the forward section of the ship to maximise cargo carrying capacity and to provide a better line of sight for the crew over huge stacks of containers, appeared to have helped in providing a barrier to prevent the spread of the fire to the aft section of the ship. This helped to prevent larger consequential

²¹⁴ The investigation team deems this requirement to imply as an "announcement", which could be either by a walkie-talkie, PA system or any other means which could be audibly heard.

²¹⁵ Such a design also provided an alternate safe area at the engine room casing if the accommodation block is on fire.

damage and allowed for more time for assisting ships to arrive to fight the fire.

2.6.2 No.3 cargo hold was designed to carry reefer containers, and as such was fitted with additional ventilation measures, which were provided by 32 natural ventilator flaps and two exhaust ventilator flaps. Although, there were no connections to supply power to the reefers inside this cargo hold, the investigation team could not establish reasons for these flaps to be kept open.

2.6.3 Regardless, if MH was carrying reefer containers, these natural ventilator flaps would have to be kept open. The investigation team thus analysed the suitability of the design of the natural ventilator flaps fitted on the hatch cover vis-à-vis the time it would take to close them without any heat or smoke. It was further recognised that even if AT-1 had managed to close the exhaust ventilation flaps on the cross-deck, it would have taken them considerable time and energy to close the 16 natural ventilator flaps on the hatch cover, squatting below the containers or using a ladder, wearing a fireman's outfit and BA set, while dealing with intense heat and smoke, considering their design, weight, and location.

2.6.4 It is possible that the design of the natural ventilator flaps, although approved by Class, had likely not considered whether closing them promptly in an emergency would be possible. A remote quick closing mechanism (engineering control) on these ventilator flaps, if fitted, may have been able to mitigate this risk. On the same note, if an emergency drill had been conducted during the periodical²¹⁶ audit to include the closing of these ventilator flaps, the difficulties in closing them would have been identified and the appropriate control measures could have been introduced.

2.6.5 It would be desirable for the flag Administration to consider requiring the conduct of emergency drills during interim and periodical audits to identify potential risks at the early stages of the ship being put into service.

2.7 The cargo and related booking process

2.7.1 The cargo booking process depends on accurate declarations (by the shipper) which are extremely important to prevent situations that may result in inappropriate stowage of dangerous goods.

2.7.2 To plug any loopholes in the cargo booking process, robust screening processes which would be able to pick up keywords in the declaration should be implemented rather than relying on scanned documents which make it

²¹⁶ Periodical audits cover initial, intermediate and renewal audits.

difficult to be interrogated.

- 2.7.3 It would thus be desirable for the cargo booking process to have technological means to be able to extract certain key properties of cargo declared to be shipped. Having such a means will not necessarily eliminate mis-declaration but may aid in reducing such a probability.
- 2.7.4 Though there was no evidence of a mis-declared cargo that led to the fire in no.3 cargo hold, the investigation team noted that the current cargo screening process in the industry is not able to ensure declarations by shippers, which are based on trust, match the description of the cargo in the container, as such a process could be too onerous and labour-intensive if carried out manually.
- 2.8 Incidental observations
- 2.8.1 The relatively favourable conditions of carrying out pre-planned drills during daylight hours can set a false sense of accomplishment or illusion amongst the crew, that emergencies could be managed effectively. While it is recognised that drills may not fully prepare the crew to anticipate every scenario, the ship's crew need to recognise that emergencies can occur at any time, as was in the case of the MH, i.e. in the hours of darkness. A higher level of preparedness in firefighting response and evacuation procedures would be needed by carrying out simulated drills in the hours of darkness, when safe and practical.
- 2.8.2 Accordingly, the effectiveness of shipboard emergency plans in identifying gaps and to modify or make changes as appropriate should be undertaken, e.g. to have simple plans (pictorial) to show numbers and locations of ventilators to be closed by relevant personnel, marking alternative/ additional routes of escape from hazardous locations, etc.
- 2.8.3 While the detailed instructions provided on the CO₂ fixed firefighting system were intended to ensure the system was operated correctly, such detailed information could be overwhelming and onerous for one to decipher in an emergency. Although there was no evidence to suggest that the CO₂ release instructions were not clear or had hampered the firefighting response on MH, efforts must be taken to simplify the instructions for use in an emergency (see **footnote 154**).
- 2.8.4 Noting the location of no.3 LS/ DB WBT(S) which was directly below the SDID block, there was a high-level alarm within a couple of minutes after the smoke alarm. The Fire Forensic Expert opined that it was probable that the occurrence was a direct consequence of the decomposition event itself.

3 CONCLUSIONS

From the information gathered, the following findings are made. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

- 3.1 As most of the evidence were destroyed by fire, it is not possible to conclusively determine the cause of the fire. However, as chlorine-smell smoke was noticed at the onset of the event, it is possible that one or more containers in no.3 cargo hold containing SDID were compromised by self-decomposition²¹⁷ of the SDID. The block stowage of the SDID further exacerbated the rate of reaction and heat production which resulted in an uncontrollable spread of the fire.
- 3.2 The actual temperature at which exothermic decomposition is initiated is much lower than the values typically declared by the shipper, and the presence of free water and/ or stowage of the SDID in large packages or consignments leads to further substantial depression of the onset temperature.
- 3.3 Given the susceptibility of SDID to exothermic decomposition in the presence of free water or impurities, serious consideration must be given to the prospect that the decomposition could be initiated as a direct result of the inherent properties of the cargo itself.
- 3.4 The special provisions (SP135) within the IMDG Code allows for the classification and carriage of SDID under Class 9 (UN no.3077), thus not recognising the potential thermal instability of this material, possibly as a result of legacy carriage requirements recognised nearly 40 years prior. As a result, despite these secondary hazards, SDID was stowed under-deck where the main fixed firefighting means in this area was CO₂, which is ineffective to tackle fires associated with such materials.
- 3.5 Noting the secondary hazards presented by SDID, which are not captured in the current provisions of the IMDG Code, the provisions in the IMDG Code would need to be reviewed. In the interim, appropriate measures, similar to those adopted for calcium hypochlorite as identified by CINS could be considered for adoption.
- 3.6 Though the muster for firefighting was prompt, instead of raising the fire alarm, the crew raised the general alarm. This had resulted in the delay in closing the

²¹⁷ Exothermic chemical decomposition of a cargo that liberated huge quantities of heat and gas, that gas almost certainly being pure chlorine or chlorine based. Source – the Fire Forensic Expert.

magnetic fire doors. The crew were not able to close the natural ventilator flaps in no.3 cargo hold, partly due to the intense smoke and heat, partly because they were not given specific location of these natural ventilator flaps. The non-closure of these flaps had resulted in no.3 cargo hold not being sealed prior to the discharge of CO₂.

- 3.7 The design of the flow charts under the ship emergency response plan did not require the ventilator flaps/ dampers for the accommodation to be closed during cargo hold fire which resulted in large amount of smoke entering the accommodation area.
- 3.8 Some of the crew had not been assigned duties in the muster list. These crew could have been assigned with specific tasks, such as closing the relevant openings in the engine room, accommodation block, and fire dampers.
- 3.9 The Master's efforts to minimise the smoke around the accommodation for maintaining command and control using the ME were ineffective. The use of thrusters to maintain the ship's heading to minimise the effect of smoke on the accommodation could be considered.
- 3.10 Firefighting response for SDID, an oxidiser, required the use of abundant water, which could not have been achieved promptly, given the existing statutory requirements for firefighting measures for container fires under-deck. Adoption of standards/ guidance like those prepared by ABS and DNV-GL, as a risk-mitigating measure, should be considered. Regardless of amendments to the statutory requirements, dangerous goods with oxidising properties such as SDID should be considered for stowage on-deck, away from direct sunlight, where water could be used more effectively.
- 3.11 Despite availability of triggers, such as excessive heat and smoke, the ineffectiveness of the first injection of the CO₂, the limitation of the boundary cooling, the ingress of smoke and activation of the water mist sprinkler system, there was a delay in decision making to allocate resources better for the abandoning of ship while attempting to fight the fire.
- 3.12 When the crew were separated after the chaos on the bridge, they had to find ways to abandon ship for their respective safety. Despite the individual group actions, the efforts of many crew members to save others are considered commendable under the circumstances.
- 3.13 When the attempts to reach out to the remaining crew were unsuccessful using the walkie talkie, the ship's paging facility could have been utilised to convey

the Master's intention to abandon ship.

- 3.14 Considering the design, weight, and location of natural ventilator flaps on the hatch cover, even if the ship's crew had managed to find and reach them, wearing a fireman's outfit and BA set, while dealing with intense heat and smoke would have taken the crew considerable time and energy to close them. A remote quick closing mechanism on these ventilator flaps, if fitted, may have been able to mitigate this risk. Additionally, an emergency drill if conducted during the periodical audit, may have been able to reveal the risks associated with this design.

- 3.15 Robust screening processes for booking of cargo are key to minimise the mis-declaration as well as to plug loopholes, which put the ship, its crew, and the cargo at risk, such as having technological means to be able to extract certain key properties of cargo declared to be shipped.

4 SAFETY ACTIONS

The following safety actions were taken by the various stakeholders.

4.1 By the Company²¹⁸

4.1.1 Banned the stowage of IMDG containers immediately forward and aft of the accommodation and engine casing for twin-island ships.

4.1.2 An extensive fire drill conducted on all ships had led to the review and amendments to emergency response procedures and strict compliance with muster lists, to ensure a standard approach to emergency response across all ships is adopted using the below illustration -

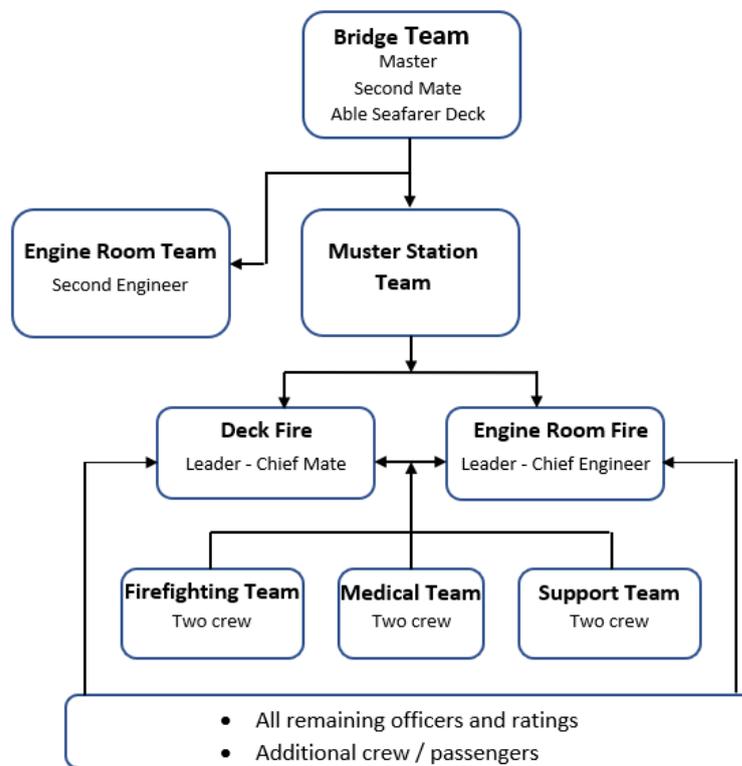


Figure 38 – Illustration of flow of the new Muster list

4.1.3 Reviewed muster lists to include the use of the paging facility in ship's telephones for making an announcement for abandon ship, where

²¹⁸ These actions were taken by the Company with the intent to minimise the risk to the crew and ship by increasing the IMDG acceptance and stowage requirements with an industry wide outlook, and to enhance the resilience of the ship and its crew to withstand a catastrophic fire in the cargo area as well as to improve the capability for firefighting and abandoning ship for the large container ships.

appropriate²¹⁹.

- 4.1.4 The emergency flow chart(s) were amended to prompt the Master to evaluate and prioritise the closure of relevant openings on board such as engine room skylight, accommodation, and fire dampers. The Chief Engineer for e.g. has been assigned to delegate tasks of closing relevant openings.
 - 4.1.5 Provided additional firefighting outfits on large ships, more spare BA bottles and larger capacity life rafts aft on twin-island ships.
 - 4.1.6 Reviewed current training and assessment programs of officers.
 - 4.1.7 Engagement with internal and external stakeholders to develop new risk-based stowage rules for IMDG²²⁰.
 - 4.1.8 Strengthened the in-house IMDG acceptance process focussing on safe stowage, establishing a scanning tool to enable better detection of undeclared or mis-declared cargo; and
 - 4.1.9 Evaluated the possibilities of making technical design changes on future new-buildings and existing ships. Areas of focus in consideration are the design of cargo hold fire dampers (enabling faster response), ventilation arrangements for accommodation, and installation of water spray systems.
- 4.2 By the flag Administration
- 4.2.1 Recognising that the existing fire protection, detection and extinction arrangements on board container ships could be inadequate to provide the crew with the necessary capability to contain and extinguish container fires in the cargo hold or above deck, and noting the urgent need to ensure that container ships are adequately equipped, flag Administration submitted a joint paper²²¹ to IMO for evaluating the adequacy of fire protection, detection and extinction arrangements with a view to amend SOLAS and the FSS Code, by developing goal-based standards.

²¹⁹ Ships with paging facility in the telephones will have the this incorporated.

²²⁰ Safety Considerations for Ship Operators Related to Risk-Based Stowage of Dangerous Goods on Containerships was published in November 2019.

²²¹ MSC 102/ 21/ 3 by Marshall Islands, Singapore, IACS and World Shipping Council on 7 February 2020.

5 SAFETY RECOMMENDATIONS

A safety recommendation is for the purpose of preventive action and shall in no case create a presumption of blame or liability.

5.1 For the Company

5.1.1 To work with non-governmental organisations for e.g. CINS, for producing guidelines for the safe carriage of SDID recognising the primary and secondary hazards of this cargo noting the IMDG Code SP 135. **[TSIB-RM-2020-022]**

5.1.2 To review the stowage requirements for SDID containers with due considerations given to prevent the increase in temperatures and ease of using water-based medium for firefighting at the storage locations, such as stowing SDID containers on the weather deck away from direct sunlight. **[TSIB-RM-2020-023]**

5.1.3 To review its safety management system for fire emergency preparedness for ensuring the proper use of alarm to be activated for any given emergency. **[TSIB-RM-2020-024]**

5.1.4 To review the design arrangements of the natural ventilator flaps on the hatch cover for them to be closed effectively in an emergency. **[TSIB-RM-2020-025]**

5.1.5 To consider amending the ship's ERM for ensuring thrusters (as a reminder to the Master) are used for maintaining the ship's heading with minimum headway. **[TSIB-RM-2020-026]**

5.2 For the flag Administration

5.2.1 To consider submitting a paper to the International Maritime Organisation (IMO) for consulting the Sub-Committee of Experts on the Transport of Dangerous Goods (UNSCETDG)², as appropriate, for the review of SP 135, taking into account the potential primary and secondary hazards associated with the carriage of SDID, for it to be classed under Class 5.1 instead of Class 9. **[TSIB-RM-2020-027]**

5.2.2 To remind operators of Singapore registered ships to load dangerous goods with oxidising properties (and those with secondary hazards of chemical decomposition) on-deck, away from direct sunlight, where water could be used more effectively. **[TSIB-RM-2020-028]**

5.2.3 To consider requiring the conduct of emergency drills during the periodical

audits especially during interim audit to identify potential risks at the early stages of the vessel being put into service during delivery. **[TSIB-RM-2020-029]**

- 5.2.4 To consider inviting its RO to develop standards/ guidance and additional notations for improving fire safety for container ships while the goal-based standards are being developed for SOLAS and the FSS Code. **[TSIB-RM-2020-030]**

- End of Report -