Isle of Man Ship Registry

Casualty Investigation

Report No. CA124

Isle of Man Registered "Hanjin Green Earth"

Cargo Hold Fire

01st May 2015

Contents

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"The fundamental purpose of investigating a casualty, an accident, or an incident under these Regulations[1] is to determine its circumstances and the causes with the aim of improving the safety of life at sea and the avoidance of accidents in the future.

It is not the purpose to apportion liability, nor, except so far as is necessary to achieve the fundamental purpose, to apportion blame"

Under Section 4 of the Isle of Man Merchant Shipping Act 1985 a person is required to answer an Inspector's questions truthfully. If the contents of this report were subsequently submitted as evidence in court proceedings then this would contradict the principle that a person cannot be required to give evidence against themselves. Therefore the Isle of Man Ship Registry makes this report available to interested parties on the strict understanding that it will not be used in any court proceedings anywhere in the world.

Abbreviations used in this report

Any rank with a letter following (e.g. 2/O (A)) is used when there are more than one person having the same rank is on board to distinguish the different Seafarers.

1/E	First Engineer
2/O	Second Officer
2/E	Second Engineer
3/O	Third Officer
3/E	Third Engineer
Aft	After
AB	Able Bodied Seaman
BA	Breathing Apparatus
CAT	Critical ambient temperature
C/O	Chief Officer
CO2	Carbon Dioxide
CCR	Cargo Control Room
CH	Cargo Hold *(followed by the number of the hold)*
DLB	Deck Log book
DPA	Designated Person Ashore
ECR	Engine Control Room
EEBD	Emergency Escape Breathing Device
ERC	Emergency Response Committee for Hanjin Shipping
FiFi	Fire fighting
fr	Frame number
frs	Frame numbers
fwd	forward
GA	General Arrangement Drawing
GT	Gross Tonnage
HFO	Heavy Fuel Oil
IWO	In way off
KRS	Korean Register of Shipping *(classification Society founded in South Korea)*
LEL	Lower Explosive Limit
LSHFO	Low sulphur heavy fuel oil
M/E	Main engine
PA	Public address system
P/P	Pump
QM	Quarter Master
SCA	Suez Canal Authorities
SMS	Safety Management System
SW	Sea Water
SWBT	Sea Water Ballast Tank
UHF	Ultra High Frequency
VHF	Very High Frequency
WBT	Water Ballast Tank

Summary

At 0202hrs on 1st May 2015 the Hanjin Green Earth suffered a fire in Cargo Hold (CH) 9 during a northbound transit of the Suez Canal. The fire rapidly spread to the containers stacked above the hold.
The ship's fixed CO_2 system was used to try and extinguish the fire, however, it had no effect on the fire which continued to burn and escalate.
Firefighting (FiFi) tugs from the Suez Canal Authority attended the scene and managed to contain and then reduce the fire.
As a result of the amount of firefighting water being jetted at the fire, CH 9 started to fill as the volume of water overcame the normal drainage arrangements on the 4 hatch covers which were partially-weathertight by design. The 2 bilge suction valves in the hold were unable to be actuated due to fire and water damage to the actuator and as a result no water could be pumped out.
The water level reached a level of approx. 22.6m above the inner bottom[1]. The crew tried to lower the water level in a controlled manner through the deck 2 underdeck passageway via an interconnecting watertight door and then into the top of ballast tanks that they had removed the manhole covers from.
Around 06:30hrs on the 2nd of May 2015 the crew tried to adjust the interconnecting watertight door to increase the rate of drainage, however, in so doing it flew open flooding water from CH 9 into the underdeck passageway which caused the ship to take on a large list to stbd.
Salvage experts boarded the vessel on the afternoon of the 2nd May 2015 and commenced tackling the fires on board.
They were eventually able to put out the majority of fires and contain a small number that were unable to be extinguished in order that the vessel could proceed to Algeciras.

Subsequent investigation revealed that the contents of the container where the fire originated had been miss-declared. The contents were believed to be calcium hypochlorite rather than calcium carbonate as was indicated on the bill of lading[1], manifest[2] and stowage plan[3].

The standard practices in the container trade were found to allow the contents of a container to be open to abuse by the shipper[4] as it relies on the honesty of the shipper when completing their side of the bill of lading.

It was found that the standard outfit of firefighting equipment was lacking in this sort and scale of fire, and that the fixed CO_2 system was not effective for this particular type of cargo.

It was also found that there was scope for improvement in relation to some of the emergency preparedness duties and responsibilities for the crew.

[1]- Structural configuration employing a complete watertight inner bottom deck above the hull bottom plating, extending from the collision bulkhead to the aftermost watertight bulkhead.
[2] - A document which evidences a contract of carriage by sea. The document has the following functions: A receipt for goods, signed by a duly authorised person on behalf of the carriers. A document of title to the goods described therein. Evidence of the terms and conditions of carriage agreed upon between the two parties.
[3] – A document giving comprehensive details of a ship and its cargo and other contents.
[4]– A plan indicating the locations on the vessel of all the consignments for the benefit of stevedores and vessel's officers.
[5] - A person or company who enters into a contract with a liner conference, shipping line or ship owner for the carriage of goods.

MV Hanjin Green Earth

1. Ships Details, Description & Crew

1.1. Vessel Particulars

Registered Owner	Resolute Leasing 9 Limited
Name of Managers ISM Code 1.1.2	Hanjin Shipping Co Ltd
Classification Society	Korean Register of Shipping
IMO Number	9503732
Port of Registry	Douglas
Flag State	Isle of Man
Ship Type	Container Ship
Keel Laid	3rd October 2012

Builder	Hyundai Heavy Industries
Construction	Steel
Registered Length (m)	352.93
Registered Breadth (m)	48.2m
Moulded Depth (m)	25.6m
Gross Tonnage	141754.00
Net Tonnage	60615.00
Container Capacity (TEU)	13100

1.2. Casualty Details

Time and date	0202 hrs 1st May 2015
Location of Accident	Suez Canal Northbound
Persons onboard	21 Crew Members
Fire location	No 9 Cargo hold (CH 9)

1.3. Description, Trading Area & Cargo

The Hanjin Green Earth registered on April 2013 was the eighth of a series of nine 13100 TEU containerships built for Hanjin Shipping Co Ltd at Hyundai Heavy Industries, Ulsan, South Korea. She trades on the East Asia- Europe service NE6 organised by the CKYHE alliance visiting Qingdao, Kwan yang, Busan, Shanghai, Singapore, Jeddah, Suez, Algeciras, Hamburg Rotterdam Le-Havre. The last port of call prior to the fire on board was Jeddah on 29/04/2015

Vessel is equipped with a Fixed CO_2 System for Engine Room (ER) and Cargo Hold (CH) fire extinguishing

The vessel can carry a variety of containers, including dry containers for general dry cargo, refrigerated (reefer) containers for refrigerated goods, dangerous goods containers and special purpose containers for larger and unusual sized goods. All of the above can be provided in both standard 20ft and 40ft length options. There is also available a container referred to as a “Hi Cube” container where the height of the container is approx. 300m higher than standard.

There are a total of 10 holds on the vessel with containers stowed within the holds and above deck on the hold hatch covers. Each of holds 1 to 9 are split into a forward (fwd) and an after (aft) section with a dividing cross deck (X Deck[1]) separating the sections and providing, ventilation, lighting and access ladders for inspection of the hold. Both fwd and aft sections of each hold are provided with 4 transversely arranged hatch covers. These hatch covers, by design, are only partially weather tight[2] having a longitudinal gap of no more than 50mm separating each cover. There is also no traditional sealing rubber between the bottom of each hatch cover and the hatch coaming. The hatch cover sits on bearing pads around the hatch coaming and has a 17mm air gap all-round the coaming.

Containers are stowed in the fore-aft direction and can be identified by individual cell numbers. The cell number indicates the **Bay, Row and Tier** that the container is located in (see Appendix 1).

1.4 Crew

The vessel operates with a crew of 21, which is well in excess of the Minimum Safe Manning Document provision of 15.

All officers are Korean nationals and all crew are Philippine nationals. Officer and crew certification was found compliant with International and IOM regulations.

[1] *Thwarts ship structure segregating the fore and aft hold sections. Provides a transverse walk way and access to lashing bridge above and an accesses hatch to all hold levels via ladders below. Lighting and hold ventilation system are provided within the X Deck.*

[2] *Ref MSC /Circ.1087 Guidelines for Partially Weathertight Hatchway Covers on Board Containerships.*

2. Narrative of Events

2.1 01/05/2015

01:00 hrs
The vessel was transiting northbound on the Suez Canal with 2 pilots on-board. On the bridge at this time was the Second Officer (2/O) (A), Quarter Master (QM) (A) and one of the 2 Suez Canal Pilots required for the canal transit.

02:01:54 hrs
The hold smoke sampling alarm sounded on the bridge followed at 02:02:08hrs by the ER fire alarm. The general emergency alarm sounded throughout the vessel.

The Master, 2/O (B) and the Third Officer (3/O) arrived on the bridge.
The alarm panel indicated that there was smoke in zones 17 & 18 which is CH 9.

The Chief Engineer (C/E) and Third Engineer (3/E) who were on standby for the Suez Canal transit were in the Engine control room (ECR) and heard the sound of several explosions directly above them immediately prior to the hold and ER fire alarms sounding.

The Bosun, on arriving at the muster station on the stbd upper deck of the accommodation was informed by QM (A) that he had seen smoke in the vicinity of CH 9. The Bosun also clearly saw smoke, so he reported this to the Bridge using his radio transceiver. Instructions received from the Bridge ordered him to go and investigate, so he made his way down the stbd side of the vessel together with the Oiler and Sailor (A).

The Master ordered the Chief Officer (C/O) to go and investigate the situation at the scene of the reported smoke.

The QM (B) on bridge reported that 2/O (A) made an announcement over the Public address system (PA) that there was smoke coming from Bay 70.

The C/O made his way down the port side of the deck to investigate the smoke. He said there was heavy smoke coming from the hatch cover natural ventilation side vents of Bay 70. He informed the Master who instructed him to close all the manual vents for CH 9.
The C/O ordered the crew on the port side of Bay 70 to close the 2 natural ventilation flaps on each of the 2 port side outer hatch covers.
The Bosun and the crew on the stbd side of Bay 70 closed the 2 natural ventilation flaps on each of the 2 stbd side outer hatch covers.

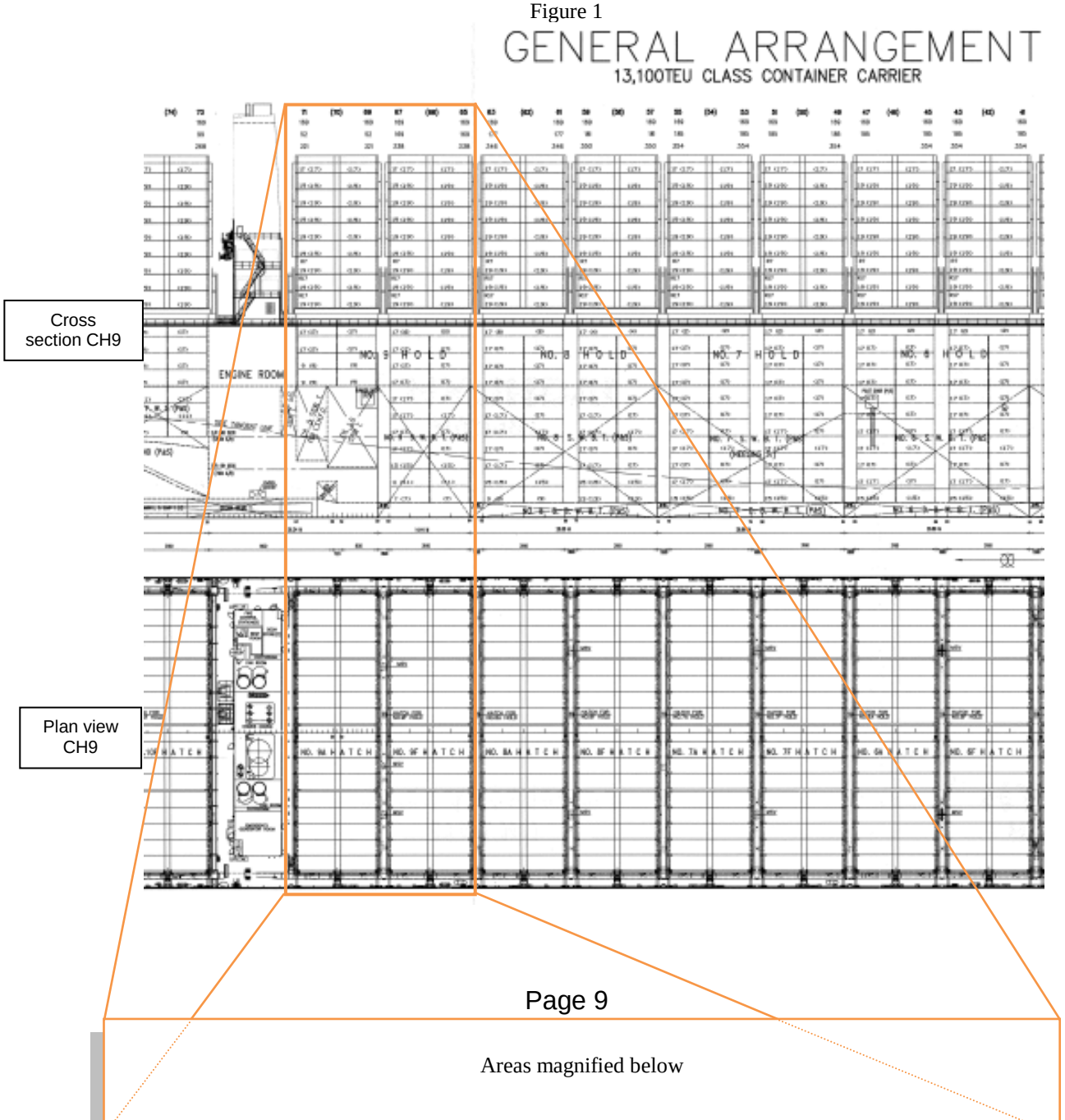
The C/O also instructed QM (A) to shut the 3 large rectangular screw-down lids for the ventilation trunking (2 for CH 9 supply fan trunking and 1 for

natural vent trunking for duct keel). These are located in recesses under the X deck with operating spindles and a transferable hand wheel located just above deck level on the X Deck.

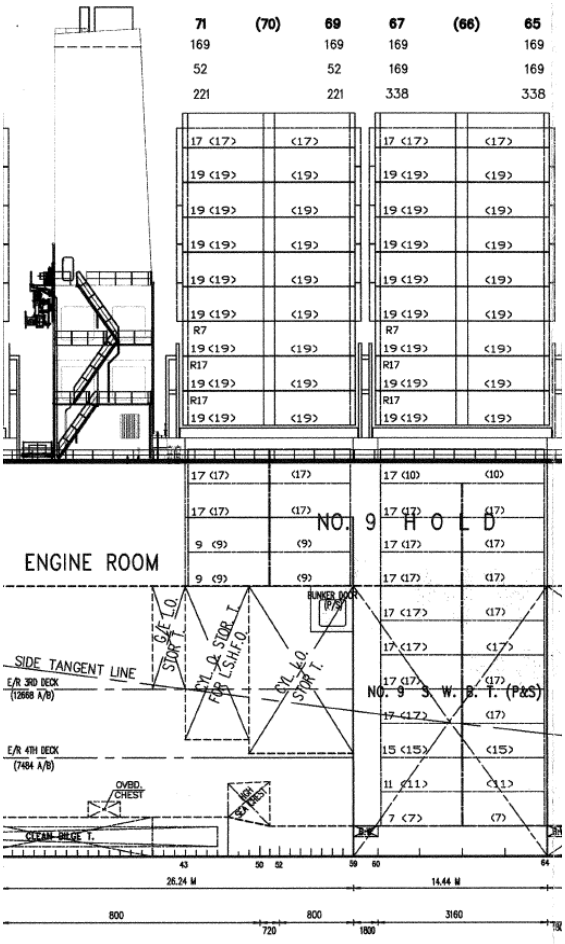
QM (A) initially tried to shut the port side screw-down ventilation trunking lid on the X Deck (at this time he reported lots of smoke on the stbd side), he then withdrew from the X Deck and made his way around to the stbd side of Bay 70.

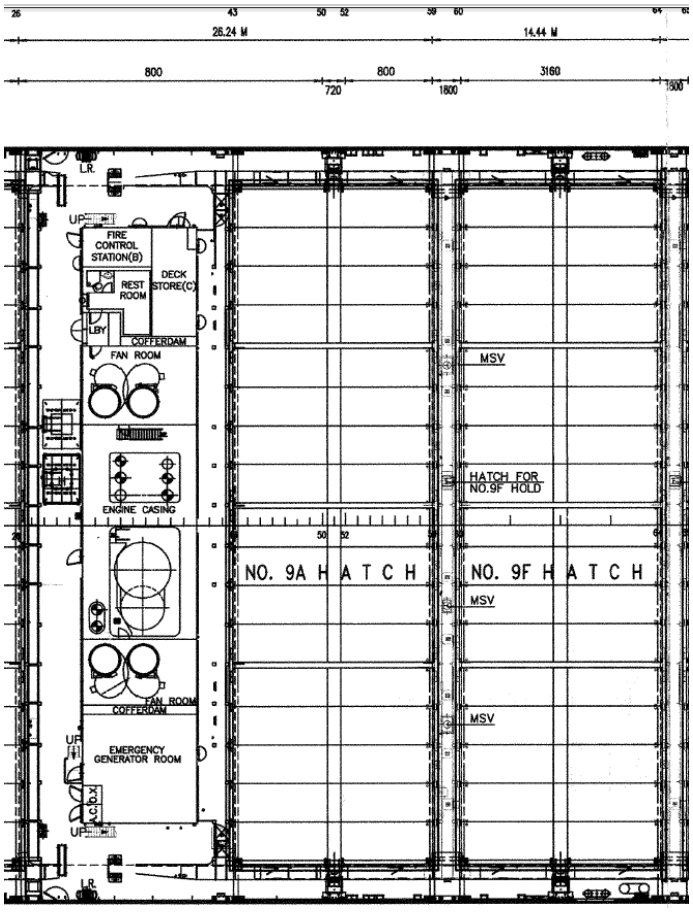
Once on the stbd side he put on Breathing Apparatus (BA) and together with Wiper (A) attempted to close the 2 screw down ventilation trunking lids on the stbd side of the X Deck. They were also requested by the C/O to try and gain entry to CH 9 via the cargo hold access hatch (just stbd of the centre line on the X Deck) however they were unable to access this area due to the heat and smoke in the vicinity. They stated that smoke was coming from the air gaps between the underside of the hatch covers and the coaming. They also reported that they could see flames between the top of the hatch covers and the bottom of the containers near the cargo hold access hatch (at Bay 70 fwd end).

Figure 1



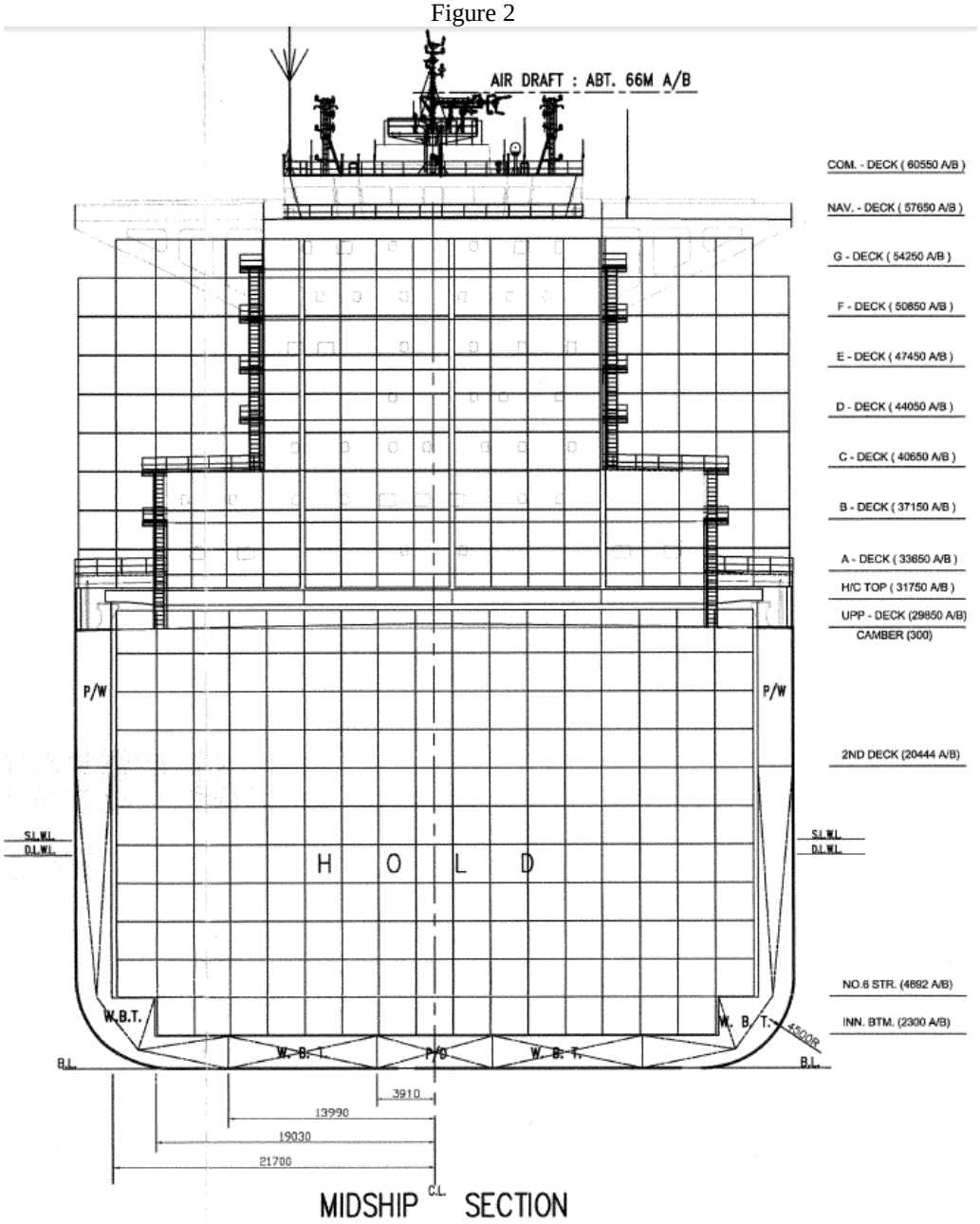
Cross section
CH9





Plan view
CH9

Figure 2



Midship cross section of CH 6.

Whilst the screw down ventilation trunking lids were being shut other fire team members started to rig fire hoses on the upper deck walkway on each side of CH 9 in readiness for boundary cooling.

Initially there was concern that the smoke was from the ER. The C/E who was on standby in the ECR sent Engineers to investigate and concluded that the smoke in the ER had been drawn into the ER from the area of CH 9 (which is directly fwd of the ER) via the large ER supply/exhaust ventilation fans. The C/E reversed the direction of the fans to reduce the amount of smoke in the ER. The C/E remained in the ECR as the vessel was still transiting the Suez Canal.

The Master instructed the C/E to isolate all power to CH 9.
The 3/E commenced isolation of the lighting for CH 9 which is located along the stbd underdeck passageway (deck 2) and then the main power isolation for CH 9 located in the port underdeck passageway (deck 2).

02:12:22 hrs
Public Address Power Failure indicated in the alarm log.
Note: There was some initial confusion as to what was happening for crew at the Muster station, as it transpired there was a fault with the PA system in that it did not override the General Alarm (GA) as it was supposed to. The bridge team were also unable to silence the GA.
It continued to sound for 16mins 50seconds (from VDR Data) until it was eventually reset in the CO_2 room.

Suez Canal Pilot on the wheelhouse assisted with the manoeuvring of the vessel at this time. Second pilot arrived on the bridge and was appraised of the situation.

Once all of the hatch cover natural ventilation side vents and X Deck screw down ventilation trunking lids were reported as closed and confirmation was received that the power to CH 9 was isolated the Master requested the fixed CO_2 be released into CH 9 following a crew muster to account for all personnel.

Fire teams had been rigging fire hoses on the port and stbd sides of CH 9. Wiper (B) reported that he, Wiper (A) and the Oiler had commenced boundary cooling on the port side directing the water through the X-Deck before the CO_2 release began.

The C/O, 2/O (B) and 3/O attended the CO_2 Room on the stbd side of the accommodation on the upper deck.

The 3/O broke the cover to the key box, retrieved the key for the cabinet labelled “Ball Valve Cabinet for Cargo Hold”. He then checked the quantity of bottles required to be released for CH 9; this was 102 bottles for a fully loaded hold, as shown on the posted instructions.

02:13:32hrs
The ball valve cabinet for "Cargo Hold" was opened and the CO_2 release alarm sounded.
Note:
The ball valve inside the cabinet labelled "Ball Valve Cabinet for Cargo Hold" was opened to allow flow from the CO_2 bottle discharge line to the CH manifold. On opening this cabinet the CO_2 release alarms sounds.

The 2 x 3-way ball valves for CH 9 were moved from the smoke sampling position to the CO_2 position on the manifold with all the distribution lines to the cargo holds.

02:15hrs
The C/O requested the Master to confirm that he still wanted the CO_2 to be released into CH 9 and having received confirmation he, the 2/O (B) and 3/O commenced releasing the CO_2 bottles manually with the operating levers provided as per the instructions posted in the CO_2 room.

Before all bottles were released the C/O and 2/O (B) returned to the scene of the fire. The 3/O remained in the CO_2 room to continue releasing the remainder of the initial batch of 102 bottles.

On returning to the CH 9 the C/O reported that the smoke was still everywhere blowing in a direction from port to stbd. Explosions coming from within the hold could be heard frequently.

02:19hrs
Deck Log book shows that the company Emergency Response Committee (ERC) and the SCA Harbour Master were informed of the events.

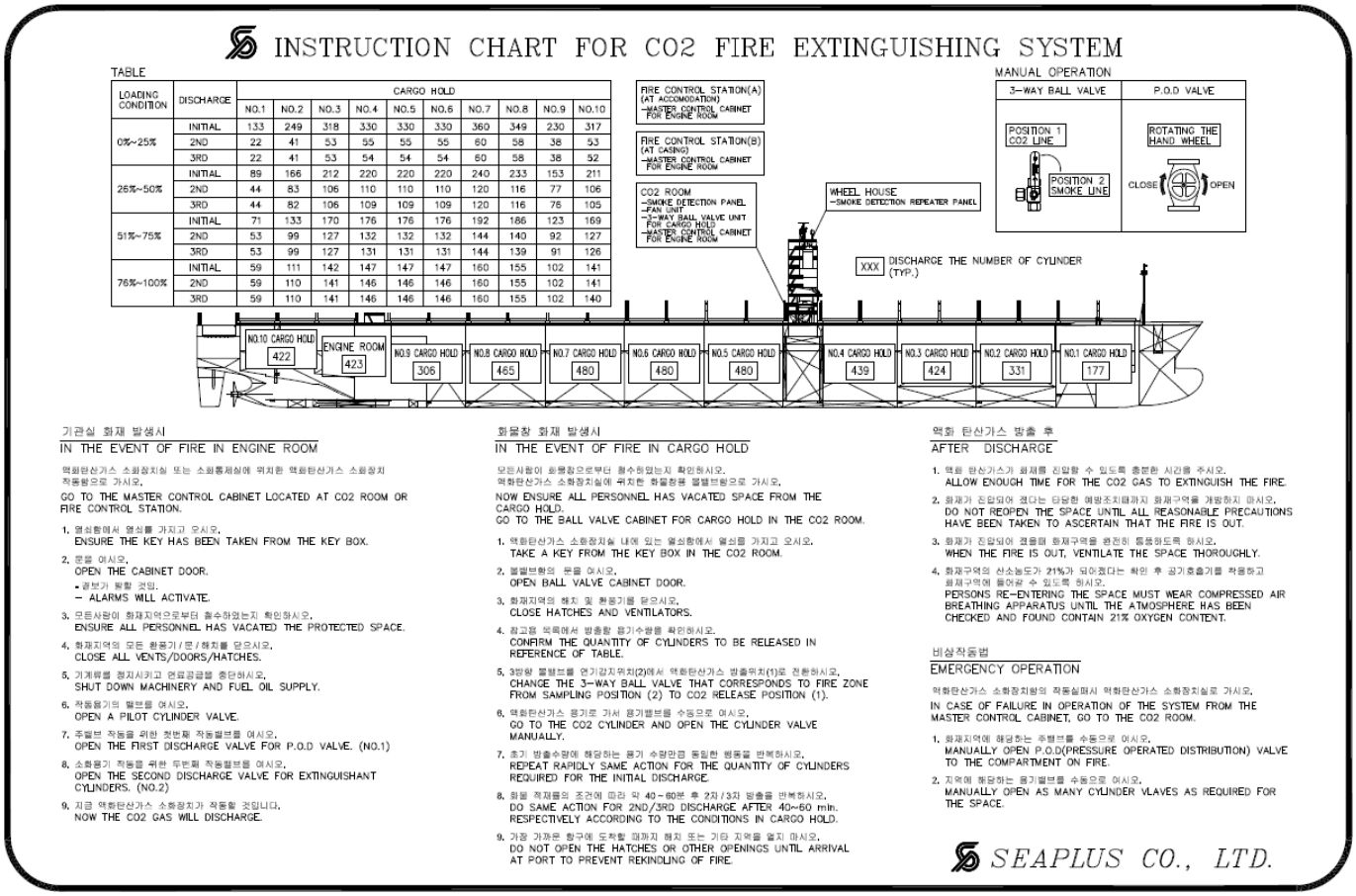
02:30hrs
Emergency Response Committee (ERC) records indicated that Master contacted the Team Manager of the Fleet Management Team to report the incident and informed them that they had commenced CO_2 release.

02:38hrs
Initial release of CO_2 was reported as completed. The release had little or no impact on the fire. Numerous crew members in the vicinity of CH 9 reported sounds of repeated explosions coming from within the cargo hold.

02:43hrs
The Master ordered the C/O to release a second charge of CO_2 into CH 9. C/O relayed this information to the 3/O who was still in the CO_2 room. The 3/O commenced release of the 2nd batch of 102 bottles.

The C/O joined the 3/O shortly after to assist with the release of the second batch of 102 bottles in accordance with the "Instruction Chart for CO_2 Fire Extinguishing System" posted in the CO_2 room shown in figure 3.

Figure 3



CO_2 instruction Chart

The Master then asked the C/O to check to see what Dangerous Goods (DG) containers there were in the vicinity of Bay 70. The C/O went to the deck office to find out this information, and confirmed there were 13 DG containers of mixed class aboard but none designed flammable and none designated explosive.

02:54hrs
Flames were now visible from the bridge. The DLB indicated that shore side support in the form of FiFi tugs was requested from the SCA Harbourmaster via one of the Pilots onboard.

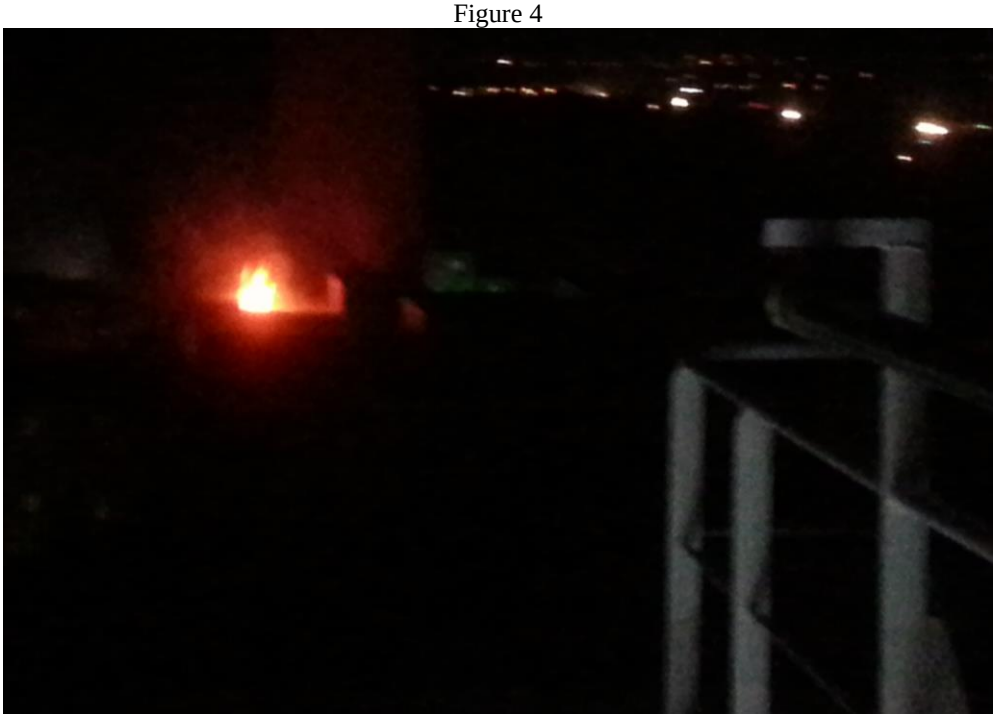
02:55hrs
Master then reported to the C/O that he could see flames from the bridge and that the fire was getting worse.
The Master ordered release of the 3rd charge of CO_2 (102 bottles)
The 3/O continued with the manual release of the CO_2 bottles in the CO_2 room.

03:00hrs
Master ordered the release of all of the remaining 159 CO_2 bottles in the CO_2 room.

Fire teams continued boundary cooling with fire hoses port and stbd sides of Bay 70 concentrating on trying to cool containers, directing jets through the X Deck. There were 2 hoses rigged on each side of the hold.

03:06hrs
All CO_2 bottles are reported as having been released.

Figure 4



View of fire following CO_2 release taken from outside Navigation Bridge

Portside fire team managed to climb up onto the X Deck and then attempted to move closer to the centreline where the fire appeared to be seated. The closest they managed to get was around half way to the centre row, but were frequently having to move out and then back in due to the numerous explosions they could hear from within the hold. They maintained this position for approx. 20 to 30 minutes.

The Stbd fire team continued with boundary cooling directing the hoses through the X Deck.

The C/E appeared and advised them that there was now a fire on the aft side of Bay 71, which was producing very strong red/orange flames and dense black smoke. The stbd fire team put down their hoses and set up another 2 hoses on the stbd side of the engine casing and started applying jets directly at the fire at the aft end of Bay 71. This area is directly adjacent to the fwd stbd ER casing.

03:24hrs
The 475GT tug "Mosad 3" arrived on the stbd side of the vessel and received instructions from the Pilot (in consultation with the Master) using the ship's 2 way VHF radio.

03:30hrs
Tug "Mosad 3" was standing by on the stbd side of the Hanjin Green Earth and jetting water in the direction of the fire, however, the water jet was not reaching the fire so the Master requested the Pilot to alter the position of the Tug in order to enable the jet to hit the fire.
It was reported that the water jet from "Mosad 3" made little difference to the fire.

Figure 5

View of fire at the time of arrival of first tug "Mosad 3"

Stbd side fire team had to move aft when the water jetting started from "Mosad 3" to take shelter due to the amount of water raining down on their position. Some of them went round the back of the ER casing to the port side to offer assistance with boundary cooling on that side.

03:45hrs
Port side fire team moved from the X-Deck up onto the second platform of the lashing bridge[1] above the X Deck.
On the lashing bridge they moved towards the centre of the X Deck again moving in and out depending on the ferocity of the fire. In addition to the

frequent explosions heard they could also clearly see flames coming from the longitudinal gaps between the hatch covers.

03:57hrs
Second Tug "Zamil 7" 1360GT arrived and started firefighting on the port side of the vessel, however, the water jet was unable to reach the fire, so it was requested that she move move to the stern of the vessel in order that the jet could be effectively directed.

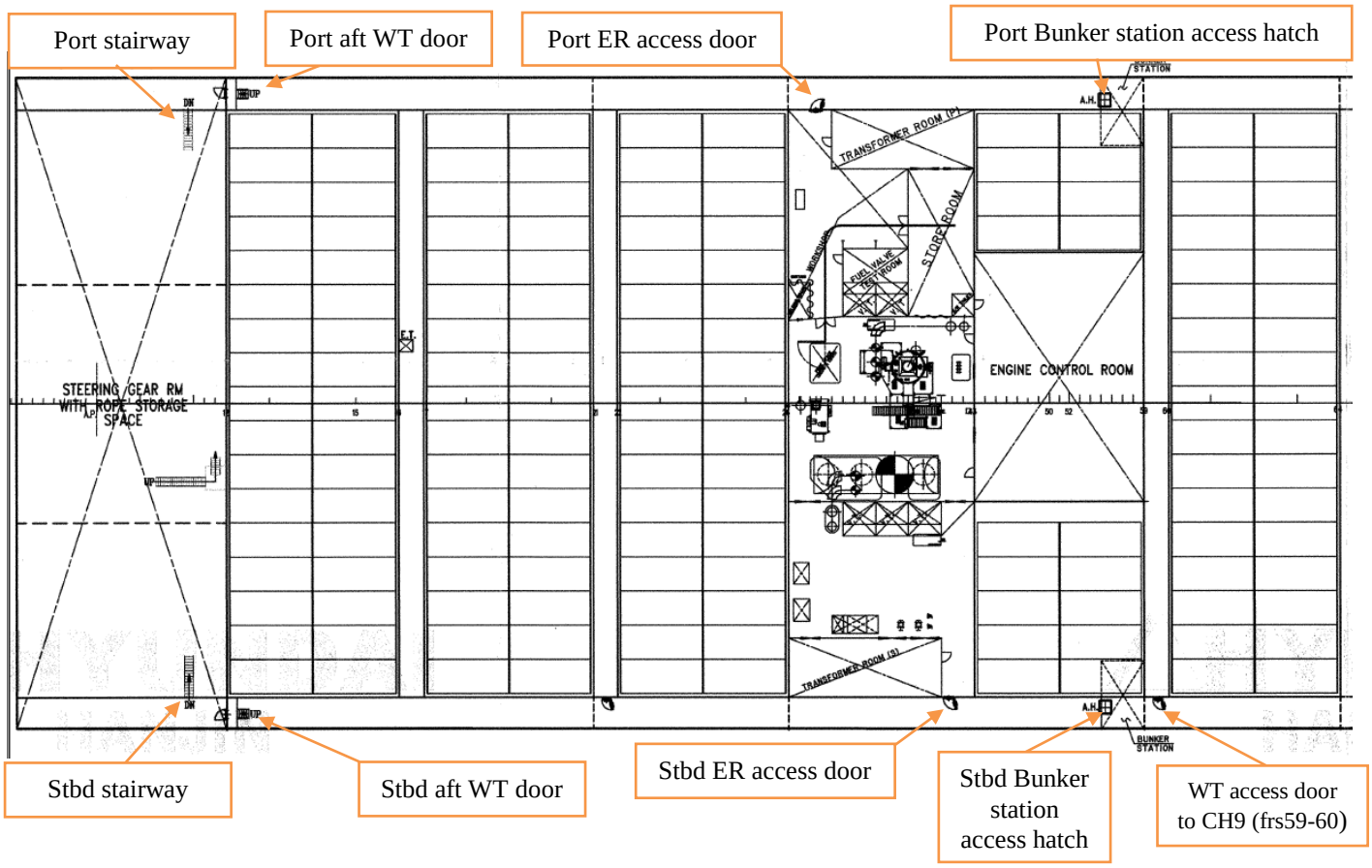
04:13hrs
"Zamil 7" positioned at the stern of the vessel and jetting water.
Port side fire team had to move further outboard on the lashing bridge due to the intensity of the water jetting from "Zamil 7".

04:30hrs
DLB entry reported Fire on deck starting to decrease.

04:38hrs
The C/O, 2/O (B), 3/E and Wiper (A) were standing by the water tight access door to CH 9 in the stbd underdeck passageway on deck 2(frs 59-60).
2/O (B) and 3/E managed to go into CH 9 a distance of 3-5m with BA and safety line however could see no flame and visibility was very poor due to thick smoke so they withdrew.

[1] Lashing Bridge: A substantial steel structure that runs athwartships between each 40 foot container bay. It is used to as part of the system to secure the stacks of containers on deck. On the Hanjin Green Earth the lashing bridges have two platforms that are accessed by vertical ladders. The walkway on each platform is approx. 1 m wide.

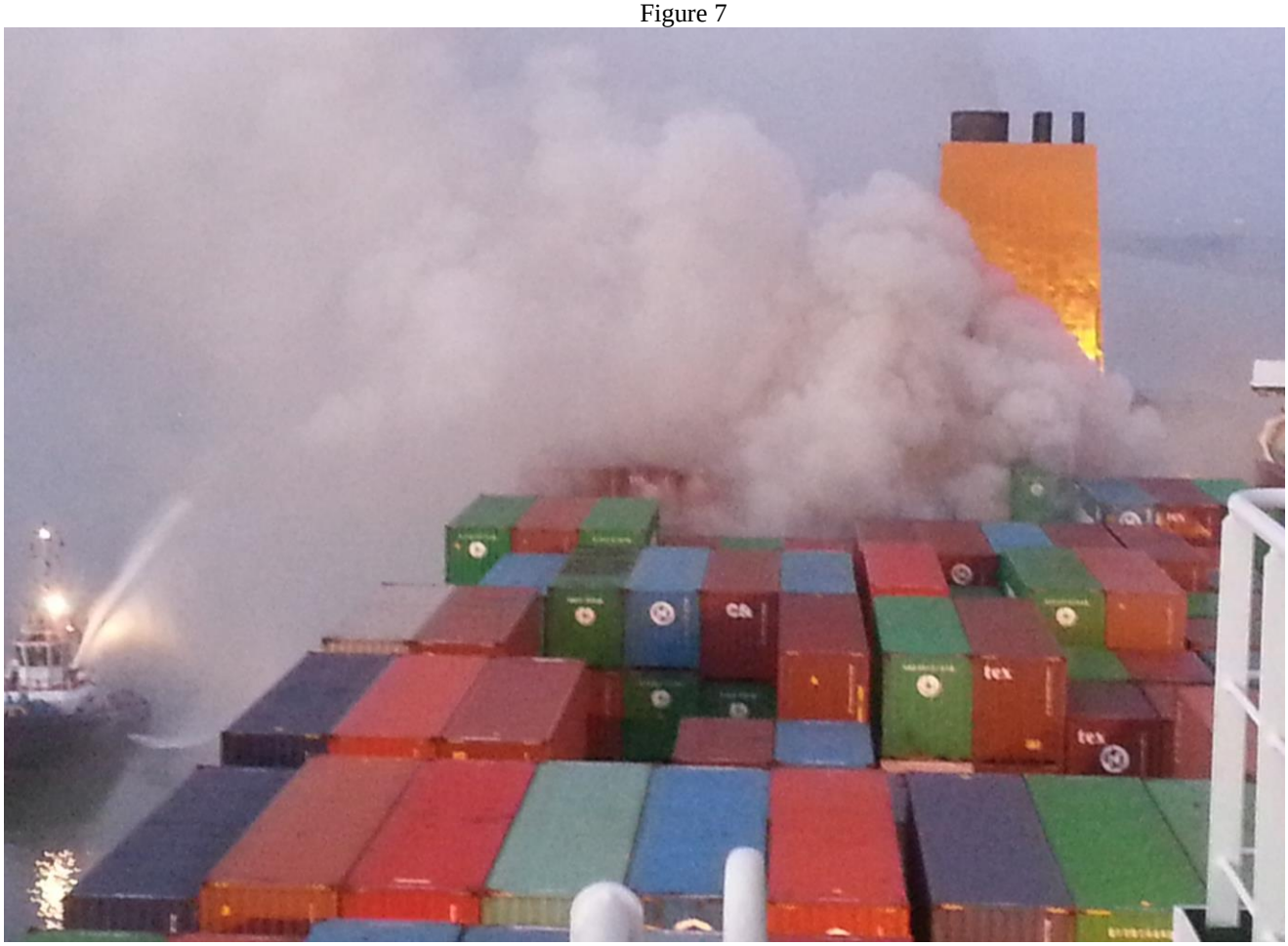
Figure 6



Locations of the various WT doors in the port and stbd deck 2 underdeck passageways.

05:06hrs
Bilge alarm ER fwd stbd side came into high level.
The water pressure from the tug on the stbd side had damaged the water catchers on the outside of the stbd ER fan room and emergency generator room. This resulted in firefighting water entering the fan room and the engine room through the fan trunking. The water was causing high levels in the bilges and thus required to be pumped out.

Figure 7



Firefighting during canal transit

05:07hrs
Deck Log Book reported Harbour Master and additional Port Said Pilot boarded the vessel.

05:18hrs
The Company ERC were at this time discussing their options, one of which was the possibility of partially flooding the hold using fire hoses. This was discussed with the vessel at this time.

05:50hrs
Third Tug "Baraka 1" arrived alongside. Ship's crew involved with fire hoses at this time had to withdraw to the poop deck due to combined strength and intensity of the firefighting water from the Tugs.
Sailor (A) described the amount of water coming down from the FiFi tugs as "like waterfalls".

Figure 8

Firefighting approaching anchorage outside Port Said

06:25hrs
DLB stated fire noted as not decreasing any further.

06:30hrs
The C/O moved to focsle for Anchoring ops while 1/E took over “on scene” fire control.

07:06hrs
The anchor was let go at the given position 31°23.4'N 032° 25.3'E. This is approximately 10nm, North East by North, outside of the North bound Northern exit of the Suez Canal just off Port Said, roughly 1.5nm to the East of the ‘Hm 165’[1] lateral buoys (see figure 10).

[1] References specific navigational marker buoys in the Port Said eastern navigation channel

Figure 9

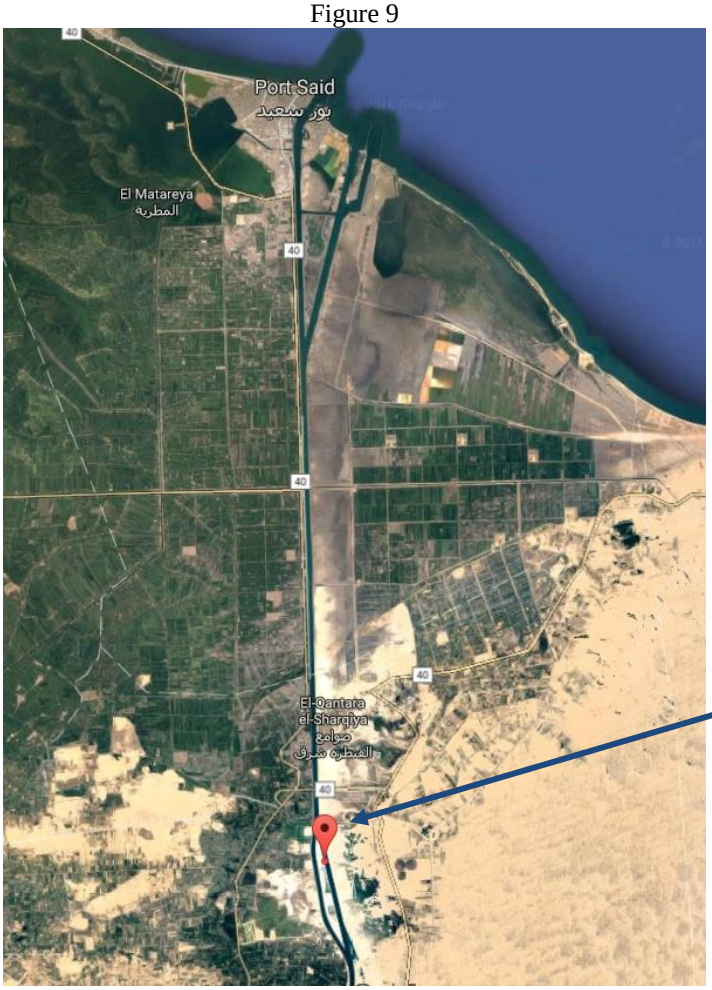
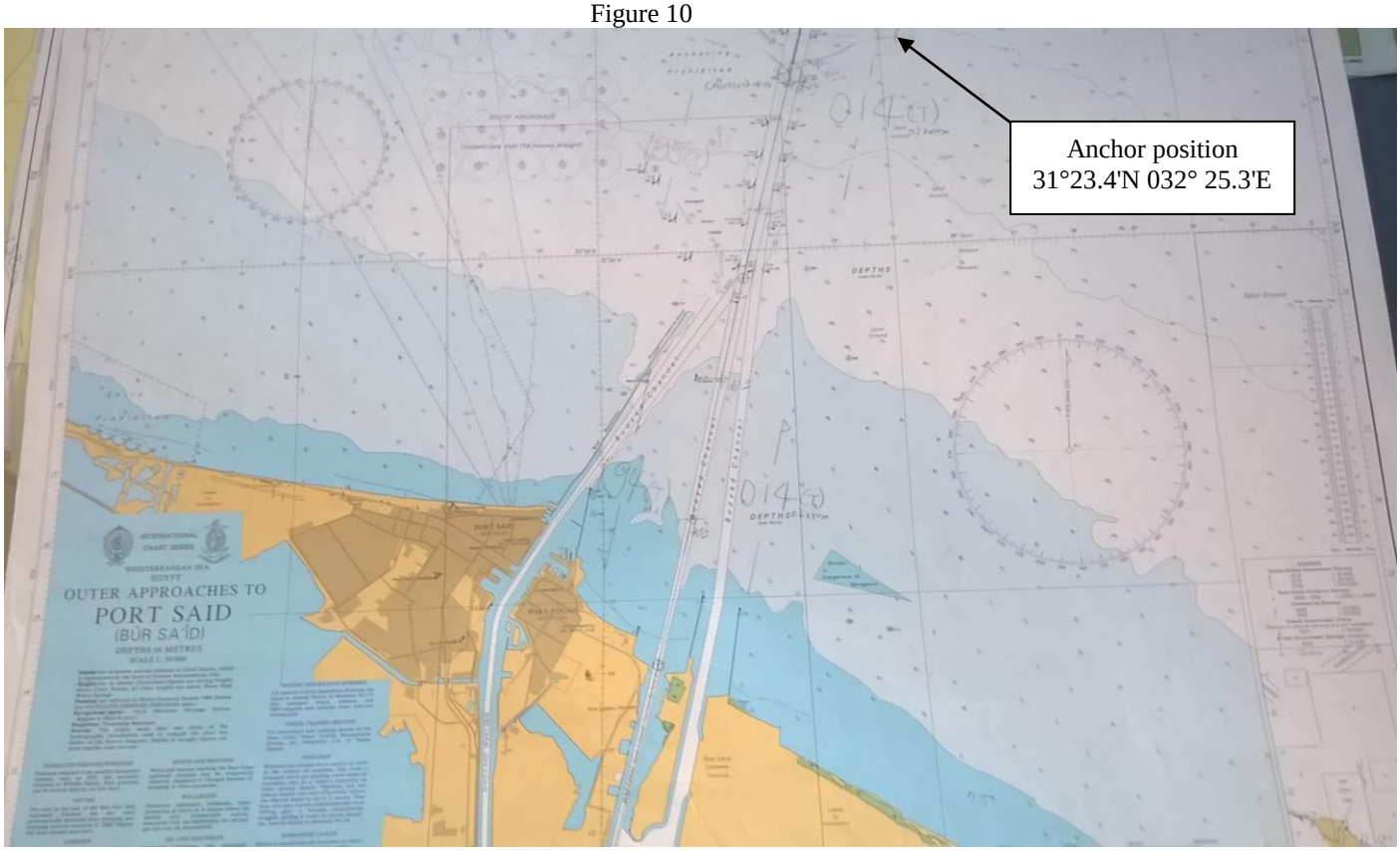


Figure 10



07:26hrs
2 x Suez Canal Pilots left the vessel

07:36hrs
Finished With Engines.

07:50hrs
2 x Tugs ("Mosad 3" and "Zamil 7") departed. 1 TUG "Port Said" started water jet making total of 2 tugs water jetting ("Port Said" and "Baraka 1")

08:00hrs (ERC log)
ERC arranged for a KR surveyor to attend the vessel to assess damage via the Athens office.
ERC requested that each Box Operator [1] send a cargo manifest so they can start to check containers to see which may contain suspect cargoes.

08:13hrs
The ER event log showed the first CH bilge valve operations indicating starting to pump out the accumulated water in CH bilges affected by the firefighting water. There is no indication of valves BG020 and BG021 (CH 9 bilge suction valves stbd and port respectively) being opened at this stage though there are "closed" and "reset" events shown on the log. The other holds affected by ingress of the firefighting water are pumped out. Namely CH 7, 8 and 10.and this pumping operation is continued to keep on top of the water entering these holds.

08:55hrs (ERC log)
ERC was in discussion with their insurer's to send a fire expert and salvage company to the scene

09:50hrs
Navy tug "Al-Areesh" arrived to support the other 2 tugs water jetting the fire.
An attempt was made to enter CH 9 via the WT door in the deck 2 underdeck passageway stbd side (frs 59-60).
2/O (B) entered with BA and a safety line and estimated he managed to get 7-10 m in-board from the WT door. Visibility was only about 1m with a torch and the temperature was described as warm and not too hot. He withdrew as he couldn't see anything due to the smoke and the large quantities of jetting water raining down around him.

10:20hrs
Tug boat "Port Said" departed leaving 2 tugs standing by jetting water

[1]Box Operator: The entity that owns or operates the box(es) (cargo carrying unit(s)) and provides the cargo details to the ship owner (operator) when required in situations such as this.

11:41 hrs
No 2 main cooling SW p/p fail
The firefighting water entering the ER via the damaged water catchers was cascading down through the fan trunking. The ER staff had tried to divert the water with plastic sheeting etc. However, some of the water had damaged the 3 sets of inverter panels for the main cooling SW pumps, at one point stopping all 3 pumps. These pumps provide SW for the central cooling system for the M/E and Generators on-board.
The C/E and 1/E made an emergency connection from the general service pump to the central cooler to enable continued cooling due to the continued risk of damage to the main SW cooling pumps from the firefighting water still entering the ER.

12:20hrs (ERC log)
ERC log stated that some of the 20ft containers in the central part of Bay 70 had collapsed. Also that due to the fire extinguishing water in CH 9 the vessel had trimmed by the stern and they estimate from a simulator that there was now about 1100 MT of seawater in the hold.

13:10hrs
Agent arrived on-board.

14:30hrs
Special Team from the Egyptian Navy was organised to attend the vessel by the port authority officer.

16:22hrs (ERC log)
ERC received an Emergency Response Service(ERS) report from KRS which, following a review by the ERC, had decided there was a need to start discharging the water accumulation that had entered CH 9 as a result of the firefighting operations.

16:35hrs
Special Egyptian Navy fire team arrived on-board and were briefed regarding the known status of the fire in CH 9.

16:50hrs
Water from Tugs was stopped in an attempt to evaluate the present situation with the fire.

16:55hrs
Egyptian Navy team arrived on scene.

17:00hrs (ERC log)
SMIT salvage Master was contacted to see if he was agreeable for the proposed pumping out of SW from the CH 9 for the purpose of the safety of the vessel. Log stated SMIT agreed it was necessary.

17:05hrs
Navy team using ships equipment of 2 charged fire hoses began jetting the fire from the stbd fan room top casing.

Figure 11

Egyptian Fire Team preparing hoses on stbd side of fan room casing and
second image shows damage to the water catchers from the FiFi tug water monitors

17:06hrs
DLB - Flames were seen coming from the bottom and top of the first tier containers IWO the centre of Bay 69. Additional fire hoses were prepared and water jetting in this area commenced.
There was thick smoke present confirmed in photographs taken at the scene.

17:20hrs (ERC log)
The ships staff attempted to start pumping out CH 9 using the bilge pump, however, found that the valve would not open due to assumed water damage to the actuator.
The ER event log shows numerous attempts to operate the CH 9 bilge suction valves BG020 and BG021 between 17:17hrs and 17:36hrs. The valves were found to be inoperative and thus they were unable to start pumping out the accumulation of the fire water from the hold.

17:40hrs
Sounds of explosions were heard periodically and the Navy fire team judged that that it would be impossible to extinguish the fire using ships hoses and equipment. The Navy and ship's fire teams withdrew from the scene.

18:00hrs
2 tugs "Baraka 1" and "Al Areesh" were instructed to resume water jetting the fire again.

18:45hrs
C/O and 2/O(B) under the instruction of the Master attempted to enter the hatch (frs 64-65) on the X deck directly aft of CH 8, however, it was impossible to approach due to the heat and smoke from the fire. They subsequently entered CH 8 through the hatch (frs 69-70) on the X Deck between the fwd and aft hatch covers. Nothing abnormal was found within CH 8.
Shortly after checking CH 8 the C/O and 2/O (B) checked the water level in CH 9 through the WT door(frs 59-60) in the stbd underdeck passageway deck 2 stbd side. The water level was reported as level with the floor (deck 2).

20:00hrs (ERC log)
The ERC instructed the vessel that they needed to open WT door in 2nd deck passageway (frs 59-60) due to increasing water level in CH 9.

20:10hrs
Additional tug "Maridive 703" arrived on scene and started jetting water at the fire. Tug "Baraka 1" stopped jetting

20:35hrs
C/O and 2/O (B) once again checked the water level in CH 9 through the WT door (frs 59-60) stbd side deck 2 and reported that it was now just below the bottom of the watertight door sill. The C/O said he had calculated that this depth was approx. 18 m above the inner bottom. He calculated that CH9 at this stage had taken in approx. 6000m^3 of sea water.

02/05/2015

00:25hrs
Tug "Al Areesh" changed from jetting water to jetting foam in an attempt to see if foam would have more effect on the fire. All other tugs stopped jetting water at this time.

01:35hrs
Tug "Al Areesh" stopped jetting foam and it was observed that the foam had had no effect on the fire as flames were sighted again.

02:30hrs
Tug 'Maridive 703' started water jetting the fire.

02:43hrs
Tug "Baraka 1" started water jetting the fire.

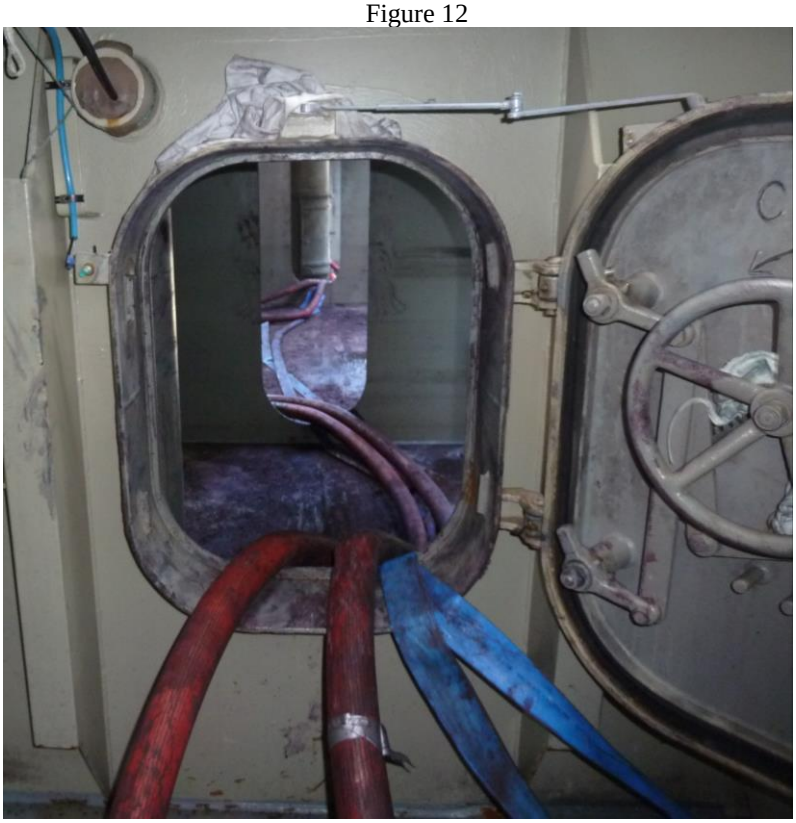
Sometime late in the evening on 01/05/2015 the crew prepared to start draining water from CH 9 via the WT door (frs 59-60) in the underdeck passageway deck 2 stbd. (2/O (B) reported that he thought the company had communicated that they should start draining the hold and that he thought this started during late evening of 01/05/2015)

A tarpaulin was rigged below the door and a portable pump provided ready to put inside the water tight door.
The flush manhole covers for No 9 SWBT (S) covers x 2 were removed
Then at some point later the manhole covers for No 5 and 6 SWBT (S) were removed though it is unclear when.

The WT door (frs59-60) was opened slightly using the central hand wheel that operates the 4 cleats (dogs). Witnesses stated that when the draining operation was started water was noted coming from around the bottom part of the door. This meant the door could not be fully opened to put the portable wilden pump into the hold so they started draining the leakage from the hold into the tarpaulin which directed the leakage into the ballast tank manhole openings (2 x No 9 SWBT (S)) in the immediate vicinity.

The C/O organised this locally and then once the draining started the 2/O (B), Bosun, 3 x Sailors and Wiper (A) were present for the majority of the time to monitor the situation. The door was never left unattended.

Figure 12



WT door (frs 59-60) from stbd side deck 2 underdeck passageway, looking through to CH 9

03:45hrs
The Egyptian Navy firefighting team disembarked the vessel

05:10hrs
Fire was reported to be spreading to bay 66 so vessel instructed some alteration to the tugs jetting to cover this area.

06:30hrs Approx.
After monitoring the WT door (frs 59-60) draining CH 9 it was noted that the level behind the door was rising due to the leakage around the door moving up over time eventually it was spraying out all around the door seal.
The decision was to try and open the door a little more. One of the sailors reported that order was given to the Bosun to open the door a little bit more. The Bosun adjusted the door then tried to close it again due to the amount of water coming out. As he struggled to try and close it the door flew open knocking the Bosun to the floor.
The Bosun, 2/O and Sailor (B) escaped fwd and out of the WT door leading into the accommodation IWO frame number 111. This door is a distance of approx. 136m fwd of where the flooding occurred.
Sailor (C), Wiper A, Sailor (A) and Oiler 1 were all stood inside the passageway IWO the WT door to the ER (frame 40, some 15m aft of where the flooding occurred) and escaped into the ER shutting the door behind them.

The 1/E was in the stbd bunker station one deck below the passageway. The bunker station is accessed through a raised hatch (frs 56-57) in the underdeck passageway just aft of the WT door (frs 59-60) to CH 9.
The 1/E was not informed that they were going to adjust the WT hatch. Once the WT door to CH 9 opened there was an enormous amount of water flooding into the underdeck passageway and also down into the bunker station below via the open bunker station hatch. The 1/E initially tried to open the bunker station ship side door, however, this could no longer be opened.
He escaped back up into the underdeck passageway through the access hatch where he found the water level on deck 2 was up to his shoulders. Because of the height of the water level he had to make his way aft by crawling on top of the pipes above the passageway until he reached the WT door(fr 12) at the aft end of the passageway (this leads to the top of the open stairway that leads down into the steering gear compartment).

The water level in the passageway was very high. Wiper (A) who escaped to the ER said that there was almost 2 meters of water around the Bosun when the door opened. After Wiper (A) had shut the WT door (frs 40-41) to the ER he heard a banging on the other side of the door which was made by the 1/E trying to get into the ER as he made his way aft. Sailor (A) stated that they tried to open the door a little however there was water leakage from the top of the door so it was decided to leave it closed to protect the ER.

Wiper (A) went to the ECR to inform the C/E about what had happened.

Wiper (A) the C/E together with some others went through the ER and into the deck 2 port underdeck passageway via WT door (frs 29-30)heading aft then up the short steps and through the aft WT door(fr 12), then down the open stairway into the steering gear compartment where they found the 1/E.
They could see water running down the stbd stairway into the open void stbd side of the steering gear. They went up this stairway and then managed to close the aft WT door (fr 12) (leading into the deck 2 underdeck passageway) to stop any further leakage into the steering gear compartment.

Following the flooding of the stbd underdeck passageway the vessel listed to stbd approx. 5 degrees.

Figure 13

Raised access hatch to stbd bunker station (frs 55-56) in foreground and further behind can be seen the open WT hatch door (frs 59-60) to CH 9.

Figure 14

Aft WT door (fr 12) at the end of the stbd deck 2 passageway, water flooded above this level and down the stairwell in the foreground into the steering gear compartment.

2/O (B) said that after the flooding the Capt stopped the tugs jetting then ballasted the port ballast tanks to maintain an even keel.
Ballast records indicate that ballasting started at 13:00hrs, however, when the SMIT team boarded the vessel at 13:38hrs their daily report log reported 3 tugs were still water jetting which is corroborated in the DLB

13:38hrs
7 men from SMIT arrived on board (Salvage Masters, Firefighters and a Marine Chemist).

SMIT team assessed situation and coordinated Tug boundary cooling and started work on the containers on fire on bay 70

17:50
KR Surveyor attended the vessel for preliminary evaluation of the vessel's condition

03/05/2015
Summary
SMIT team managed to extinguish fires in some of the containers on deck. Holes were made in various containers on deck to enable direct attacking of fires within. Setting up water barriers/cooling points
Working inside CH 9 making access to attack the fire in a container they had detected as burning within the hold; cell position 700322

SMIT salvage master advised the Master that the fire was under control but not yet out.
It was agreed with SCA that only 2 tugs would now be required to standby, "Maridive 703" and Egyptian Navy "Tug 113".

Figure 15

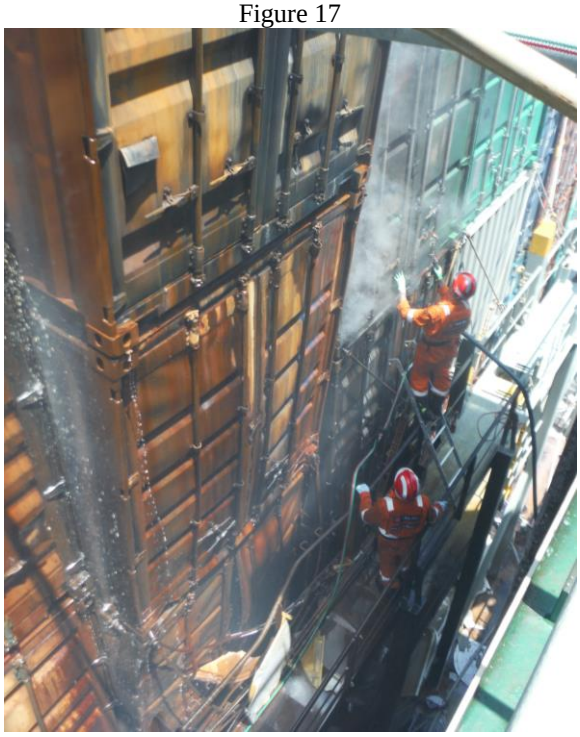
SMIT Team setting up water barriers

Figure 16

SMIT Team checking hold condition and temperature

04/05/2015
Summary
Additional firefighting and salvage equipment for SMIT loaded onboard together with 9 additional SMIT personnel.
The salvage team's fire pumps set up to draw suction from within CH 9 for firefighting and cooling in order not to increase the water level in the hold.

Figure 17



SMIT firefighters burning an access hole into a burning container

Figure 18

Cooling hose rigged into container aft end of bay 70 adjacent to ER casing

05/05/2015
Summary
SMIT continued with firefighting operations.
Commenced pumping out water in CH9 to No 5 SWBT (S). Received permission from company to reduce water level to 6m in CH9.

06/05/2015
Summary
SMIT continued with firefighting operations.
Pumping out water from CH 9 to No 5 SWBT (S) stopped

Figure 19

Cutting access holes into hatch covers to allow access for cooling hoses

Figure 20

Cooling hose in cut-out

07/05/2015
SMIT continued with firefighting operations. Only one container in the hold was still burning but it was a deep seated fire in container 700422 and not easily extinguished (it was full of marine plywood) but was able to be contained and controlled.
Resumed pumping out water from CH 9 to No 5 SWBT (S)

08/05/2015
Summary
SMIT continued with firefighting operations. This consisted mainly of monitoring and boundary cooling and temperature reduction.
Some SMIT crew disembarked the vessel prior to the ship's departure on passage to Algeciras. 7 SMIT crew remain onboard.
Water from CH 9 was being pumped out and transferred to 5 SWBT (S) then 6 SWBT (S)
1648hrs Departed for Algeciras

09/05/2015
SMIT team continued with ongoing firefighting operations of cooling and reducing temperatures. Fire in container 700020 still not out and was being continuously sprayed.
Water transfer from CH 9 to 6 SWBT (S) suspended following the onboard Marine Chemists recommendation to the Master. The danger was that containers 650606, 650608 and 650804 containing Ferro Silicon Manganese could release phosphine and hydrogen gas if the water level dropped below 10 meters and exposed them to air. It was decided to keep them submerged under the water until more expert assistance and equipment was available to discharge them once alongside in Algeciras.

10/05/2015
SMIT continued firefighting activities, container 700020 still emanating smoke.

11/05/2015
SMIT continued firefighting activities, container 700020 still emanating smoke.

12/05/2015
SMIT continued firefighting activities, container 700020 still emanating smoke.

13/05/2015
SMIT continued firefighting activities, container 700020 still emanating smoke

14/05/2015
0148hrs Berthed Algeciras to commence offloading containers from CH9, pumping out remaining contaminated water from hold 9, cleaning hold 9 and assessing damage to vessel.

3. Comments & Analysis

3.1 Fire fighting

3.1.1 Was the Initial Response to the Fire Effective?

Following the smoke from CH 9 being detected by the cargo hold smoke detection system and sounding on the bridge fire alarm repeater panel the general emergency alarm started sounding throughout the vessel.
Upon the sounding of the general emergency alarm, the crew should start to muster at the designated muster station which is upper deck port side outside the entrance to the CO_2 room. This position is approx. 137m from the centre of CH 9

An announcement was made over the public address system by the 2/O (A) stating that there was smoke in the vicinity of Bay 70, however, due to a fault occurring with the PA system the PA did not override and silence the general emergency alarm as required by 7.2.1 of the LSA Code. A number of other announcements were made over the PA, however, the problem of the general alarm not being silenced persisted. Eventually (16mins 50seconds later) the alarm was silenced when the C/O pushed the reset button on the hold fire detection system panel in the CO_2 room.
The problem with the PA/General Emergency Alarm caused some initial confusion for those at the muster station as to exactly what was going on.
Whilst the PA was not effective, there had been swift communications as to where the fire was and the Bosun was ordered to go and investigate taking 2 men with him. Shortly thereafter the C/O was also on scene to make an initial assessment of the situation.

The Master instructed the C/O to close the vents which the C/O relayed to the firefighters locally. He also asked them to see if it was possible to enter the CH9 access hatch which is located just to port of the ships centreline on the X deck and check the location and extent of the fire.
The Master requested the C/Eng to isolate all power to CH9. This he in turn directed the 3/E to carry out, who then completed this task swiftly.

The crew successfully shut the natural ventilation flaps on the outboard sides of the outer 2 hatch covers (figure 21).

The 3 large ventilation trunks within the X Deck are individually closed by placing a portable hand-wheel(located nearby) on top of the exposed operating spindle (consisting of a threaded bar with a square end to fit the hand wheel), which when turned, lowers a large rectangular lid onto the top of the ventilation trunking.

Each lid has a position indicator in the form of a steel rod that is welded to the top of the lid and protrudes through the walkway indicating the position of the lid, when flush with the walkway the lid is fully down (see figures 22 and 23).
Only two of these ventilation trunks are for CH 9, having supply fans in the trunking lower down the X deck on deck 2. The port ventilation trunking lid is located IWO row 8 and the stbd ventilation trunking lid is located IWO row 9.The screw down ventilation trunking lid IWO row 3 on the stbd side is for natural ventilation of the pipe duct.

Figure 21

One of the manual natural ventilation flaps on the outboard side of an outer hatch cover

Figure 22

Portable handwheel for operating the ventilation trunking lid.
The end of operating spindle can be seen (red end) as can the opening for the position indicating tell tale rod

Figure 23

Example of the screw down ventilation trunking lid arrangement
situated directly below X deck walkway

It could not be established if the screw down lids for the 2 hold ventilation supply trunkings were fully shut by the firefighting crew tasked with the job.
QM (A) was tasked with shutting the port side screw down ventilation trunking lid and was doing so without a BA set on. He said he turned it till it got stiff, at that time it was very hot with lots of smoke coming from the stbd side. Then someone told him to go over to the stbd side. He couldn't remember how many turns he got on the spindle.

Once on the stbd side QM (A) said he and Wiper (A) (both now in BA) went to try and shut the 2 stbd screw down ventilation trunking lids. QM (A) said he was pretty sure that they shut both of them
Sailor (B) said he thought QM (A) and Wiper (A) were about 5 mins closing the vents and that they said to him they had tried to close screw down ventilation trunking lids but it was hard.

The position of the position indicators was not mentioned by any of those interviewed. These indicators are not painted in an easily visible colour, however, are very close to the handwheel operating position.

Pictures taken by the ships staff on 05/05/2015(figure 24) show- one of the screw down ventilation trunking lid's nearly fully open with the debris on the grill and in the screw thread bar indicating that the lid was in this position during the fire. This would indicate that at least one of these lids was not shut during the fire though it is not clear if the picture is of one of the 2 hold supply trunkings or for the pipe duct trunking

Figure 24

Open ventilation trunking referred to above

Note
During the investigation the stbd screw down ventilation trunking lid on the X deck was tested and found to take 3 mins 15 seconds to shut and was hard work in the fresh air with no BA set or heat and smoke. It could be shut but was very stiff. It is noted that deterioration in condition could have been due to its exposure to heat from the fire. There was a lot of grease on the spindle indicating periodic greasing though to ensure proper and free operation, such equipment needs to be operated from the fully open to fully closed position.
Another identical screw down ventilation trunking lid was sampled from CH No 6 X Deck and was able to be closed in a time of 1 min 57 seconds. It was easier to turn and it was easier to tell when the lid reached the fully shut position.
It goes without saying that it is critical that all fire dampers of any type should be maintained to operate as designed i.e. be easy to operate and easy to ascertain when they are in the fully closed position.

Once the above was carried out and it had been established that the fire was unable to be directly attacked by the firefighting crew the Master took the decision to use the fixed CO_2 system following a head count of all crew onboard.
Once all crew were accounted for the C/O, 2/O (B) and 3/O made their way to the CO_2 room to make ready for the release of the CO_2.
The time taken from the initial smoke alarm sounding to the time the CO_2 release alarm sounds(on the event log) indicating the start of the initial release of the first batch of CO_2 was some 13 minutes.

It can be concluded that the initial response to the fire was effective despite some communication issues experienced with the PA system not cutting out the general emergency alarm.
It could not be concluded that both the screw down ventilation trunking lids were fully shut.
It can be concluded that the Master took the correct decision to inject CO_2. It was quickly apparent that there was a substantial fire within the hold and the correct action in such cases would always be to isolate the hold and then to release the fixed system CO_2 as quickly as possible.

3.1.2 CO_2 Release

The number of CO_2 bottles required to be released for each cargo hold can be found in the instruction table "Instruction Chart for CO_2 Fire Extinguishing System" located in the CO_2 Room (figure 3).
This table specifies how many CO_2 bottles are to be released into each hold for 1st, 2nd and 3rd discharges for 4 given loaded conditions i.e. 0%-25%, 25%-50%, 50%-75% and 75%-100%
The chart also provides guidance on times between the discharges.
CH 9 is one of the smallest holds on the vessel as the aft half of the hold has the engine control room and engine room directly below it so is much shallower than the fwd part of the hold.
CH 9 was loaded to capacity therefore the required number of CO_2 bottles for the initial release in 100% condition was 102 bottles.
The chart specifies that the 2nd and 3rd discharges of a further 102 bottles respectively should be carried out at 40-60 minutes after the previous release and depending on the conditions in the cargo hold.

The CO_2 release for any cargo hold onboard is carried out manually with individual CO_2 cylinders activated with a manual lever as opposed to the pilot bottle activated release in the case an engine room fire.
To release the CO_2 to a cargo hold the glass fronted key-box has to be broken to obtain the key to open the "Ball Valve Cabinet" that has a single valve inside, which when moved to the open direction directs the main CO_2 bottle discharge line to the cargo hold manifold.
Once this valve is opened the operator must then change over a 3 way valve to direct the CO_2 to the required cargo hold. This 3 way valve is normally in the "smoke sample" position where it draws air from the respective cargo hold to the smoke

sampling panel in the CO_2 Room. In the case of CH 9 there are 2 distribution lines to the hold therefore 2 valves require to be changed over.
Once the above valves have been correctly set, release of the individual CO_2 bottles can be started by removing the manual lever from the "Manual Lever Box" and placing in a slot in the cylinder actuator on the top of each bottle. The manual lever is then pulled to pierce the cylinder and release the CO_2. This manual operation should be completed as quickly as possible until the required numbers of CO_2 cylinders have been released. (see Annex 3 for details)

According to the timings in the deck log book the initial release of the first batch of 102 CO_2 bottles commenced at 0215hrs and finished at 0238hrs therefore taking some 23 minutes. This equates to a bottle being released every 13.6 seconds.
The release of the second batch of a further 102 bottles commenced at 0243hrs, the Master then ordered the 3rd batch of 102 bottles to be released at 0255hrs and ordered all the remaining bottles(174) be released at 0300hrs due to the observed spread of the fire.
The Deck Log Book recorded that completion of CO_2 release was at 0306hrs indicating the release of 378 bottles in 24minutes.This equates to a CO_2 cylinder being released every 3.8 seconds(release of second, third and final batches).

The officers attending the CO_2 room were the C/O, 2/O/ (B) and the 3/O.
According to the Muster list the C/O's duties in the event of a fire are listed under the Control/Support team:
On Scene Control, Transceiver, Operation of Fixed Fire Extinguisher

The 2/O (B) muster list duty is indicated as stationed in the Radio Room with duties listed as
Communication and passenger call.

The 3/O is in the Rescue party with duties listed as
Leader of Rescue Party, First Aid Kits, Transceiver

Individual statements had considerable variation in regard to times spent in the CO_2 room however an overview of what happened and the location of personnel was established:-

Once the order from the Master to release the CO_2 to CH9 was given all 3 officers above attended the CO_2 Room.
3/O stated his duty was to find out how many CO_2 bottles were required to be released and to break the glass fronted key box in order to obtain the key to open the door to the locked box containing the single ball valve that directs the CO_2 to the cargo valve manifold. He then had to change over the 2 x 3 way valves to cargo hold 9 from the smoke sampling position to the CO_2 release position.
Once this had been completed and all the officers had checked the position of the valves the C/O contacted the Master on the radio transceiver to confirm he still wished for the fixed CO_2 to be released.
Upon receiving confirmation from the Master the C/O, 2/O (B) and the 3/O started manually releasing the first batch of 102 bottles.
The C/O then returned to the scene of the fire

The 2/O (B) returned to the scene of the fire though statements are conflicting as to whether this was before the completion of this first batch of CO_2 or not.
The 3/O remained in the CO_2 Room for the duration.

The order to release the 2nd discharge of a further 102 CO_2 bottles was given by the Master to the C/O who in turn ordered the 3/O to commence the release. The 3/O started this release and was joined at some point later by the C/O
After completing release of the second batch of CO_2 cylinders the C/O was instructed by the Master to go and check the locations and quantities of dangerous goods containers in the vicinity of the fire. The C/O made his way to the deck office to see the records.
Shortly after the order was given to start the 3rd discharge of a further 102 bottles and then 5 minutes later to continue on and release all CO_2 bottles as the fire was seen to be escalating. The 3/O completed most of this on his own as the C/O had returned to the scene of the fire.

The time taken for the initial batch of CO_2 to be released appears to have taken much longer than the release rate of the remaining bottles. The entry in the deck log book for commencement of CO_2 release was 0215hrs which would tie in with the alarm event log which records at 0213hrs "CO_2 Release Alarm (Cargo Hold)". This alarm would sound as a result of opening the door of the cabinet "Ball Valve Cabinet for Cargo Hold"

Due to his responsibilities the C/O left the CO_2 room following commencement of the CO_2 release in order to return to the scene of the fire.
It is very important that a fixed CO_2 system is released as quickly as possible in order to have maximum chance of extinguishing a fire. It would have been preferable for the C/O to be in the CO_2 room for the duration of the release as a senior ships officer rather than placing this responsibility on a junior officer. This is even more important when the CO_2 system is a manual release unlike a typical engine room system where pilot bottles are employed to ensure a rapid discharge the CO_2.

The service engineers report following arrival in Algeciras confirmed that all CO_2 bottles had been released and there was some minor damage to CO_2 pipe paintwork in CH9 confirming that it had been released in to the correct hold.

Concluding unless the time entered in the deck log book for completion of initial release of CO_2 at 0238hrs is incorrect then the time taken for releasing the first batch of CO_2 bottles took considerably longer than it should have.
The release of the remaining CO_2 bottles was carried out at an acceptable rate.

The duties and responsibilities of the C/O in this sort of emergency require him to be in 2 places at once. He is expected to be the "On Scene Controller" and to be in charge of "Operating the Fixed Fire Extinguishing System.
Time would also be saved by having someone ready in the CO_2 room rather than the Chief Officer having to try and be in two places at once.

3.1.3 Firefighting Actions after CO_2 Release

Towards the end of the CO_2 release the port side firefighting team moved onto the X deck and moved inboard approx. half way to the centreline. They then moved inwards and outwards depending upon the ferocity of the fire and the frequency of explosions. After 20-30 minutes they retreated and then moved up onto the second level of the lashing bridge and boundary cooled from this position again having to move inwards and outwards depending on the state of the fire.
The stbd firefighting team were boundary cooling by directing water through the X deck towards the centre of the fire.
After some time the C/Eng advised them that there was also a fire on the aft side of Bay 71 directly adjacent to the ER casing. On receiving this information the stbd firefighting team stopped boundary cooling CH9 X deck and moved aft to set up 2 more hoses and attacked the burning containers on the aft side of Bay 71 in order to try and protect the ER casing.

The arrival of the first firefighting tug the 497GT "Mosad 3" was noted as making little difference to the fire.
Only after the second tug the 1267GT "Zamil 7" was positioned to the stern of the vessel was it reported in the deck log book that the fire that could be seen on deck started to decrease in intensity. This was noted at 0430hrs on 01/05/2015.
After the arrival of "Zamil 7" the port side firefighting team had to reposition themselves further outboard on the lashing bridge due to the amount of water jetting from the tug.
A third tug the 1805GT "Baraka 1" arrived at 0550hrs and shortly after this the ships firefighting crews had to withdraw completely due to the huge volumes of water being directed at CH9 from the tugs. The amount of water raining down from these tugs was described by one of the crew members as being "like waterfalls".

The fire at this point appeared to be effectively contained from spreading further on deck by the tugs which were continuously spraying the containers in this area.

The containers on fire within CH 9 were found to be limited to those within the relatively shallow fwd part of the hold in Bay 70. Here the containers are stowed 4 deep towards the outer sides of the hold and only 2 deep in the centre of the hold due to the ER deckhead and ECR deckhead respectively being directly below. The spread of the fire into the fwd Bay 66 was largely prevented due to the dividing X deck structure.
A considerable amount of firefighting water from the tugs was also entering the hold due to the design of hatch covers which have longitudinal gaps between them and gaps where they sit on the hatch coaming. This water would have the effect of providing cooling for the containers in way of the gap and also to cool the bottom of the hold of bay 70 therefore providing some protection to the deck head of the ECR and ER below.
It was noted in the deck log book on 01/05/2015 at 0430hrs that fire on deck appeared to be decreasing and from this point on, the firefighting water from the tugs prevented the fire on deck from spreading fwd or aft of CH9.

The tugs continued to firefight whilst the vessel made its way to anchor (0706hrs 01/05/2015) and then continued to do so after it anchored just outside the port of Suez at position 031°23.4′N 032°25.3′E. The tugs were periodically relieved by other tugs.

An attempt to extinguish the fire was made by an Egyptian navy firefighting team assisted by the ship's crew and using the ships firefighting equipment at approx. 1700hrs on 01/05/2015. The tug jets were stopped in order to assess the status of the fire. They attempted to fight the fire from the top of the stbd ER fan casing. The team quickly realised that the fire was still widespread with dense smoke covering the area of bay 70. Deck log book recorded that flames were sighted at the bottom and top of the first tier of containers in bay 69 (no row number was indicated) and that additional hoses were prepared to attack this area.
The firefighting attempt was sustained for around 40 minutes by which time the navy team concluded that it was not possible to extinguish with hoses at this time and withdrew together with the ship's crew who had been assisting and supporting. At this time explosions could still be heard coming from within the hold.

The firefighting efforts made by the ship's crew and later by the Egyptian Navy with assistance from the ship crew were made with the ships own firefighting equipment. This consisted of standard SOLAS approved fire hydrants, hoses and nozzles. The vessel is certified for IMDG so there are some additional firefighting equipment requirements in that the fire pump shall be capable of supplying 4 nozzles simultaneously. Three extra fire hoses and jet/spay nozzles are also required. Nonetheless, having only such basic equipment to try and contain such a fire is a very big ask for the crew and the odds are very much stacked against them in being able to contain let alone extinguish such a fire as was found on board the Hanjin Green Earth.

On 01/01/2016 Resolution MSC.365(93) "Amendments to the International Convention for Safety at Life at Sea 1974, as Amended" came into force.
Included in these amendments are new requirements in SOLAS Chap II-2 Reg 10.7.3 "Firefighting, applicable to ships carrying containers on or above the weather deck; Extra equipment for this size of vessel include at least 1 water mist nozzle capable of penetrating a container wall and producing water mist inside a confined space, 4 mobile water monitors, each water monitor is to be supplied by a separate hydrants which there must be sufficient number of to allow the monitors to operate simultaneously and to create an effective water barrier fwd and aft of each hold. There should be sufficient water pressure to allow the monitors to reach the highest containers on deck.

These improvements for new ships should provide more chance to contain any fires above deck and opportunity to tackle fires inside individual containers.

During the above firefighting operation there was no real opportunity to attack the fire within the hold of CH 9. Access for a fire team was not possible due to the intensity of the fire and even if entry could have been gained it is unlikely that the efforts of a fireteam with a hose would have made any difference at all due to the intensity of the fire.

SOLAS Chapter II-2 Reg 19.3.1 provides for water supplies for cooling designated underdeck cargo spaces when required to carry certain classes of DG, however, it is not mandatory to provide this underdeck water supply if these classes of DG are not carried under deck. A vessels "Document of Compliance with Special Requirements for Ships Carrying Dangerous Goods" will stipulate the carriage requirements of individual classes of DG.
The Hanjin Green Earth has a Document of Compliance with Special Requirements for Ships Carrying Dangerous Goods and a Record of Equipment. This indicates that Reg 19.3.1 is not applicable as she does not carry any of the DG's in her holds that would require an underdeck water supply.

Although not required in the case of this particular fire it could be seen that having the ability to attack the fire in the hold remotely with either a fixed water drenching system or the ability to completely flood the hold with water would have been extremely advantageous

At 1800hrs following the navy team's unsuccessful attempt at firefighting, two tugs were instructed to resume jetting on the fire.
At 0025hrs on 02/05/2015 water jetting from the tugs was stopped and one of the tugs, "Al Areesh" started jetting foam to see if this medium would make any difference to the fire. This continued until 0135hrs, however, it was found that it had made little difference to the fire. Following the attempt with using foam, water jetting was resumed at 0230hrs.

At 1338hrs on 02/05/2015 the first members of the marine salvage team from SMIT arrived on board consisting of a marine chemist, salvage masters and firefighting experts.
Having completed their initial assessment of the situation onboard they commenced firefighting the containers on Bay 70 at 1700hrs using the ships equipment. In addition they provided direction to the tugs that were carrying out the boundary cooling.

On 03/05/2015 SMIT- set up water barriers/cooling points, using oxy acetylene torches to make access holes in some of the burning containers on deck in order to directly attack the fires within. This proved successful in extinguishing some of the burning containers on deck.
They inspected CH 8 and found no containers burning and also inspected CH 9 and identified one burning container inside. By 1500hrs the Salvage Master was able to report that the fire was under control but not yet out.

On 04/05/2015 specialist salvage and firefighitng equipment was received on board and SMIT continued with their work.
The vessel departed Suez on 07/05/2015 bound for Algeciras with only 1 container in CH 9 (700020) still smoking. A high performance spray system was rigged up to cover this and additional nozzles and cooling points were set up to provide water screens if needed.
This container continued to emanate smoke during the passage to Algeciras. The vessel arrived in Algeciras at 0148hrs 14/05/2015.

It is worth noting that the container emanating smoke (700020) contained marine plywood. Despite all the water used to isolate this and try and extinguish it, the

container was still not out by the time the vessel reached Algeciras. This shows how difficult it can be to extinguish certain types of fires, even with specialist equipment and knowledge.

It can be concluded that:-

The crew firefighting actions following the release of the CO_2 were commendable. The nature of the cargo and the layout of this type of vessel meant that it was very difficult to directly attack a fire. They were faced with fires within containers on top of the hatch covers and fires within containers within CH9 below the hatch covers that they could not access.
The size and scale of the holds on this class of container vessel are huge. Realistically little can be done with 4 fire hoses other than try and boundary cool and contain the fire externally from spreading fwd to the next bay or aft to the engine room and superstructure.
The crew monitored and reacted to the spread of the fire in these early stages as best as they were able with the equipment they had. They prevented the fire spreading fwd across the hold X deck to the containers on Bay 67 and tried to reduce the impact of the flames and heat from the containers on fire on the stbd hatch covers in Bay 71 adjacent to the engine room casing.

The standard firefighting equipment provided onboard was not capable of containing a large fire on deck. There was no effective means to fight the fire within the hold following the unsuccessful release of the fixed CO2 system.
There was no provision to remotely attack the fire in the hold with water which although not a requirement would have been advantageous in the case of this particular fire.

The arrival of the tugs with their large firefighting cannons was a critical point in the firefighting operation. The volume of water directed at the fire had the desired effect of cooling the fire on deck and boundary cooling, preventing it spreading further.
The water from the tugs entering the hold through the gaps in the hatch covers provided some cooling in the hold.
If the large FiFi tugs had not been available when they were, it is likely that the fire would have started to spread as the ships hoses were not adequate to control the situation.

The further combined attempts at attacking the fire with the use of the ship's hoses carried out by the crew and specialist Egyptian Navy Firefighters proved ineffective as the fire was too large and deep seated.

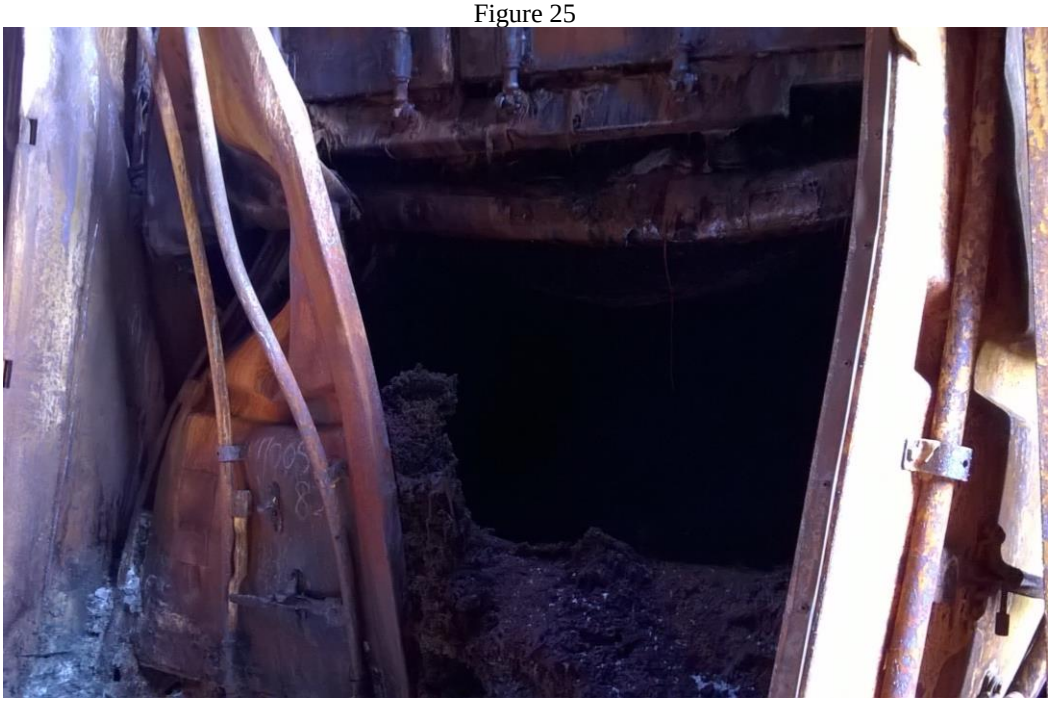
The effect of the continued jetting from the tugs had contained and partly reduced the fire on deck by the time the SMIT team came onboard. This boundary cooling was not able to directly attack the individual containers on deck or within the hold.

The specialist skills, knowledge and equipment that the SMIT team possessed soon had a real effect on the fires onboard. They were able to identify, contain and extinguish the majority of the fires in a relatively short period of time. Those fires that could not be extinguished were effectively isolated to allow the vessel to continue on to Algeciras.

3.2 Where did the fire start?

Initial information from the ship's firefighting team indicated that the fire was originating from just below the fwd end of the hatch covers of bay 70 in the vicinity of the centre line of the vessel.
Once the vessel was berthed at Algeciras the operation of removing all the damaged containers commenced.
The containers fwd of the X deck of CH9 i.e. Bay 66 had largely escaped damage.
The containers aft of the X deck of CH 9 i.e. Bay 70 had suffered varying degrees of fire damage. Above the hatch covers the containers directly on the two inboard hatches of Bay 70 suffered more damage than those on the 2 outboard hatch covers with those containers in the lower 2 tiers suffering the worst damage. One of these containers in position 700582 containing polypropylene caused damage to the engine casing and lashing bridge. As a result of the heat within, its aft facing door became distorted and partly opened, allowing the flames to fan out and cause the above mentioned damage. (see figures 25-31)

Figure 25



Container 700582 containing polypropylene ruptured at the aft end causing fire damage to ER casing fwd bulkhead, lashing bridge above and surrounding containers

Figure 26

Damage to containers above and surrounding 700582

Figure 27

Damage to the lashing bridge in the foreground and to ER casing fwd bulkhead behind

Figure 28

Damage to Lashing Bridge

Figure 29

Damage to lashing bridge

Once the containers on top of the 4 hatch covers had been removed it could be seen that there was significant damage to the 2 inner hatch covers. The deformation of some of the large structural members of the hatch covers could easily be seen as could the deformation of the steel plating on top of the hatches.

Figure 30

Bay 70 stbd inner hatch cover being removed in Algeciras

Figure 31

Bay 70 stbd inner hatch cover showing deformation due to heat damage

Figure 32

Heat damage to stbd inner hatch cover

Figure 33

Distortion on top of stbd inner hatch cover

The sounding pipes for the hold bilge sounding were bent, lights and power junction boxes burnt out. There was some deformation to the X deck and to the transverse bulkhead.
Appendix 2 provides a summary of the damage found by KRS.

With the hatch covers removed it was noted that there was some debris lying on top of the upper most tiers of containers. This appeared to be small items and remnants from the contents of some of the fire damaged containers.

In the hold of Bay 70 the upper 2 tiers of containers were found to have suffered the worst of the fire damage.
As the containers were removed it became apparent where the fire had originated from.

The layout in the hold of Bay 70 as previously described consists of containers 2 tiers deep in the midsection (directly above the ECR) i.e. from port to stbd rows 08, 06, 04, 02, 00, 01, 03 and 05.
Then outboard of rows 08 and 05 the hold is 4 tiers deep i.e. rows 10, 12, 14 and 16 on the port side of the vessel and rows 07, 09, 11, 13 and 15 on the stbd side.

The container in position 700222 directly above 700220 when lifted out of position was found to have its base ruptured.

Figure 34

Container loaded directly above 700220 being lifted out loses the remnants of its contents which fall on top of 700220

Figure 35

Contents on top of 700220

It could be seen from what was left of the container in position 700220 (the container sat directly above the ECR void space) that there had been a large explosion or series of explosions, The sides of the container were convex having been blown outwards and as a result the roof was deformed and had collapsed inwards. The doors (at the fwd end of the container) were completely deformed with the stbd side door blown open. The floor of the container was destroyed with only a skeleton of cross members remaining.

Figure 36

Container 700220 viewed whilst still in the hold, showing ceiling collapsed and sides blow out

Figure 37

Container 700220 with debris above removed

The container in position 700420 directly on the port side of 700220 was found distorted. The side adjacent to 700220 was deformed in a concave direction and its outboard side in a convex direction.

Figure 38

Container 700420 showing deformed side adjacent to 700220

Container in position 700020 directly on the stbd side of 700220 was also deformed. The side adjacent to 700220 was deformed in a convex direction and the outboard side having a concave deformation.
It could also be seen IWO one of the fixed steel cell locators welded on the deck that the lower edge of the container had been torn on the guide as the blast force has tried to move the whole container in an outboard direction past the cell locator.

Figure 39

Container 700020 showing deformed side adjacent to 700220

Figure 40

Container 700020 showing deformation on outboard side

Figure 41

Base of container 70020 is torn on the cell locator as it is blasted outwards

It can be concluded that the fire originated in CH 9 from the container in position 700220 i.e. the second container down from the hatch cover and just to the left of the centre line.

3.3 What was the source of the fire in container 700220?

According to the manifest the container in position 700220 contained Calcium Chloride which was loaded in Shanghai on the 12th April 2015.

Calcium chloride is an ionic compound of calcium and chlorine. It is soluble in water and used in several common applications such a brine for refrigerant plants, ice and dust control on roads and in cement.
It is not listed in the IMDG Code and has no special carriage requirements in relation to shipping or stowage onboard a ship.

Although container 700220 was listed on the bill of laden as containing 2046 drums of calcium chloride, the damage to this and the surrounding containers and the violent explosive nature of the fire from the onset indicates that the contents of this container would definitely not have been calcium chloride i.e. the contents of the container had been mis-declared by the shipper in China.

There was a lot of debris found ontop of the containers when the hatch covers were removed also on the bottom of the aft section of the hold. A number of samples were taken by the group of fire experts who were onboard representing the various interested charter parties. 3 of these samples were sent for laboratory analysis to determine their physical characteristics using optical microscopy, Scanning Electron Microscopy (SEM) with Energy Dispersive X-ray analysis (EDX). Further analysis techniques such as X-Ray Diffraction (XRD), Fourier Transform Infa-Red (FTIR) spectroscopy and Ion Chromatography (IC) were used to look for chloride/chlorite and chlorate anions.
The extract below is the conclusion from the report.

The three samples tested by FTIR spectroscopy, appear to be matches for either Calcium Hypochlorite or forms of Calcium Carbonate mineral.
All three samples have the ability to release ppm levels of anions commonly found in bleach products such as chloride and chlorate.
Sample 7 appears to be largely formed from Calcium Hypochlorite, but this appears to be slowly being carbonated by reaction with Carbon Dioxide from the air. The elemental signature identified by EDX is largely composed of calcium, chlorine, oxygen and carbon.
Samples 8 and 9 appear to be largely formed from Calcium Carbonate minerals. This is likely because of the carbonation reaction (see equation 1) having completed to a greater degree with these two samples. These two samples also have much lower chlorine contents, which is consistent with the loss of volatile chlorine products (dichlorine monoxide) to the atmosphere.
Sample 9 also has a crystalline form of calcium carbonate, which is consistent with the calcite form of this mineral.
Certain areas of the samples have taken on a turquoise colouration, which appears to be due to the formation of copper (II) chloride dihydrate within the samples.
The three samples have likely all started out as impure Calcium Hypochlorite material, showing different degrees of being carbonated to Calcium Carbonate minerals.

Mis-declaring the contents of a container has been a long standing problem in the container shipping industry. There have been a number of well documented casualties' on-board vessels where containers with mis-declared contents have been "identified as" or "suspected of" containing calcium hypochlorite and being the source of the fire on-board.

Calcium Hypochlorite is a chemical that is shipped on a regular basis worldwide. It is commonly used in water treatment purification and as a bleaching agent and can be found listed under a variety of different names and of differing levels of strength and grades.
The IMDG Code currently lists a total of 16 entries for these various strengths, grades and mixtures of Calcium Hypochlorite under 6 different UN numbers i.e.

UN 1748, UN 2208, UN2880, UN3485, UN3486 and UN3487.

The later 3 numbers were added to the IMDG Code in 2012 and effectively update the earlier numbers to indicate the fact that not only is the mixture an oxidising substance (class 5.1) and having a subsidiary risk "P" (pollutant) they also carry the subsidiary risk of being a "corrosive substance" (class 8).

Other information common to all these variations of calcium hypochlorite are as follows:

Their stowage and handling requirements necessitate that they are only to be stowed on deck; protected from sources of heat; and cargo transport units shall be shaded from direct sunlight. Packages in cargo transport units shall be stowed so as to allow for adequate air circulation throughout the cargo.

Special provisions code 314 advises that these substances are liable to exothermic decomposition at elevated temperatures. Decomposition can be initiated by heat or by impurities (e.g. powdered metals (iron, manganese, cobalt, magnesium) and their compounds). 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.

The container 700220 was assumed to be a non DG container and therefore unwittingly stowed below deck with no precautions taken to protect it from sources of heat or provide adequate ventilations as would have been provided had the shipper correctly declared the contents.

There is a lot of information issued by various industry bodies and organisations on the dangers associated with mis-declaring calcium hypochlorite.

Class 5.1 - Oxidizing substances
Substances which, while in themselves not necessarily combustible, may, generally by yielding oxygen, cause, or contribute to, the combustion of other material. Such substances may be contained in an article;

Class 8 substances (corrosive substances) means substances which, by chemical action, will cause severe damage when in contact with living tissue or, in the case of leakage, will materially damage, or even destroy, other goods or the means of transport.

In April 2011 The UK P&I Club issued bulletin 759 “Calcium Hypochlorite Frequently Asked Questions – International Group of P&I Clubs” to raise awareness to the wider maritime industry of the hazards and precautions associated with calcium hypochlorite. The bulletin includes the following information:

When involved in a fire the calcium hypochlorite decomposes without burning to release oxygen which will intensify the fire. Also if calcium hypochlorite is mixed organic materials such as sawdust or oil, it can result in a fire of without the need for an external ignition source.

One other important characteristic is that it is unstable and self-reactive. At normally encountered temperatures calcium hypochlorite decomposes only very slowly and releases heat. However at higher temperatures the rate of decomposition increases and if the heat is not able to escape from within the material then its temperature increases and so on. As such the reaction can runaway and result in a violent decomposition of a calcium hypochlorite.

Also

The lowest ambient temperature at which the runaway reaction occurs is the critical ambient temperature (CAT) of the material for the sample size (under test)

Hold temperatures onboard the Hanjin Green Earth were taken locally and recorded once per day. On 30/04/2015 the highest temperature recorded in CH9 port side was 39 °C. Records show CH9 was consistently at a higher temperature than the other holds.
This is because the aft part of the hold is above the machinery space and ECR.
The majority of the aft bulkhead of the deeper fwd part of the hold is adjacent to the machinery space.

Company SMS procedures states in the case where remote hold temperature sensors are fitted then the high level alarm has a set point of 40°C. For vessel without remote temperature measurement it states that the temperature should be measured adjacent to bunker tanks and that the company should be informed if the hold temperature rises to over 45°C. There is no specific instruction on how to ventilate the holds.
C/O stated that the 2 hold supply fans were off with the natural vent flaps open on the hatch sides and the 2 x rectangular screw down vent lids for the hold supply trunkings left open during the voyage. He commented that if the hold temperature rises to 40°C then the ventilation fans would be started.

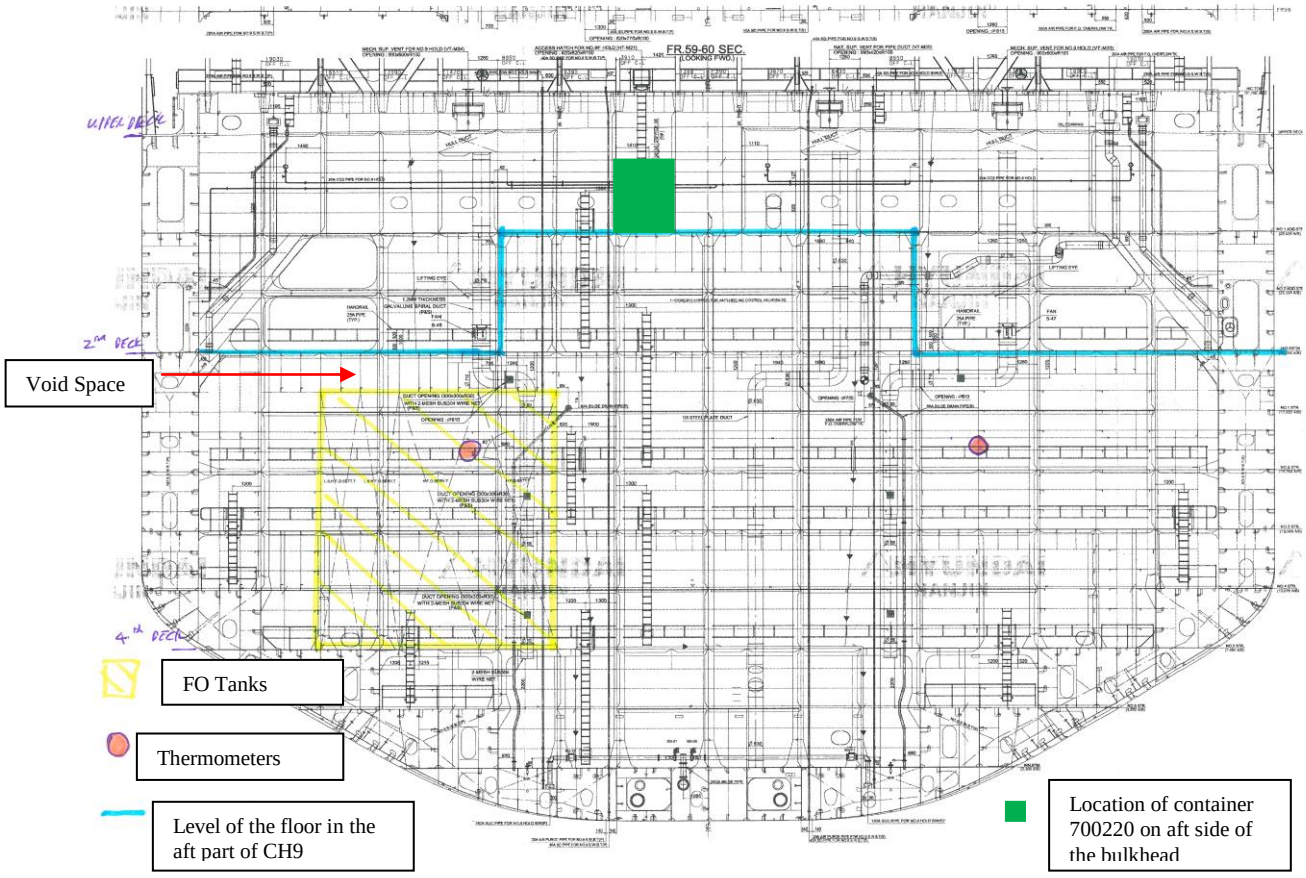
Two hold temperature readings are taken daily by local thermometers placed in the X deck though not positioned directly against the bulkhead. The local thermometer on the port side is located in the area of the X deck adjacent to the fuel oil settling and service tanks on the port side of the mid hold X deck bulkhead (see figure 42).

These tanks run aft under the much shallower port aft area of the hold however there is a void space between top of the tanks and the deckhead dividing the ER and aft part of the hold. The location of these fuel tanks would no doubt contribute to the overall higher temperature of this hold compared to the others onboard.

On the day of the casualty the fuel tank temperatures were shown recorded as
LSHFO Settling Tank > 77°C,
LSHFO Service Tank > 86°C
No 1 HFO Settling Tank > 91°C
No 2 HFO Settling Tank > 89°C
HFO Service Tank > 105°C

HFO has a mandatory min flash point of 60°C though typically the actual flash point of 380cst HFO can vary between 65-90°C. It is common practice to store fuel in the settling tanks approx. 5°C below the flash point. HFO storage tank temperatures would typically be around 95°C. There would have been scope to reduce the fuel tanks temperatures a little, however, these storage temperatures would not be considered excessive.

Figure 42



Section of X deck CH9 (looking fwd) showing the position of the port local thermometer in relation to the fuel oil tanks which are on the aft side of this bulkhead. The aft half of CH9 is relatively shallow, the base of which is at deck 2 level.

The CAT for calcium hypochlorite depends on the size and shape of the package, a smaller package will be able to lose heat to the surroundings easier than a larger package. For a 40kg keg of CH containing 8.5% moisture, UN2880 the CAT is about 55°C whereas for a 200KG drum of the material it is about 44°C. It follows from this

that a container load of 200kg drums will have a CAT lower than 44°C because the drums will thermally interact with each other within the container.
Bearing in mind that the product in the container was mis-declared the quality and packaging of the product could have considerable bearing on the CAT

From the bill of lading it was declared that the gross weight of the 40ft container was 14526kg and it contained 2046 drums in total. Take away the standard weight of an empty container which is listed as between 3620-3770kg and divide by 2046 and we are left with a drum weight of between 5.25 and 5.33kg. The above is based on the assumption that these particular figures on the bill of lading are accurate.
If the above was correct it is unknown how closely the drums were packed.
There would be very little ventilation inside this container or benefit from any natural circulation through the CH 9 supply ventilation ducts and natural ventilation flaps on the outboard hatch cover sides. It is not unrealistic to suspect that the temperature inside this container could have been somewhat higher than the hold temperature recorded which was only logged in the 2 locations once a day.

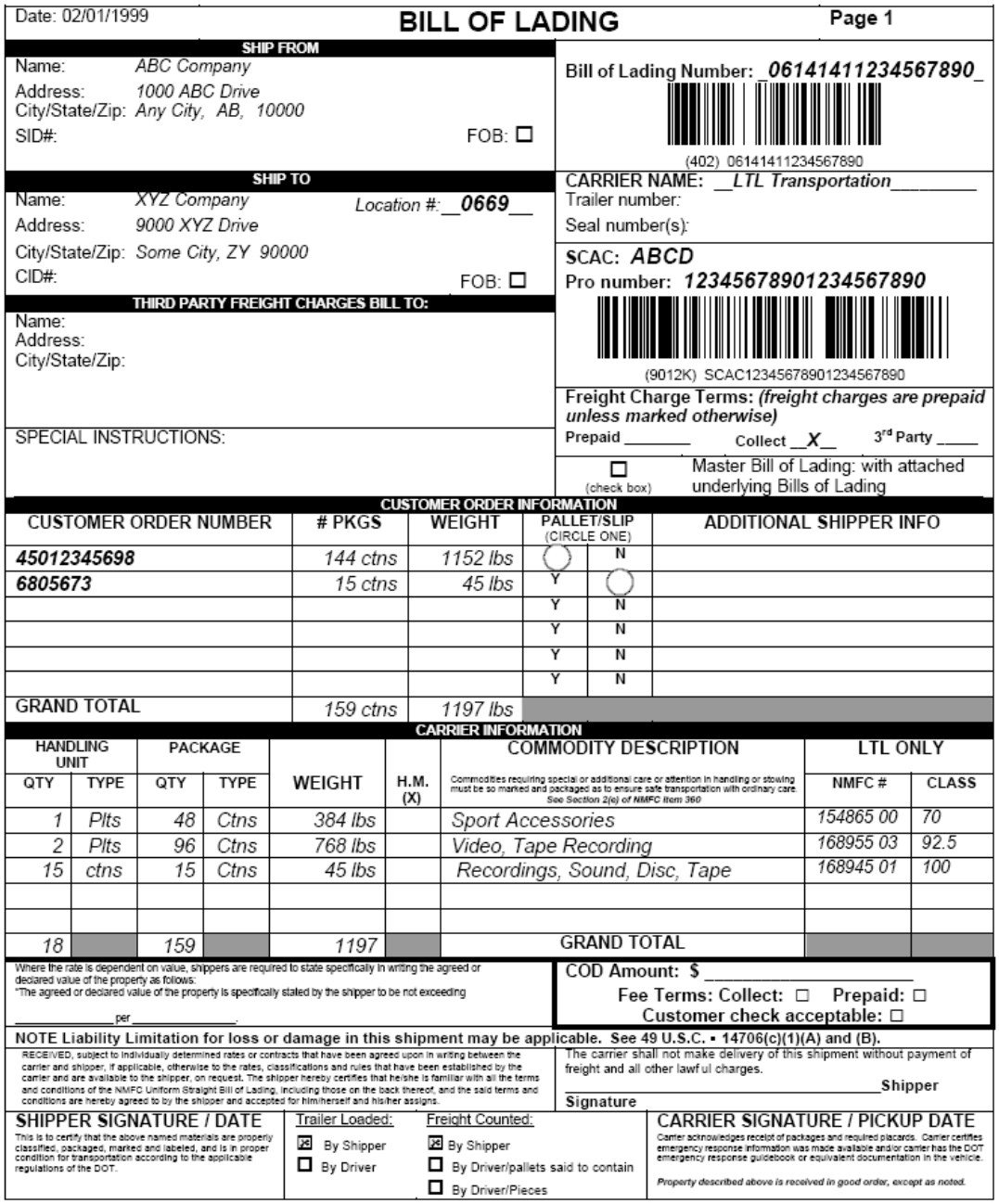
It can be concluded that the fire escalated rapidly from the onset with violent explosions reported which would not be a typical characteristic of a non-combustible substance like calcium chloride which was reported to be in the container in position 700220. Therefore it can also be concluded that the contents of the container were mis-declared.
From the results of the analysis of the 3 samples taken from the cargo hold it can be further concluded that it was likely that this container contained impure calcium hypochlorite and that this was the source of the fire.
The combination of the location of the container below deck in CH 9, the likelihood of poor ventilation within the hold and container, together with the outside ambient air temperature when transiting the Suez Canal would give rise to conditions likely to allow impure calcium hypochlorite to reach its CAT causing a runaway reaction and subsequent fire.

3.4 Why was it not known what was in container 700220

Cargo information is available at different levels of detail depending on which interested party is involved throughout the cargo transportation process. These documents include:

Bills of lading –
Document issued by a ship-owner or carrier to a shipper of goods. It serves as a receipt for the goods, evidence of contract of carriage and document of title. As a receipt, it contains the description and quantity of the goods as well as suitable notations if the goods are not in apparent good condition when received by the ship.

Figure 43



Date: 02/01/1999

BILL OF LADING

Page 1

SHIP FROM

Name: *ABC Company*
Address: *1000 ABC Drive*
City/State/Zip: *Any City, AB, 10000*
SID#:
FOB: ☐

Bill of Lading Number: *_06141411234567890_*

(402) 06141411234567890

SHIP TO

Name: *XYZ Company* Location #: *__0669__*
Address: *9000 XYZ Drive*
City/State/Zip: *Some City, ZY 90000*
CID#:
FOB: ☐

CARRIER NAME: *__LTL Transportation_____*
Trailer number:
Seal number(s):

SCAC: *ABCD*
Pro number: *12345678901234567890*

(9012K) SCAC12345678901234567890

THIRD PARTY FREIGHT CHARGES BILL TO:

Name:
Address:
City/State/Zip:

Freight Charge Terms: *(freight charges are prepaid unless marked otherwise)*
Prepaid _____ Collect *__X__* 3rd Party _____

SPECIAL INSTRUCTIONS:

☐ (check box) Master Bill of Lading: with attached underlying Bills of Lading

CUSTOMER ORDER INFORMATION

CUSTOMER ORDER NUMBER	# PKGS	WEIGHT	PALLET/SLIP (CIRCLE ONE)		ADDITIONAL SHIPPER INFO
45012345698	*144 ctns*	*1152 lbs*	(Y)	N	
6805673	*15 ctns*	*45 lbs*	Y	(N)	
			Y	N	
			Y	N	
			Y	N	
			Y	N	
GRAND TOTAL	*159 ctns*	*1197 lbs*			

CARRIER INFORMATION

HANDLING UNIT QTY	HANDLING UNIT TYPE	PACKAGE QTY	PACKAGE TYPE	WEIGHT	H.M. (X)	COMMODITY DESCRIPTION (Commodities requiring special or additional care or attention in handling or stowing must be so marked and packaged as to ensure safe transportation with ordinary care. See Section 2(e) of NMFC Item 360)	LTL ONLY NMFC #	LTL ONLY CLASS
1	*Plts*	*48*	*Ctns*	*384 lbs*		*Sport Accessories*	*154865 00*	*70*
2	*Plts*	*96*	*Ctns*	*768 lbs*		*Video, Tape Recording*	*168955 03*	*92.5*
15	*ctns*	*15*	*Ctns*	*45 lbs*		*Recordings, Sound, Disc, Tape*	*168945 01*	*100*
18		*159*		*1197*		GRAND TOTAL		

Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property as follows:
"The agreed or declared value of the property is specifically stated by the shipper to be not exceeding
_____ per _____.

COD Amount: $ _____
Fee Terms: Collect: ☐ Prepaid: ☐
Customer check acceptable: ☐

NOTE Liability Limitation for loss or damage in this shipment may be applicable. See 49 U.S.C. • 14706(c)(1)(A) and (B).

RECEIVED, subject to individually determined rates or contracts that have been agreed upon in writing between the carrier and shipper, if applicable, otherwise to the rates, classifications and rules that have been established by the carrier and are available to the shipper, on request. The shipper hereby certifies that he/she is familiar with all the terms and conditions of the NMFC Uniform Straight Bill of Lading, including those on the back thereof, and the said terms and conditions are hereby agreed to by the shipper and accepted for him/herself and his/her assigns.

The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.
_____ Shipper Signature

SHIPPER SIGNATURE / DATE
This is to certify that the above named materials are properly classified, packaged, marked and labeled, and is in proper condition for transportation according to the applicable regulations of the DOT.

Trailer Loaded:
☒ By Shipper
☐ By Driver

Freight Counted:
☒ By Shipper
☐ By Driver/pallets said to contain
☐ By Driver/Pieces

CARRIER SIGNATURE / PICKUP DATE
Carrier acknowledges receipt of packages and required placards. Carrier certifies emergency response information was made available and/or carrier has the DOT emergency response guidebook or equivalent documentation in the vehicle.
Property described above is received in good order, except as noted.

Example of a Bill of Lading

Cargo Manifests

Document containing a full list of a ship's cargo extracted from the bills of lading. The usual details shown are: Box operator, container number, size of container, type of container stowage location, port of loading, port of discharge, DG class & UN number and cargo description.

Dangerous Goods (DG) Manifest

Document required to be available on-board by SOLAS Chapter VII – Regulation 4. This document has greater detail of all dangerous goods. Details contained include: Container number, proper shipping name, DG class & any subsidiary risk(s), UN number, flash point, packing group, if it is a marine pollutant or not, gross weight, EMS (emergency response procedures references), stowage location, emergency contact, if it can be carried in limited quantity or not, port of load and port of

discharge.

Reefer Container Plan/Monitoring Log
Reefer (temperature controlled) container details are provided at each stage of transportation. When on-board a ship this data is recorded as a monitoring log to ensure the cargo remains at the correct temperature for the voyage. The format used on-board the Hanjin Green Earth was as follows:

Figure 44

HANJIN SHIPPING — Monitoring Log

M/V : HANJIN GREEN EARTH — VOY : 0010W — YEAR : 2015

No.	Position	Container No.	POL	POD	Sett. Point			29/04/2015		30/04/2015		01/05/2015		02/05/2015		03/05/2015		04/05/2015		05/05/2015	
					Temp	Vent	Humidity	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM

Stowage/Cargo/Bay Plans

These are provided on-board to the vessels Officers and ashore to the Stevedores. A central Planner creates the plan, which is then checked by the vessel before the final plan is agreed. The name of the plan varies based on which information is being displayed. For example a 'Special Cargo Stowage plan' displays any special (none standard cargo) container positions as an overview of all bays. A bay plan shows a layout of each bay (above and below deck) and usually includes: the container number, the port of load & discharge, DG class, UN number, reefer temperature, operator code and the containers weight.

From the above documents only the Stowage/Cargo/Bay Plans, DG manifest and reefer container monitoring log were provided to staff on-board as per standard practice. As container 700220 was mis-declared as Calcium Chloride (a non DG cargo) it was not included in the DG manifest and the contents were unknown to anyone on-board the vessel.

In the event of a manifest being required for more information on the contents of the standard containers onboard a Hanjin vessel, Hanjin would have this available for its own containers (but not supplied to the vessel) but for the other standard containers being shipped on its vessel, would usually need to request this information from the respective Box Operators.

Should the ship's staff need to know what is in a standard container they would have to be provided with a copy of the manifest which will identify what the shipper has declared the contents of the container to be on the bill of lading. Effectively the carrier and Box Operators are relying on the honesty of the shipper when providing information on the contents of the container. The crew on-board the ship will have no idea as to what is in the majority of containers loaded on-board.

The Deck Officers interviewed during the investigation had a good understanding of the cargo procedures and Company SMS instructions. The C/O's checks were summarised as follows:

- Check the Planner's plan
- Input tank data (this gives stability data)

- Tank Level Sensors (which are calibrated every 3 months & verified through soundings) will automatically update the tank information (for any tanks used in the stability program).
- Special cargos are automatically checked to ensure locations are correct for the particular cargoes and an error report is automatically generated to highlight any that are not.
- Due to importance and high risk DG segregation is manually checked against tables after an auto check is carried out.
- Lashing forces are checked and coloured red where there are any errors.

Cargo operations consisted of 3 man watches. This was stated as giving many difficulties in conducting these checks and usually only the Special cargo was being checked. Standard cargo can often have errors in positions. Several errors were noted in container positions during the discharge of CH 9 in Algeciras.

There are no checks or procedures in place on-board that would have uncovered the mis-declared cargo and hence prevented the fire and with the quantity of containers carried on-board these vessels it is unreasonable to expect that this could be prevented by those on-board.

3.41 What is being done in the mitigation of mis-declared cargo issues ?

There is no simple or quick fix for this problem. The checking of all containers would be both extremely time consuming and costly. This in itself could be open to abuse.

The industry is acutely aware of the problems of mis-declared containers with initiatives such as the Cargo Incident Notification System (CINS) which was originally set up by 5 of the largest container lines and now has 17 shipping line members. There are also 3 advisory members (International group of P&I clubs, TT Club Mutual Insurance Ltd and Exis Technologies) plus 2 honorary members (Container Owners Association (COA) and the World Nuclear Transport Institute who share information on all cargo related incidents on an online database which highlight risks posed by certain cargoes. The reports are also analysed in order to try and provide an early warning of worrying trends, whether relating to cargoes that display dangerous characteristics or unsafe practices in the container supply chain.

The CINS website states their objectives as follows:

To highlight risks posed by certain cargoes and/or packing failures in order to improve safety in the liner shipping industry, by:

- *Capturing and analysing information within the CINS database.*
- *Looking for specific incidents which may require immediate action or assessing incident trends.*

Once areas of concern become apparent they can be addressed to relevant authorities to formulate appropriate recommendations or advice, such as amendments to the IMDG Code. This may include advice on training issues on the packing and securing of cargo in containers.

For any clear pattern emerging that could require regulatory intervention, the lines will now have the hard facts to support their claims and no longer have to rely on anecdotal evidence when presenting their case.

The CINS and the International Group of P & I Groups have joined forces to produce a new set of guidelines for the carriage of calcium hypochlorite entitled "Guidelines for the Carriage of Calcium Hypochlorite in Containers" which effectively replaces and updates the earlier 2011 Bulletin 759 (referenced earlier in the report).
These new guidelines give further advice on selected provisions of the IMDG Code and also include science based information produced in 1999 by consulting scientists J H Burgoyne and Partners who were advising the International Group of P & I Clubs. These guidelines will no doubt help improve the safe carriage of calcium hypochlorite on-board container ships as they will be adopted by the vast majority of responsible shippers who already properly declare shipments of this product.

What this guidance and any other such guidance issued with the aim of improving the safety of carriage of the product won't do is to discourage the irresponsible shipper who knowingly mis-declares calcium hypochlorite in order to save on shipping costs.

In light of the above, where money is the motivating factor for the shipper to mis-declare calcium hypochlorite, there is some logic in the thought that if the carrier were to absorb the higher cost of shipment of this product (and certain other dangerous goods) reducing it to the same cost as that of a standard container, then the incentive to mis-declare is eliminated. This may be one of the best options to reduce the incidence of mi-declaration of such products.

A number of high profile carriers have now decided that they will no longer ship calcium hypochlorite. This may well eliminate the risk from legitimately declared containers of calcium hypochlorite, however, it is unlikely to have any effect on those who chose to knowingly mis-declare this product. Additionally should the availability of being able to ship calcium hypochlorite legitimately as a DG be reduced to a point where a shipper finds it hard to find a carrier, then there is a risk that they might mis-declare such a product for the sake of convenience and in doing so increase the risk to the carrier of carrying mis-declared containers.

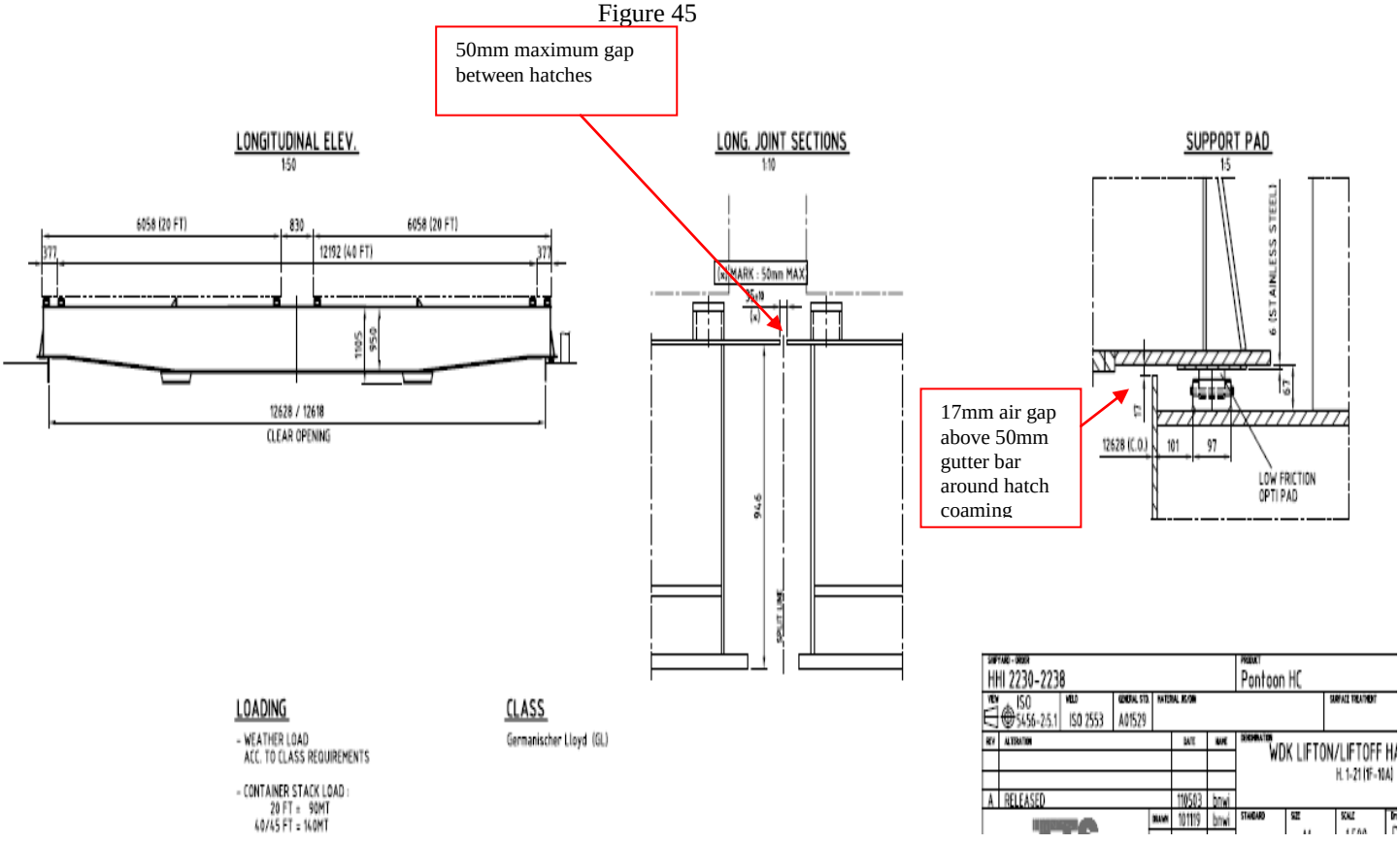
It can be concluded that it was not known what was inside container 700220 because long established practices in the container industry do not require checking of individual containers. As previously stated, to do so would be extremely costly and time consuming. Whilst systems are in place to try and identify mis-declared containers, mis-declaration of a container is a relatively simple for a dishonest shipper wishing to save on higher transportation cost of shipping as a DG container as happened in this instance onboard the Hanjin Green Earth.
As a result the mis-declaration by the shipper, the safety of ship's crew and their vessel were put at serious risk.

3.5 Why did the Fixed CO_2 not extinguish the fire?

The design of modern very large container vessels allows for longitudinal air gaps between the individual hatch covers and between the bottom of the hatch covers and the hatch coaming as provided for in MSC/Circ.1087 “Guidelines for Partially Weathertight Hatchway Covers on Board Container Ships”.
This longitudinal gap running between each hatch cover can have a max width of 50mm with the longitudinal length of each hatch in this case being 12.95m
There is also a 17mm air gap between the bottom of the hatch covers and hatch coaming as no rubbers are fitted on this design of vessel with the hatch resting on bearing pads.

In consequence this inability to seal the hatch covers would seem contrary to what would normally be expected to be found on a more conventional vessel. Typically once all vents and dampers have been closed it would be assumed that the space would be relatively air tight in order to prevent air entering the space and CO_2 from escaping from it once released. As indicated above this is not the case on Hanjin Green Earth.

Figure 45



WDK lift on/lift off hatch cover

Figure 46

Longitudinal gaps between hatch covers. Gutter bars shown are for preventing water entering between the gaps in the hatch covers so it instead runs fwd or aft and off the hatch covers

To combat the issue of the designed air gaps, MSC/Circ.1087 also provides guidelines for increasing the quantity of CO_2 required to flood a hold based on a calculation involving the total maximum area of clear air gaps. For a conventional hold of the size of CH9, 256 x 45kg CO_2 bottles would be required. The additional capacity provided to mitigate for the air gaps equates to an extra 50 x 45kg CO_2 bottles giving an increase in capacity of 19.5%

The number of bottles indicated on the instruction chart in the CO_2 room required for the "initial discharge" is calculated to provide the required minimum volume of free gas equal to 30% of the gross volume of a hold (taking into account leakage in this case) i.e. enough CO_2 for the initial release to be sufficient to put out the fire within the hold.

Second and third discharges are reserved for failure of the first batch to extinguish the fire or possible re-ignition in the hold.

The Fixed CO_2 System instruction manual recommends in the event of a fire in a cargo hold to try and seal all air gaps to prevent excess leakage of CO_2. There were no dedicated materials provided for trying to seal the open air gaps, however, it is acknowledged that due to the heat and smoke even if this material had been provided, trying to do this would have been quite impractical under the prevailing circumstances.

In accordance with the instruction chart for CO_2 fire extinguishing in the CO_2 room, 102 bottles of CO_2 are required to deal with a fire in CH 9 with a loaded condition of between 76-100%.
In CH 9 there are a total of 8 CO_2 nozzles, 2 in the fwd bulkhead, 2 in the after bulkhead and 4 in the X deck bulkhead delivering gas into the aft part of the hold. One of the nozzles in the X deck is situated along the centreline of row 02 and it sits vertically between cell positions 700222 and 700220 so the nozzle was very close to the container in position 700220.

During the inspection of CH9 following the fire it was noticed that there was a blank flange hanging from the very end of the CO_2 piping in way of the outer CO_2 nozzle on the stbd side of the X deck bulkhead (along the centreline of row 13). This blank flange should normally be bolted tight against the open flange of the CO_2 pipework. It would only be removed for maintenance purposes when the CO_2 lines are blown through with air.
This solid blank flange was found bolted to the flange of the CO_2 pipework with one nut and bolt and was also resting on a single bolt that was in one of the lower holes in CO_2 pipework flange (see figures 47 and 48), effectively resulting in an open end to the pipework.
Below the flange, lying on the transverse bulkhead (Fr.59) stiffener, were the other two nuts and bolts and a single nut all from the above flange.
There was a lot of black debris from the fire lying on the stiffener. It can be seen from figure 50, that when moving one of the bolts there was clear paintwork below the bolt. This would indicate that these had been in this position at the time the fire occurred. This meant that any CO_2 in the line was free to escape out of this open flange rather than be dispersed through the CO_2 nozzle located nearby at the end of this line.

The consequences of this open flange were put to fire experts at Class KR for their expert opinion. It was calculated that about 20% of the CO_2 would have leaked through this open flange rather than being distributed though the CO_2 nozzles. Even though there was a pressure drop in the discharge line it would not have had a great impact on the fire extinguishing performance. Ultimately all of the CO_2 from the initial discharge still ended up in CH9. Also the subsequent release of all other CO_2 bottles would have been more than adequate in provided enough CO_2 for the hold.

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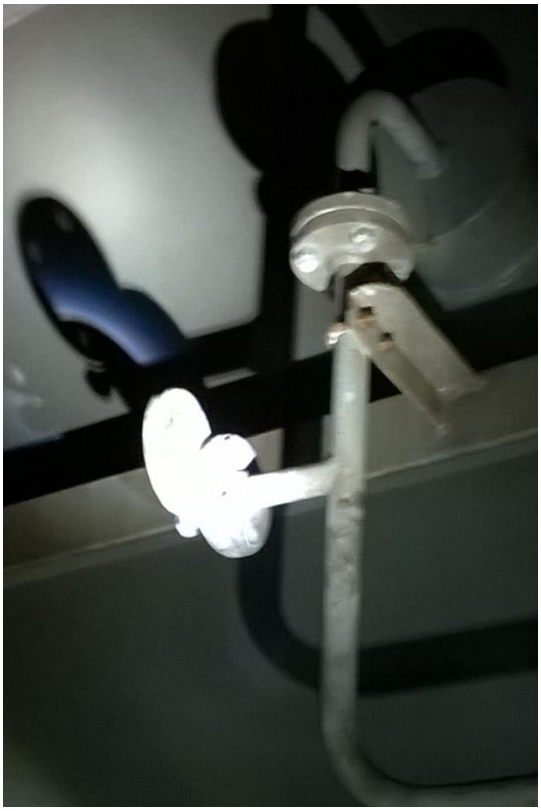
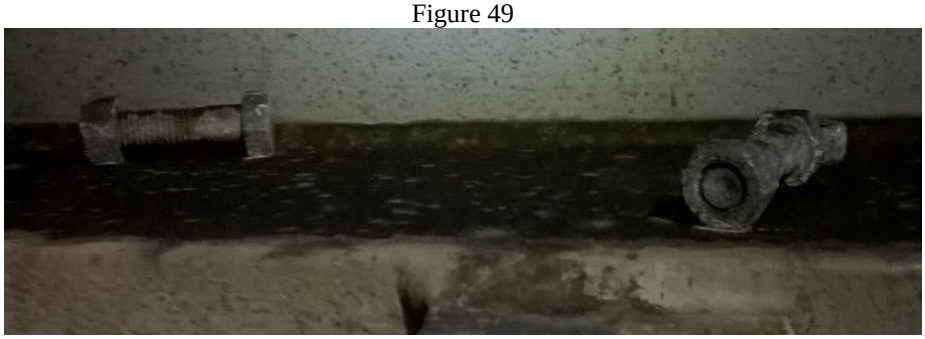
Figure 47 Figure 48



Open ended flange

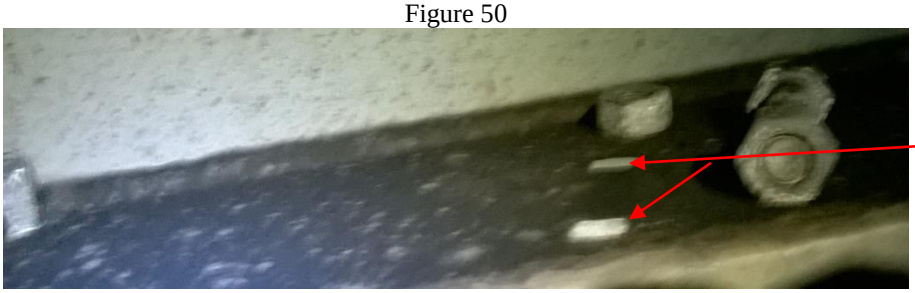
Open ended flange alternate view

Figure 49



Missing nuts and bolts on framing below

Figure 50



Nut and bolt moved to the right of original position revealing 2 areas of clean paintwork where it contacted the framing.

The fire originated from a container in position 700220 that was at the bottom of a 2 tier stack just below the hatch cover. According to the firefighting teams, flames could be seen between the top of the hatch cover and the bottom of the containers sitting on the hatch covers. This was before the fixed CO_2 injection was commenced indicating that there was significant heat being given off by the fire below and that it was burning with great intensity.
The deck log book states "Operated Initial Fixed CO_2" at 0215hrs some 13 minutes after the fire had started. As discussed previously, the time for the first batch of CO_2 to be injected appeared to take considerably longer than the time to release all the remaining CO_2 bottles which may indicate that the actual release of the first batch of CO_2 cylinders started a little later after the time noted in the deck log book. Any delay in release of the CO_2 will allow the fire to intensify and spread which will as a result reduce the effectiveness of the CO_2 once released.
Recent amendments to the FSS Code Chapter 5.2.2.1.7 as a result of the adoption of Res. MSC339(91) require that "*at least two thirds of the required CO_2 gas is able to be discharged into the cargo hold space within 10 mins*" entered into force on 1 July 2014. However, this requirement was not applicable to this vessel which had an earlier keel laying date. It is, however, an improvement in the performance requirements of the fixed extinguishing system.

There was noted to be substantial deformation of the 2 x inner hatch covers in bay 70 due to the heat which had the effect of opening up the air gaps and therefore further reducing the ability to seal the hold.
In addition to the above, even though the crew shut the natural ventilation on the sides of the outer hatches, it could not be ascertained or concluded that the 2 large rectangular screw down ventilation lids on the X deck for the hold supply trunking had been fully shut by the crew and therefore could have resulted in further reducing the ability to seal the hold.

There were therefore a number of factors that could have adversely affected the performance of the CO_2 system:-

The effectiveness of the CO_2 nozzles was reduced due to the end of the CO_2 line IWO the X deck being left open.

That the sealing of the hold was inadequate due to a combination of the ventilation dampers not being closed and the increased gaps around the hatch covers due to heat distortion. This allowed for more of the CO_2 to escape that calculated design losses and provided a source of air for the fire to continue burning.

The time taken to isolate the hold and prepare for CO_2 release was acceptable.
The time taken for the release of the first batch of CO_2 could have been quicker

The release of all 423 CO_2 bottles in the CO_2 room had no noticeable effect on the fire.

Notwithstanding all of the above findings in this section even if the CO_2 release and sealing of the hold had been carried out in a textbook manner **it can be concluded that** it would have made little difference. As previously discussed above in 3.3, if the

contents of the contained were calcium hypochlorite, or a similar substance that can under certain circumstances directly or indirectly evolve oxygen, CO_2 would be an ineffective firefighting medium. In the case of a calcium hypochlorite, water is the recommended extinguishing medium and there was no requirement for a dedicated water drenching system to be fitted in the holds of this particular vessel.
For water to be effective for such a cargo, modifications would need to be made to containers intended to carry this cargo to allow for direct water injection.

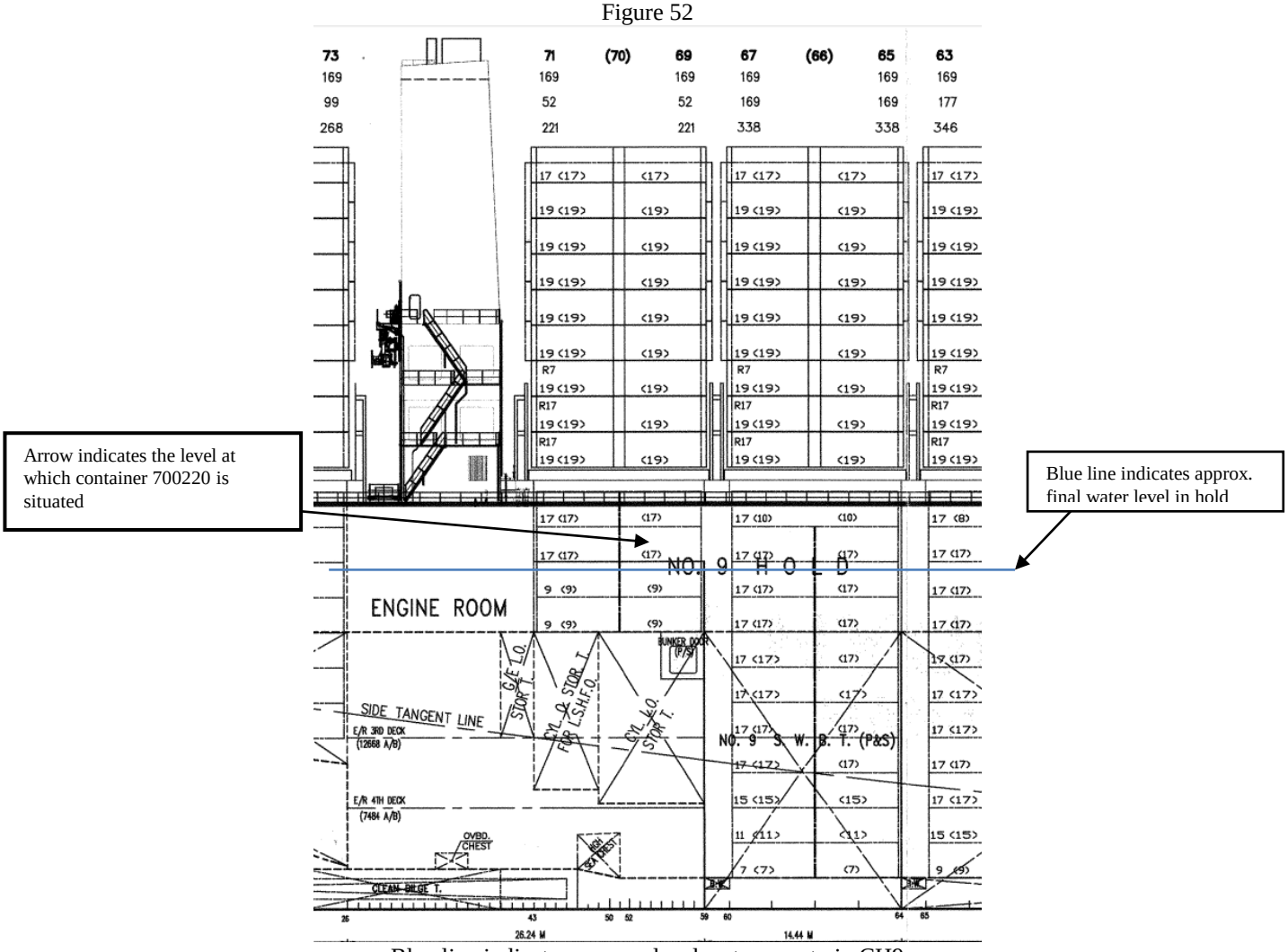
3.6 Why was there so much water in the hold?

Just prior to the opening of the watertight hatch in the deck 2 underdeck passageway at approx. 06:30hrs on 02/05/2015 the height of the water in CH 9 was estimated to be approx. 22.6 m above the inner bottom. As the hold sounding pipes were situated on top of the X deck and could not be accessed due to the fire, the water level could not be accurately monitored as events progressed. It was known that the level had passed the top of the above mentioned watertight hatch following the last entry for inspection of this hatch on the evening of 01/02/2015 and by subsequent observation when trying to drain the water through the hatch.
Following the lowering of the water level in the cargo hold as a result of flooding the deck 2 underdeck passageway, a tide mark was left as can be seen in figure 51. It is estimated that the level of this tide mark was approx. 4.5 m above the bottom of the lower aft section of the CH 9 which equates to approx.22.6 m above the inner bottom of the fwd part of CH 9.

Figure 51

Tide mark clearly seen above ladder on deck 2.

Figure 52



Blue line indicates approx. level water rose to in CH9

The water in the hold was a result of the firefighting water used to fight the fire on deck which entered the hold through the longitudinal gaps in the hatch covers and gaps between the hatch coaming and the bottom of the hatch covers. As it could not be ascertained if the rectangular screw down lids for the 2 hold supply trunkings were fully shut it is also possible that some water flooded into the hold via his route.
It would seem odd that such a large volume of water could enter the hold via the hatch covers as it may be assumed that a hatch cover should be weathertight. However, as discussed in 3.5 above MSC/Circ.1087 allows longitudinal gaps between individual hatch covers and also between the bottom of the hatch covers and the top of the hatch coamings.
In order to reduce to a minimum the quantity of water penetrating the hold via the longitudinal gaps between the hatch covers, each hatch cover has a min 65mm gutter bar IWO of its longitudinal upper edge which will allow the water to run fwd or aft off the hatch cover and onto the transversal hatch coaming(see figure 46). In turn the longitudinal and transversal hatch coaming has a 50mm high gutter bar surrounding it IWO the hatch surround to prevent water running into the hold(see figure 45). These gutter bars are designed to deal with the normal quantities of water to be expected on deck during a voyage.

With the volume of water that was being jetted at the fire from the monitors of the various FiFi tugs there would be some water entering the longitudinal gaps in the hatch covers directly. Additionally the volume of water coming down onto the hatch covers and X deck areas was much greater than they were designed to deal with. As a result some of the water on the hatch covers would have overcome the height of the gutter bars and discharged down between the longitudinal gaps running the full length of the hatch cover.
The water running off the hatch covers onto the X deck together with the water landing directly on the X deck resulted in a volume of water that would overcome the height of the gutter bars on the hatch coaming and pass through the small air gap and into the hold leading to further ingress into the hold.

As previously mentioned it could not be ascertained as to whether the rectangular screw down lids for the 2 x supply fan ventilation trunkings had been fully shut. On the top of the X deck there are large grids on the deck (figure 53) to allow air to be drawn into the ventilation trunkings that sit directly below the X deck. If the above was the case then the firefighting water could have poured down into these spaces. Normal drainage for these spaces is through small drainage holes in the corners as shown in figure 55. Larger quantities of water as could have been experienced would rise up until level with the larger lightening holes then travel outboard. Both spaces would eventually drain out onto the main deck walkway via 2 elliptical holes at the end of the spaces on both port and stbd sides (fig 56-57). These elliptical drainage holes would only normally have to deal with rainwater run-off. Due to the amounts of water entering the space it is likely that these 2 elliptical holes would not be large enough to disperse the quantities of water entering these spaces, thus the level inside the space would continue to rise. Once the level reached 760mm i.e. the top of the ventilation trunking opening (if the cover was not fully screwed down) then the water could run down the trunking and into the hold.

Figure 53

One of the grids flush in X deck walkway leading to X deck supply fan inlet trunking situated directly below the X deck.

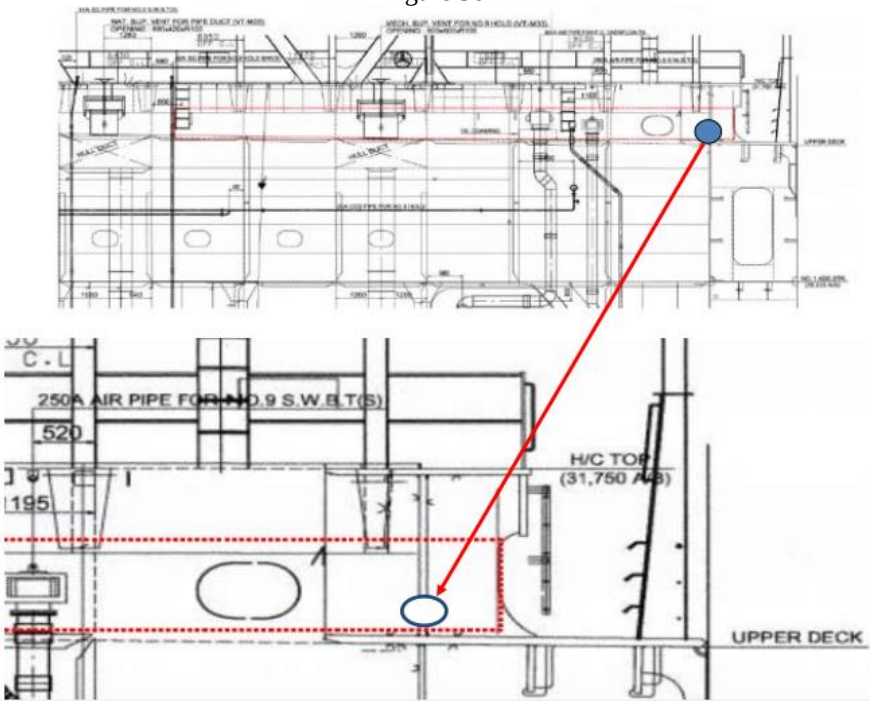
Figure 54

Supply fan ventilation trunking inlet

Figure 55

Space directly below X deck where vent trunking inlets are situated showing small drainage cut-outs on floor for normal drainage of this space (upper deck).

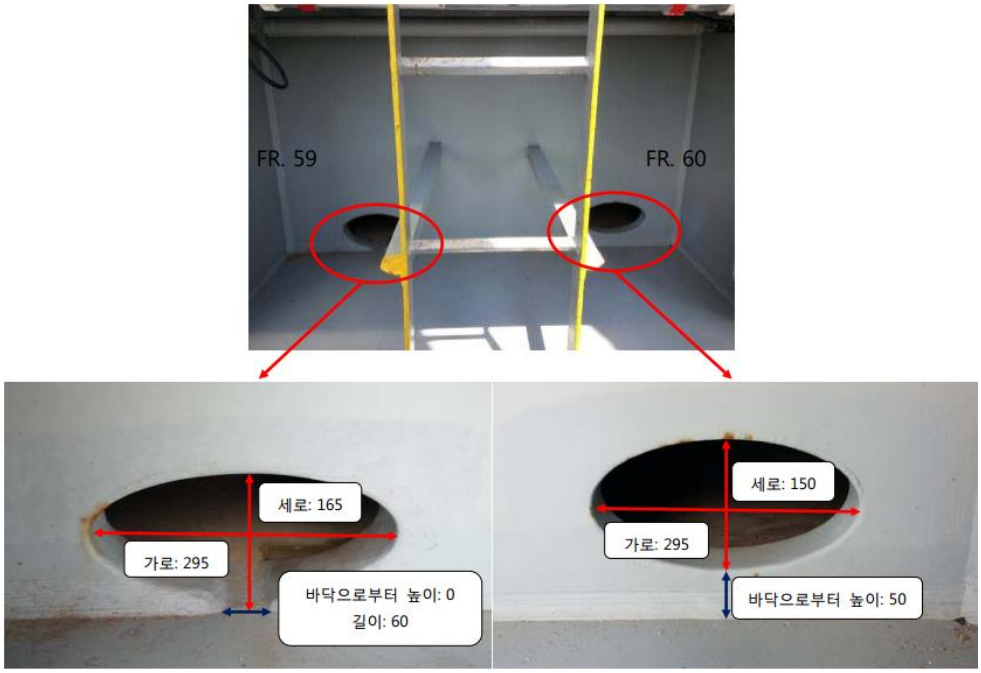
Figure 56



Section showing location of drain holes to open deck

Figure 57

B. DRAIN HOLE 사진



Further detail of the four drain holes are at upper deck (port side two holes and starboard side two holes).Length and width of oval: 165mm x 295mm (two holes), 150mm x 295mm (two holes, height is 50mm).

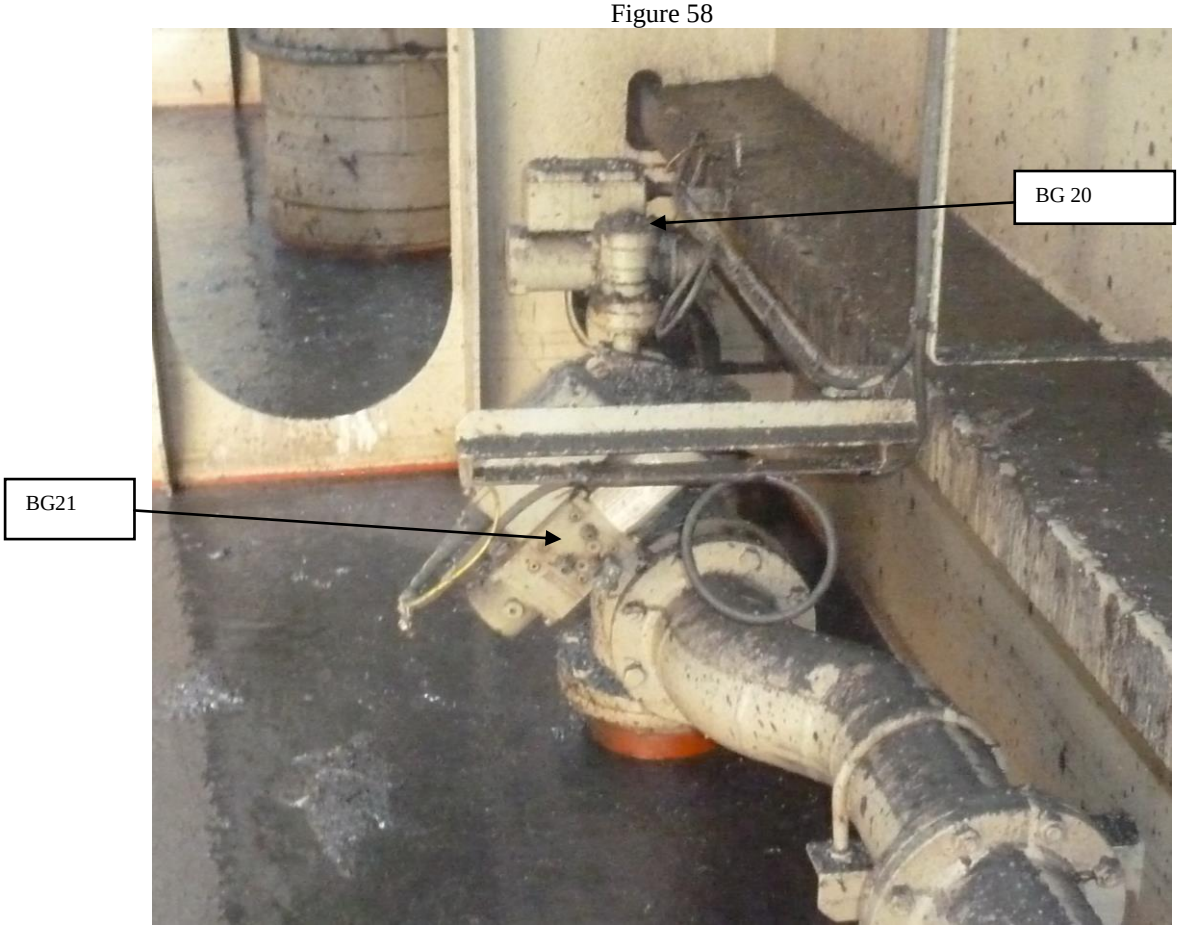
In order to put large quantities of water in the hold i.e. by deliberately flooding using fire hoses the best options would be either:
Directing fire hose water through the gaps between the hatches,
Directing fire hose water through the hatch cover natural ventilation flaps,

Directing fire hose water through the above mention supply ventilation trunking lids located directly below the X deck.

The ERC had initially considered as an option partial flooding of the hold, however said that they decided against using this option following discussion with the vessel. As the fire in the hold was predominantly in the upper part of the aft section of the hold so partial flooding at this time would only have submerged containers in the deeper fwd part of the hold and not have reached any of the containers that were on fire in the much higher after part of CH 9.

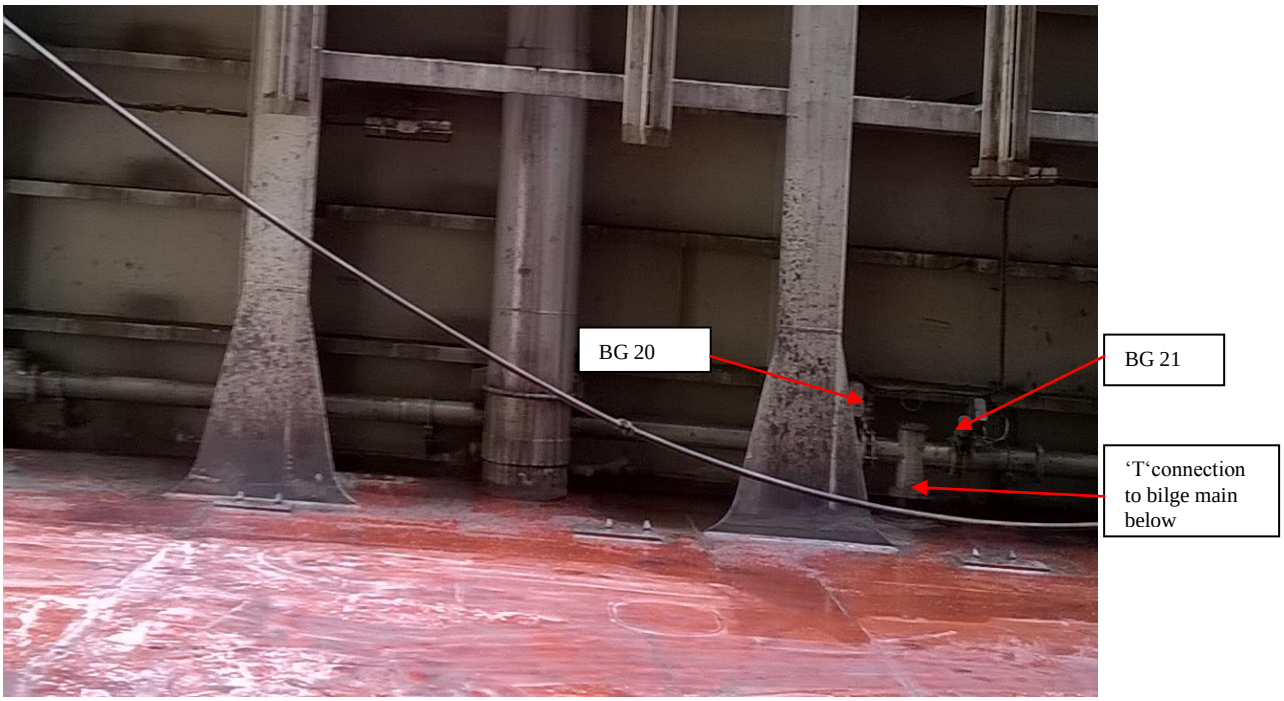
The bilge pumping arrangements installed in CH 9 consist of 2 bilge suction lines to bilge wells on the port and stbd sides of the fwd hold IWO of the bottom of the X deck.
Each suction line is 150mm diameter and has an electro hydraulic actuator with all hydraulics contained within the actuator housed ontop of the butterfly valve. There is also an in-line non-return valve fitted between the actuating valve and the end of the suction line.
The suction lines are connected to the 350mm diameter bilge main line that passes into the ER (figure 58-59).
In the ER there are 2 x Bilge, Fire and GS pumps rated at 530/90M³/H x 30/100 MTH. Either of these pumps suction lines can be lined up with the hold bilge main line to be used individually or both together if desired.
In their use as bilge pumps they would each have the higher rating of 530M³/H so they would have no trouble dealing with any leakage.
At 17:l7hrs on 01/05/2015 the ship's crew attempted to start pumping out the contents of CH 9 following instructions from the ERC that there was a need to reduce the water level. The crew were unable to pump out the hold as it was discovered that each actuator was not working on the respective 2 suction valves.
The IP rating for the actuators is IP68 which according to the manufacturer will provide protection for submersion in water to a depth of 3 bars for 24 hours. 3 bars equated to a depth of water of 30.6m.The Company stated that they found that on inspection in Algeciras the actuators had suffered from the combined effects of the fire and then flooding.
On inspection of this lower part of the fwd hold after the fire there did not seem to be a great deal of damage from smoke or heat, the electrical cabling to the actuators was still in good condition so it is more likely that the submergence under the contaminated firefighting water caused the failure of the actuators.

Figure 58



Shows stbd bilge valve and actuator BG21 in the foreground and port bilge valve actuator BG20 can be seen in the background. Both lead into bilge main below via T connection (orange pipe).

Figure 59



Port and stbd bilge lines arrangement dropping down to bilge main in duct keel below tank top.

If the bilge pumping system in CH 9 had been effective it would have allowed the hold to be pumped out and ensured the vessels' longitudinal strength and stability were not put at risk. The concern with the amount of fire extinguishing water being used on the fire by the FiFi tugs would also have been unnecessary.
In such scenarios it is critical that these valves and actuators and cabling remain operable and intact so the option to pump out the hold is always available.

However, the fact that there was such a large amount of water in the hold could be seen as beneficial from the fire fighting point of view in that it protected the majority of containers in the hold from the effects of the fire.

It can be concluded that the water was able to enter the hold as the hold and hatch arrangements were, by design not as weathertight as would be found on a more conventional cargo ship.
The amount of water being targeted at the fire by multiple FiFi tugs meant that there was far more water than the gutter bars were designed to cope with so down flooding into the hold occurred. Open ventilation trunking for the CH supply fans may also have contributed to the flooding.
The failure of the bilge suction valve actuators prevented any of the water being pumped out of the hold thus the level continued to rise as the firefighting operation continued.

3.7 What were the effects of the firefighting water in the hold on the vessel's structure?

The water level in CH 9 reached a level of approx. 22.6 m above the inner bottom prior to the water tight door being opened. This caused some deformity to structural members of the aft bulkhead of No.8 Cargo hold namely:-
- Both side end of No.2 Stringer plate
- Brackets and vertical girder on No.4 stringer
- Both side Vertical girder on inner bottom

Figures 60 and 61 show some of the damage to the structure

Figure 60

Brackets on stringer deformed

Figure 61

Deformation on vertical girder

Class KR were consulted for their expert opinion on the effects of this level of water in the hold and reported the following:-

Considering water level up to 22.6m (from inner bottom) in No.9 Cargo Hold, longitudinal strength & stability is in satisfactory.
And based on review of procedure for the water over-flowed transfer method from No.9 Cargo Hold to Water Ballast tank through passage way, it was revealed that the heeling angle is 5 degree in stbd side and longitudinal strength & stability is in satisfactory.

This would be as in the earlier technical report produced for the owners by KR based on the fact that the vessel is stopped in the water in order to prevent dynamic load of the sea water.

Considering that this max water level is only 2 containers short of reaching the top of the hold it would be of interest to find out how much extra strength would need to be included in the design of a typical container vessel of this size to safely allow total flooding of a hold with the ability to allow continuation of passage at reduced speed. Total hold flooding could then be an available firefighting option should a similar serious fire occur on a vessel of this type.

Concluding the water level in CH 9 rose to approx. 22.6m from the inner bottom where it had started to cause minor structural damage to the fwd bulkhead adjacent to CH8 however the longitudinal strength and stability still remained acceptable considering the emergency condition the vessel was in.

3.8 Actions in dealing with the water in the Cargo Hold no 9

After the release of all the CO_2 and prior to anchoring the Company ERC were considering a number of options in light of the developing fire. One of these options was partial flooding of the hold with SW using fire hoses. However the ERC reported that they decided against this option after considering its merits and discussing the possibility with the vessel.

At 12:20hrs on 01/05/2015 the vessel was trimmed by the stern due to the flooded water in CH 9 and it was calculated following a simulation report that there was 1100 metric tonnes of SW in the hold.

At 16:22hrs the ERC received an emergency response service and simulation report from KRS. This report was originally requested at 06:01hrs by one of the ERC team members in respect of assessing the vessel's stability and longitudinal strength in its condition at that time and the options regarding possible flooding of CH 9.
The report indicated that following some ballasting operations it would be possible to flood CH 9 with 6473 m^3 of SW and to a height of 15m from the inner bottom without permanent deformation to the hold boundary structure based on the vessel being stopped in the water to reduce the effects of dynamic loading of SW. The report advised that the condition of the dividing ER bulkhead and CH 9 forward bulkhead should be monitored consistently during the filling operation. If any deformation was

observed then water should be discharged from the hold immediately. The report also stated that once the fire was extinguished the water should be discharged from the hold as soon as possible and that still water bending moment and shear force should remain within assigned values given on the report under any circumstances.

Following receipt of this report the ERC was of the opinion that there was a need to start discharging the firefighitng water in CH 9. It is not clear if at that time if they had information indicating the level of water in the hold or if the still water bending moment was approaching its limit.

At 17:00hrs the ERC contacted the SMIT Salvage Master (who was not yet on the vessel to see if he was agreeable to the pumping out of the contaminated fire water in CH 9 for the vessels condition and safety. The ERC log states he was in agreement.

At 17:20hrs the ship staff operated the CH 9 bilge valves and it was discovered that the water could not be pumped out as the valve actuators were not working

Just after 18:45hrs ship's crew entered the hold via the stbd underdeck passageway WT door on deck 2 (figure 62) and the water level was found to be level with the floor of deck 2. This level is 18.14 m above the inner bottom and 20.55 m above the base line[1]

20:00hrs Hanjin ERC report states - request ship to open the WT door in 2nd deck passageway to CH 9 due to the increased level of water in the hold.

20:35hrs DLB reports that the water level was checked again. The C/O reported that the water level in the hold is now just below the bottom of the WT hatch.

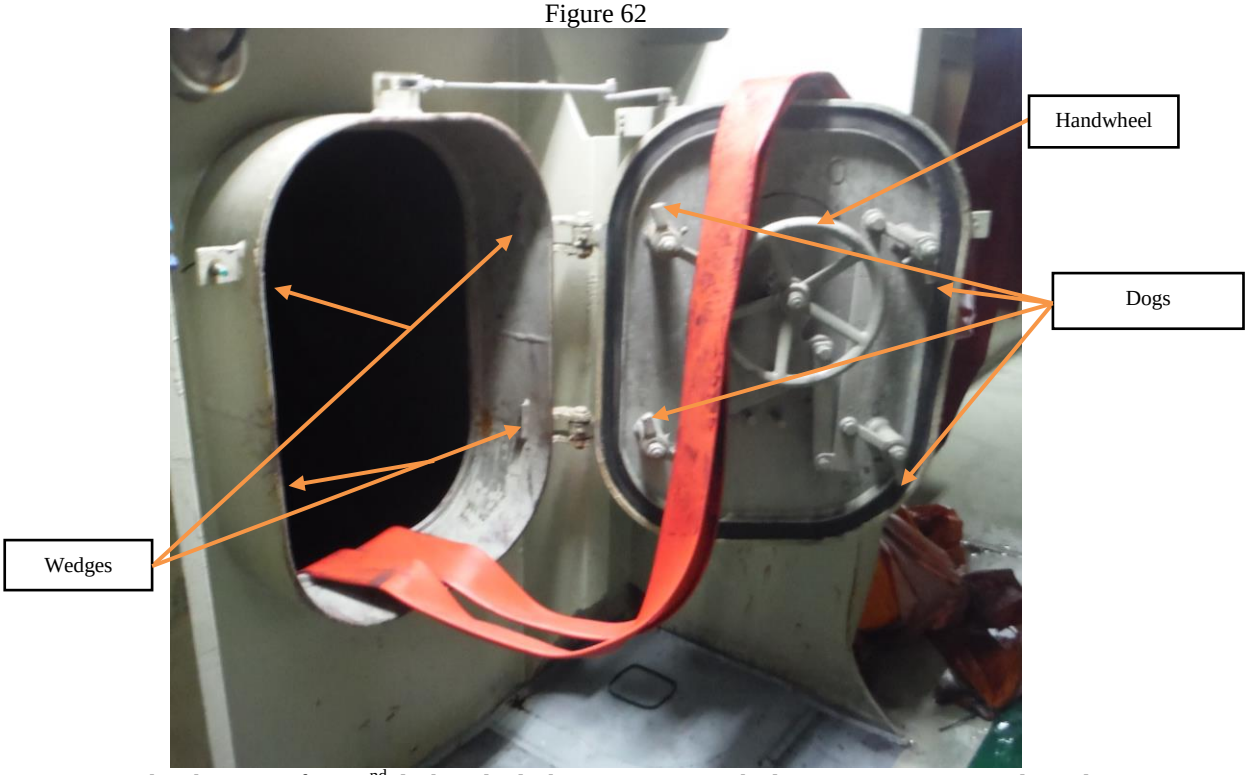
In the time between the last inspection inside CH 9 through the WT hatch (20:35hrs) and time taken by the crew to prepare for the draining operation, (which would include removal of ballast tank covers in the underdeck passageway (figure 63), preparing a portable air driven salvage pump and rigging a tarpaulin at the bottom of the WT hatch to direct any leakage into the closest ballast tank), the water level rose past the bottom of the WT hatch.
Therefore when the draining operation commenced and the hand-wheel was slowly cracked open, water started leaking around the lower part of the WT hatch thus they were unable to fully open it, being uncertain of how much water would enter the passageway.
It is estimated that the initial opening of the WT hatch would have been sometime late in the evening of 01/05/2015 based on witness statements, and on the level of water leakage reported around the hatch door.
The record keeping in the DLB was poor in that it made no mention of flooding, the attempt to lower the level of water in the hold or the subsequent flooding so no details or times were thus available.

[1] *A horizontal and longitudinal datum (reference) line, usually taken at the inner surface of the keel plating, to which all vertical measurements are referred. [Alt. moulded baseline.]*

The VDR recordings were unclear due to a continuous alarm sounding in the background. This made the recording difficult to understand, however, at around 06:30hrs on 02/05/2016 there was snippets of very heated conversations heard over a few minutes including ref to a list to stbd. This together with similar estimations of the time given by witnesses provides the best indication of what time the flooding of the underdeck passageway occurred.

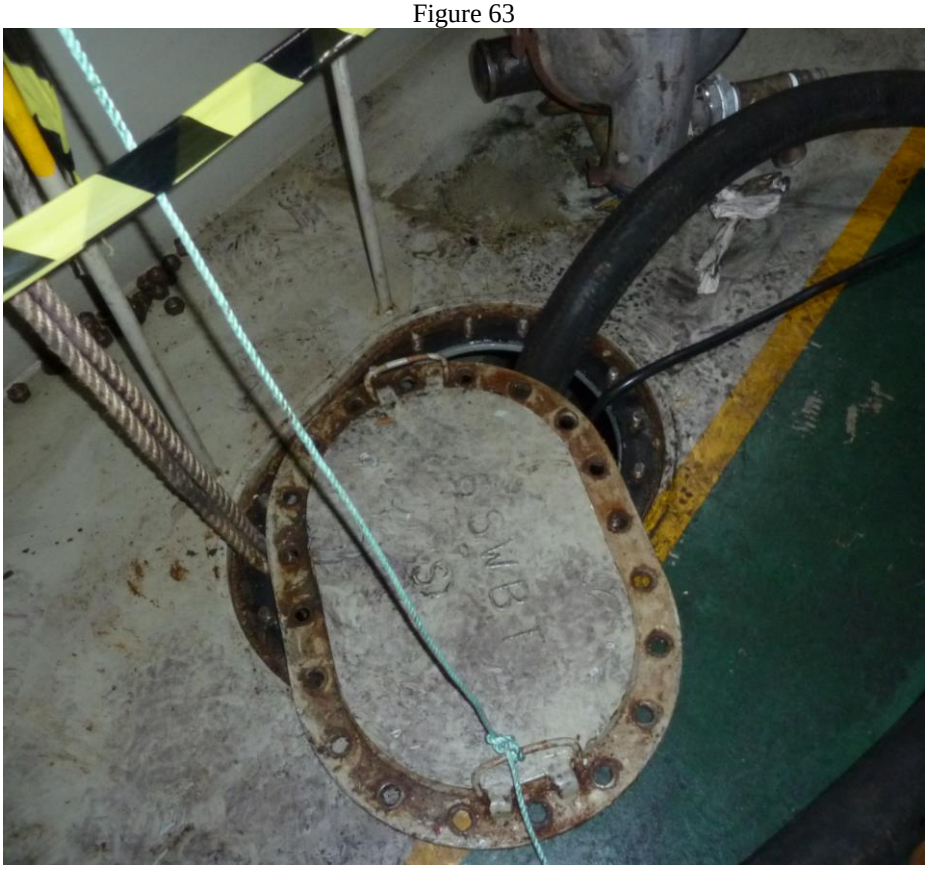
It is not known why the WT door was not left open after the inspection at 20:35hrs as the order for the need to open the door was given by the ERC at 20:00hrs. It was clear that the level would rise past the bottom of the door shortly after this last inspection.

Figure 62



WT hatch to CH9 from 2nd deck underdeck passageway, with closing arrangements indicated

Figure 63



Ballast tank lids removed for drainage

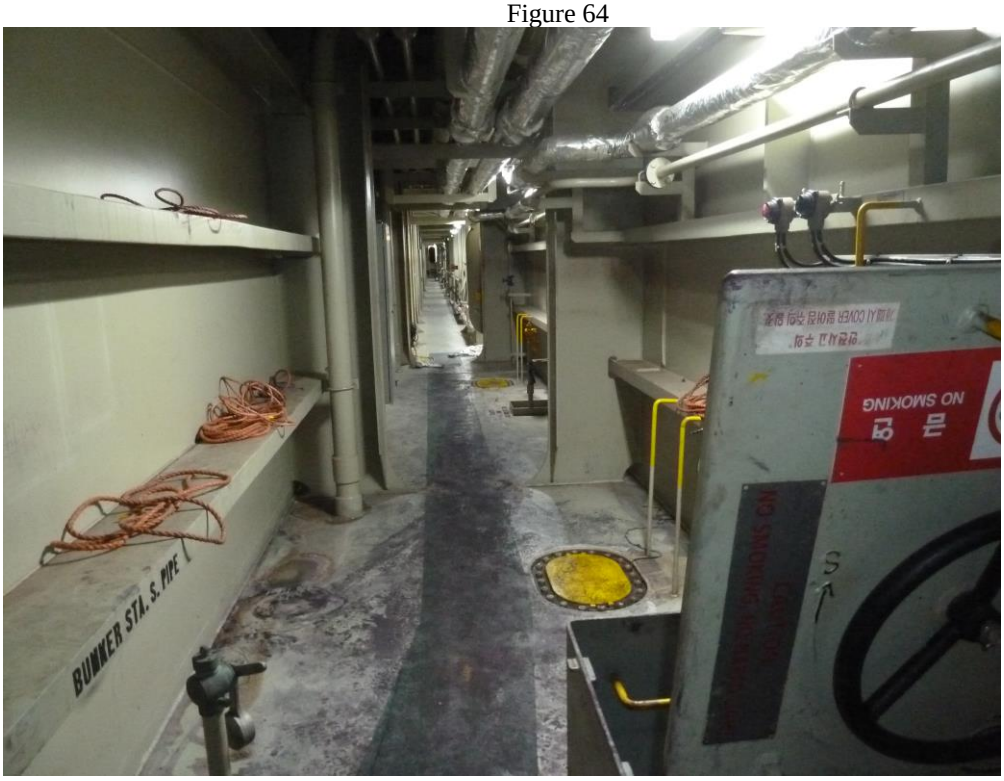
When the Bosun tried to adjust the hatch door to allow more water to drain it was not the intention for the door be opened fully as it did.
The design of this WT hatch door consists of a gear toothed central wheel operating a geared rack that in turn via link arms close and open the 4 dogging levers (figure 62). The dogging levers locate onto tapered wedges welded within the circumference of the hatch frame and pull the hatch door inwards until it seals tight against the frame. The design means that from the fully closed position the hatch cannot be opened more than a few millimetres before the dogging levers will disengage completely from the tapered wedges. As soon as they disengage from the wedges the door is free to open.

The exact time the hatch was opened could not be established due to the lack of record keeping and poor quality VDR recordings. There is mention of a 4 degree stbd list at 06:17hrs on the VDR recording accompanied by the sound of raised voices on one of the recording clips. It is thought that this is likely to be when the hatch was opened.

There were 7 people in the passageway when the hatch door burst open and the 1/E was in the bunker station below. He was not warned that they were attempting to adjust the hatch door. He said that he was in the bunker station looking to see if there was any possible way the water from CH 9 could be released directly into the bunker station and then overboard as one of a number of options that were being investigated. The 7 crewmembers in the vicinity of the water tight door managed to escape either into the ER through the WT door at frame 40 aft of the opening to CH 9 or fwd into the accommodation IWO the WT door at frame 111.

The 1/E was fortunate to survive the flooding. The distance from the bottom of the bunker station to the top of the ladder exiting at the top of the hatch coaming is just over 4 meters. He was lucky in so far as the watertight hatch lid is hinged at the fwd end of the coaming and when opened fully, automatically latches open preventing closure without manually lifting the latch. As the bunker station is aft of the CH 9 WT hatch the water flooding aft hit the open bunker station hatch coaming and lid first, providing some protection around the open hatch exit.
Upon finding the bunker station being flooded from above, the 1/E had initially tried to open the bunker station ships side door to release the water however he said it would not open. He managed to escape from the bunker station via the ladder fixed to the aft end of the inside of the hatch coaming. He stated that the water was up to his shoulders once he got into the underdeck passageway. Due to the high water level he had to climb along the pipe hangers just below the deckhead in order to escape, traversing aft to get out of the passageway.

Figure 64



Bunker station WT hatch foreground – ER WT door opening is 2 frames aft out of sight behind framing –Aft WT door found at the very end of the passageway. Pipe hangers can be seen above

There seemed to have been little consideration given to the implications of what would happen if the WT door opened fully i.e. the consequences and risks to those in the immediate vicinity of a sudden release of a huge amount of water into the narrow underdeck passageway which runs the length of the stbd side of the vessel on deck 2. Those involved should have realised that due to its design that this type of door could only be opened very slightly before the dogging levers would become disengaged from the tapered wedges. It was obvious that the water level was some way above the top of the door and as a result there would be substantial flooding to the space if the door inadvertently opened.

Attempting to rig some sort of strops or lashings across the front of the door may have given more chance of a controlled opening or at least helped in restricting the amount the door opened. All but essential personnel should have left in the vicinity when any attempt to adjust or open the door was made.

Trying to further open this type of door in this manner to release more water was an ill judged decision which ultimately put people's safety in jeopardy

Attempting to drain the water through such a limited available opening in the watertight door was never going to make any real difference to the water level in CH 9 when considering the enormous volume of water in the hold.

The sudden movement of water from CH 9 to the underdeck passageway caused a large list to stbd which was corrected by ballasting within a couple of hours. It did not put the vessel at risk as far as longitudinal strength or stability was concerned

It can be **concluded** there was a requirement to lower the water level in CH 9 due to the perceived risks posed to longitudinal strength or stability as the water level continued to rise due to the ingress of the firefighting water from the tugs.
The way the operation was tackled did not fully appreciate or take into account the risk to personnel involved in the incident and could have been better planned and co-ordinated by those on-board.
The instantaneous flooding of the deck 2 passageway posed as serious risk to the safety of those involved in the operation

4. Conclusion

4.1
The firefighting actions of the ships staff were commendable in dealing with and containing the fire in its early stages. They did as much as they could with the limited equipment they had on-board and managed to prevent the fire spreading fwd and aft from Bay 70 until the FiFi tugs arrived to assist.

The initial CO_2 release could have been quicker. The duties of the C/O meant he was required to be in two places at once and consequently had to leave the CO_2 room in the early stages of the release.

The arrival of the FiFi tugs prevented the fire spreading further, and after some time they were able to reduce the fire on deck.
The effect of the firefighting water from the tugs draining into the hold helped in reducing the spread of the fire to the fwd section of the hold and also reducing the heat transfer to the ECR and ER including adjacent fuel tanks.

The standard firefighting equipment provided on-board is not capable of containing a large fire on deck for a lengthy period of time. There was no effective means to fight the fire within the hold following the unsuccessful release of the fixed CO2 system. Having the provision to remotely attack the fire in the hold with water or by total flooding would have been advantageous.

The multiple fires on deck and in the hold were only controlled and extinguished once the specialists from SMIT came on-board the vessel.

Should this fire have occurred mid-ocean, the outcome may have been much worse without such prompt availability of FiFi tugs.

4.2
The fire originated from below deck in CH 9 from a container in position 700220.

4.3
The ferocity of the initial fire and reports of violent explosions within CH 9 were most likely caused by the presence of calcium hypochlorite in container 700220 which was mis-declared by the shipper as calcium chloride.
Due to the mis-declaration the container was stowed below deck within the hold where a combination of temperature and lack of adequate ventilation for such a product gave rise to providing conditions for calcium hypochlorite to reach its CAT which resulted in the start of the fire on-board.

4.4
The crew were unable to identify that container no 700220 contained a substance other than calcium chloride as long established practices in the container industry made mis-declaring the contents of a container a relatively simple task for a dishonest shipper. The shipper would be motivated to mis-declare the contents of the container in order to avoid the higher costs of shipping a DG container.

The safety of the crew and the vessel were put at serious risk as a result of the above mis-declaration.

4.5
There were a number of factors discovered that reduced the effectiveness and performance of the fixed CO_2 system i.e. the missing blank from the hold discharge piping, the lack of ability to make the hold air tight and the time taken to release the CO_2.
Nonetheless, the fixed CO_2 system failed to extinguish the fire in CH 9 primarily because calcium hypochlorite requires a different extinguishing medium (water) to effectively extinguish it.
Calcium hypochlorite would not normally have been carried in the hold if it was properly declared as a DG cargo i.e. shipped legitimately.

4.6
The hatch and hatch covers were not designed to be fully weathertight like on more traditional vessels. The design of the hatch cover waterfreeing arrangements could not cope with the enormous quantities of firefighting water from the tugs and consequently the water ended up running into the hold through the gaps between hatch coaming and hatch cover and longitudinally between the hatch covers.
Water may also have entered through the 2 supply ventilation trunking opening located just under the X deck as it could not be ascertained if the rectangular screw down lids were fully closed or not. The drainage arrangements from these underdeck spaces was inadequate when subjected to the amount of water from FiFi tugs

The water level rose to approx. 22.6m above the inner bottom which was within 6-7m of the CH upper coaming.

The water could not be pumped out of the hold due to the failure of the 2 actuators for the bilge suction valves within the hold. The damage to the bilge valve actuators was reported as a combination of the effects of the fire and water. Had these actuators not failed the bilge pumping system provided should have had the capacity to be able to cope with the amount of water entering the hold.

4.7
The water in CH 9 rose to a level that started to cause localised minor structural deformation. In the sheltered confines of the anchorage the longitudinal strength and stability of the vessel remained acceptable considering the emergency situation the vessel was in. Had the vessel not been stationary and in relatively calm waters the same level of hold flooding could have caused more serious damage.

4.8
The actions to reduce the level of the water in the hold by draining the water into the 2nd deck stbd underdeck passageway were necessary but not very well planned. When the hatch door opened it put the safety of the crew in the locality of the incident at considerable risk.

5. Recommendations

The following recommendations are made:

5.1

1. The Company should examine their arrangements on-board for tackling container fires on their existing vessels and if and where practicable, consider retrofitting extra firefighting equipment as is now required for ships where the keels were laid after 1st January 2016.
2. The container shipping industry should consider the viability of fitting remote operated water spray nozzles or the ability to completely flood, each underdeck cargo space when building large container vessels. Having either of the above options would provide a much greater ability to deal with a fire below deck, especially in situations where assistance is not available for some considerable time due the location of the vessel.
3. The Company should look at firefighting assignments on the Fire Muster List to ensure that no one individual officer or crewmember has responsibilities that may result in them being overstretched during and emergency on-board.
4. A senior officer should remain in the CO_2 room for the duration of the discharge of the fixed CO_2 system should its use be required in an emergency. As CO_2 release to cargo holds is a fully manual operation the Company should evaluate and clarify if more than one person is required to be present for the release and they should again ensure this or these persons are aware that they should remain in the CO_2 room for the duration of the discharge or multiple discharges of the fixed CO_2 system.
5. Consideration may be given to an alternative to a manual release of the CO_2 bottles i.e. the possibility of a pilot assisted release which would ensure a quicker discharge.
6. Particular attention is paid to and awareness is made of the requirement to maintain fire dampers in fully working order and regular testing of the full movement of such dampers.
7. Fire team members may, by nature of the location of the screw down ventilation lids of the supply ventilation trunking for the cargo holds on the X decks, be exposed to excessive heat and smoke whilst trying to shut the lids. It is recommended that for future new buildings alternative types of damper or methods of closure are considered such as quick release or remote release. These would enable much quicker closing of such equipment and would ensure that the crew have a realistic chance of operating them in an emergency situation. Alternatively the location of such dampers/closers may be able to be repositioned in order that they can be more easily accessed.

5.2

1. The company should provide more detailed guidance in the SMS on the operational procedures for ventilation of the cargo holds when high hold temperatures are being encountered. This may include more frequent monitoring of the hold temperature and guidance on the use of the ventilation

supply fans in such conditions. Also SMS guidance should be provided on max temperatures of any adjacent fuel oil tanks.

2. A detailed temperature analysis of any hold or holds that are consistently warmer than others should be carried out with and without forced ventilation to determine if there are any particular hot areas within the hold. If it is found that the fixed temperature monitoring equipment is not located in these areas, extra thermometers should be provided in these locations to ensure temp readings reflect the warmest areas in the hold. If it is found that there are localised areas with higher temperatures then if practicable remedial steps should be taken to reduce the temperature, such as providing extra insulation. For future new buildings higher temperatures in such areas should be designed out as far as it is practical to do so, with special attention given to areas adjacent to machinery spaces and fuel oil tanks.

5.3

1. The industry in general may wish to consider, as one of a number of options, reducing the cost of carriage of calcium hypochlorite as a DG to that of the cost of a standard container shipment in order to try and further reduce the risk of it being carried as a mis-declared container.
2. The result of a company instigating an outright ban on the carriage of calcium hypochlorite should be considered in relation to the likelihood of subsequently unknowingly receiving the product in a misdeclared container as the option to ship legitimately has been removed.

5.4

Following external servicing of the fixed CO_2 system, ships staff should satisfy themselves that the equipment has been returned to its fully operational condition.

5.5

1. The company should reflect on the fact that both of the bilge valve actuators in CH 9 failed to operate as designed and the consequences of their failure. Consideration should be given to retrofitting alternative arrangements to all valves in the system in order that they can have confidence that the bilge system will remain operable under similar harsh conditions.
2. Future consideration should be given to the requirements of drainage arrangements of any spaces containing ventilation trunking closers (in the case of this vessel the space directly below the X Deck walkway). In addition to dealing with any normal water encountered on deck due to adverse weather or sea conditions and water from the standard firefighting equipment, such spaces may also need to deal with large volumes of firefighting water from Tugs, in the event they are required to assist with a fire onboard.

5.6

1. Accepting that this was an entirely unexpected event, the crew should still have given careful consideration to the opening of the WT hatch in the deck 2 underdeck passageway.
   In light of what did occur with the possibility of serious injury as a result of the uncontrolled opening and subsequent flooding of the passageway some form of risk assessment should be carried out as to how to manage a more controlled release of a large volume of water through this type of WT door.

Annex 1

Bay, Row, Tier description

Bay:-

A Bay refers to a transverse line of containers across the hold. Individual Bays run from Bay 1 at the fwd end of hold 1 to Bay 87 at the after end of the vessel (effectively these show cross sections of the holds). The Bay number also indicates whether a 20 foot long container or a 40 foot long container is stowed in the position, odd Bay numbers indicating stowage of 20 foot containers and even Bay numbers indication stowage of 40 foot containers.

For example on Hanjin Green Earth looking at Hold 9 (which comprises of a fwd hold and an aft hold divided by a the cross deck). From fwd to aft, the Bay numbers are as follows, 65, (66), 67, 69, (70), 71.
Missing even numbers indicate a break in the ships structure such as accommodation or x deck divisions/walkways. e.g. between 67 and 69 is a gap where the dividing X deck splits CH 9 into the fwd and aft sections.
The stowage plan for Bay 65 would show the details of the 20 foot containers in the fwd half of the fwd hold (any 40 foot containers in this location would be marked on the stowage plan with an X)
The stowage plan for Bay (66) 67 would show the details of the 40 foot containers in the fwd hold and also any 20 foot containers in the aft half of the fwd hold.
Similarly the stowage plan for Bay 69 would show the details of any 20 foot containers in the fwd part of the aft hold (with any 40 foot containers marked with an X) and the stowage plan for Bay (70) 71 would show details of all the 40 foot containers in the aft hold and 20 foot containers in the aft half of the aft hold.

Row:-
The “Row” number referrers to the transverse position of the container in the hold. The container located along the centreline of the hold is referred to as Row 00. Those rows to the port side of Row 00 are labelled as even numbers, increasing the further outboard the location so looking at hold 9 as an example you have rows, 02, 04, 06, 08, 10, 12 , 14 and 16 for the 8 containers on the port side of Row 00 and similarly the containers located to the stbd side of the centre Row 00 are labelled with odd numbers i.e. 01, 03, 05, 07, 09, 11, 13 and 15 being the outboard row. As can be seen there are a total of 17 rows so hold 9 has capacity to stow 17 containers across its width within the hold.
Note an additional two Rows can be stowed above the hatch covers that extend beyond the edge of the hatches to the Ship’s side (one on each side).

Tier:-
The “Tier” number refers to the vertical position of the containers in the hold. Containers are labelled from the bottom of the hold upwards including those containers stowed above the hatch covers. In the fwd section of hold 9 the

containers can be stacked up to 11 deep, in the deepest section of the hold, with a further 9 containers stacked on top of the hatch cover. Oversized containers, such as ‘High Cubes’ are taller than standard sized containers and can make the hold appear almost full even when there are only 10 in the tier.
The tier number starts with the lowest number at the bottom of the hold and the highest tier number referring to the highest container on the stack on top of the hatch cover. Tier numbers are always an even numbers to lowest being 02 indicating the container at the bottom of the hold, the container above this would be tier number 04.

Each container has a six digit cell number referring to its Bay-Row-Tier and can be used to find its exact location onboard the vessel. For example a container numbered 700220 would be located in Bay 70 Row 02 and Tier 20

Annex 2

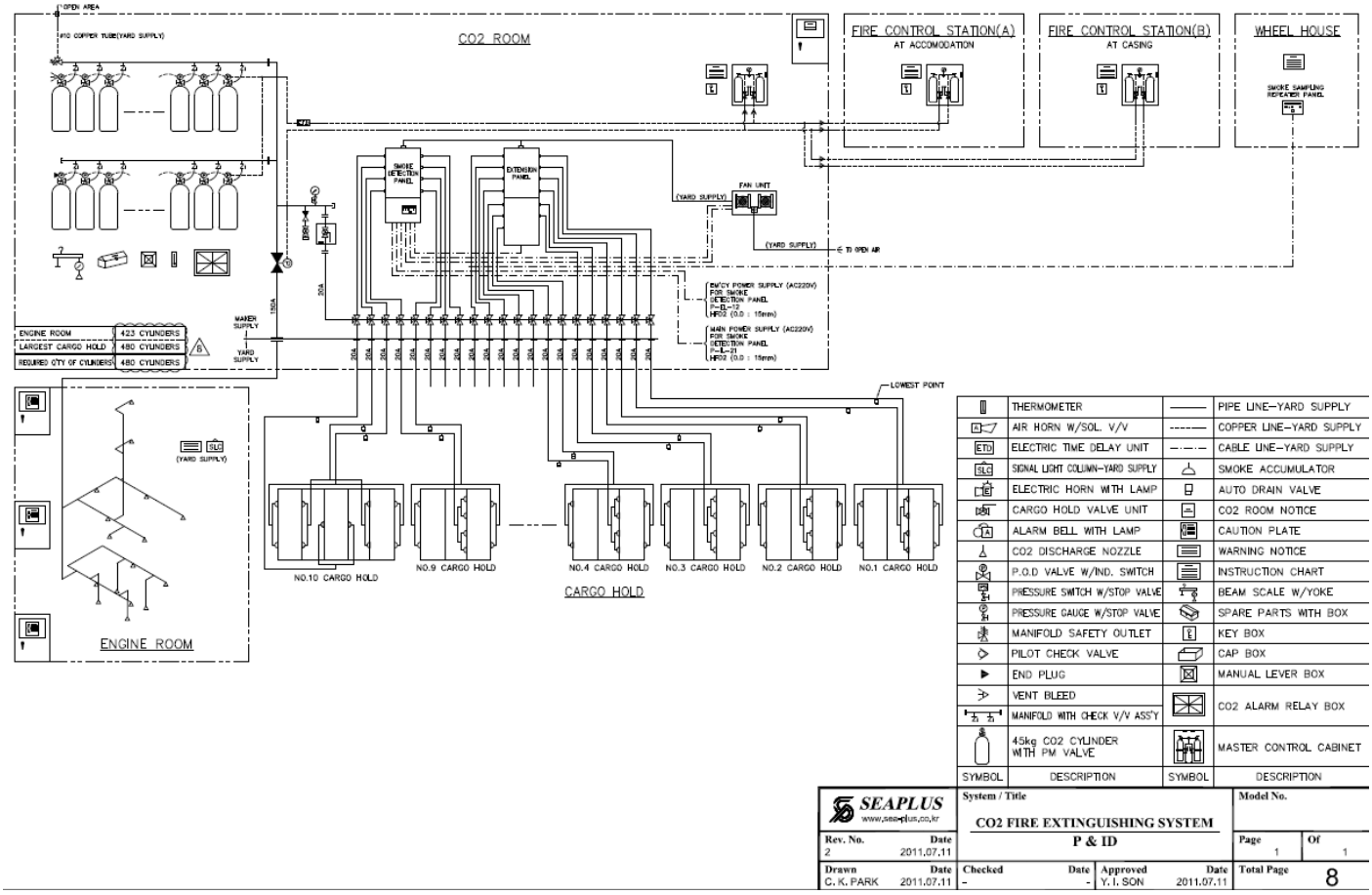
Summary of damage found following by Korean Register of Shipping Surveyor

1 Deformed structural members of Aft Bulkhead of No.8 Cargo hold
   - Both side end of No.2 stringer plate
   - All brackets and vertical girder on No.4 stringer
   - Both side vertical girder inner bottom
2 Pain burn damage:Fr.43, Aft bulkhead of No.9 cargo hold above 2nd deck level
3 E/R Fan Room Front wall (Fr.43 stbd side) form A deck to C deck was deformed.
4 Hatch coaming top plate between No.9A and No.9F hatch center and port side was deformed.
5 Fr.59 Trans bulkhead in way of No.9 hold, form No. 1 ADD. Stringer to hatch coaming plate , port and stbd side, were deformed.
6 No.9 hold inner bottom plate adjacent to ECR void was deformed
7 Lashing bridge of No.9 hold Aft , (stbd side) on upper deck deformed.
8 No.9 hold 2 sets of hatch covers, No.9 Aft center stbd and No.9 Aft center port to be replaced
9 No.9 Hold ventilator fan duct (P/S) partly broken and require repair.
10 Thermal insulation attached at purifier room aft bulkhead in way of No.9 hold to be checked and replaced if required
11 Malfunctioned indicators of WT door to No.9 hold located on stbd under deck passageway.
12 Not working condition of No.9 Cargo hold bilge valves
13 Fixed CO2 bottles to be recharged
14 Machineries
   - 3 sets of inverter panel for main c.s.w. pump
   - Engine fan room and E/G room water catcher 11 sets (2300mm x 2400mm)
   - ESBD220V control power panel NFB HBD52D
   - REF Dis power NFB & Bridge Head HW-BH-1 Series
   - Stbd bunker station hyd control panel and F.O hose davit switch
   - ER casing and deck and stbd fan room light
   - No.9 Cargo hold light system and cable
   - ACONIS AMS SYS. PCM Card AI-16
   - No.9 Cargo hold ref. container receptacle and cable
   - M/E No 10 exhaust gas temp sensor and amplifier
   - Side shell plates (P/S) in way of FWT in E/R were slightly indented by tug boats, which were used for fire fighting

Annex 3

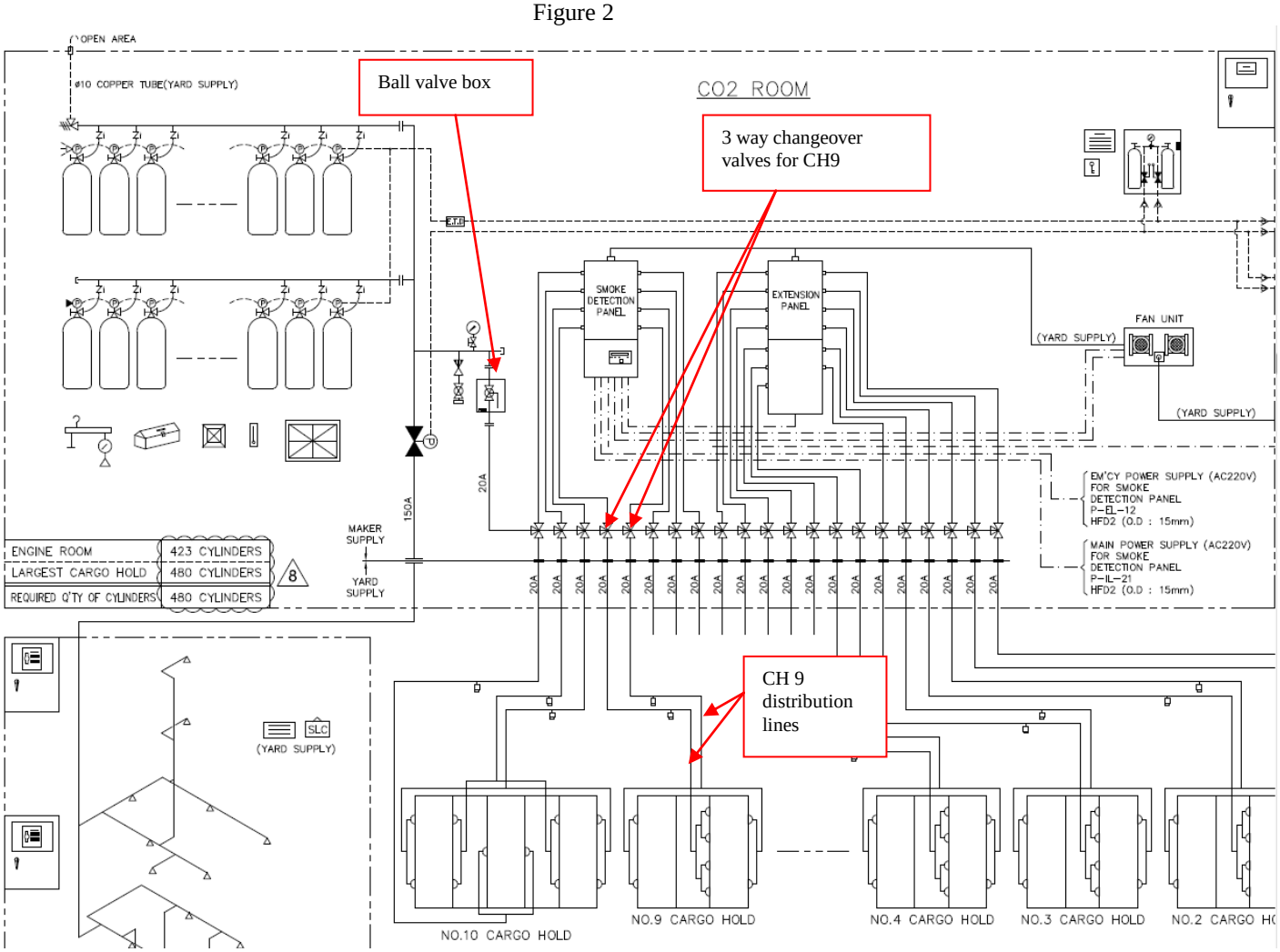
Fixed CO2 System Diagrams

Figure 1



Overview of CO2 System

Figure 2



Enlargement to show; ball valve cabinet, 3 way changeover valves (smoke/CO2) and CH9 distribution lines.

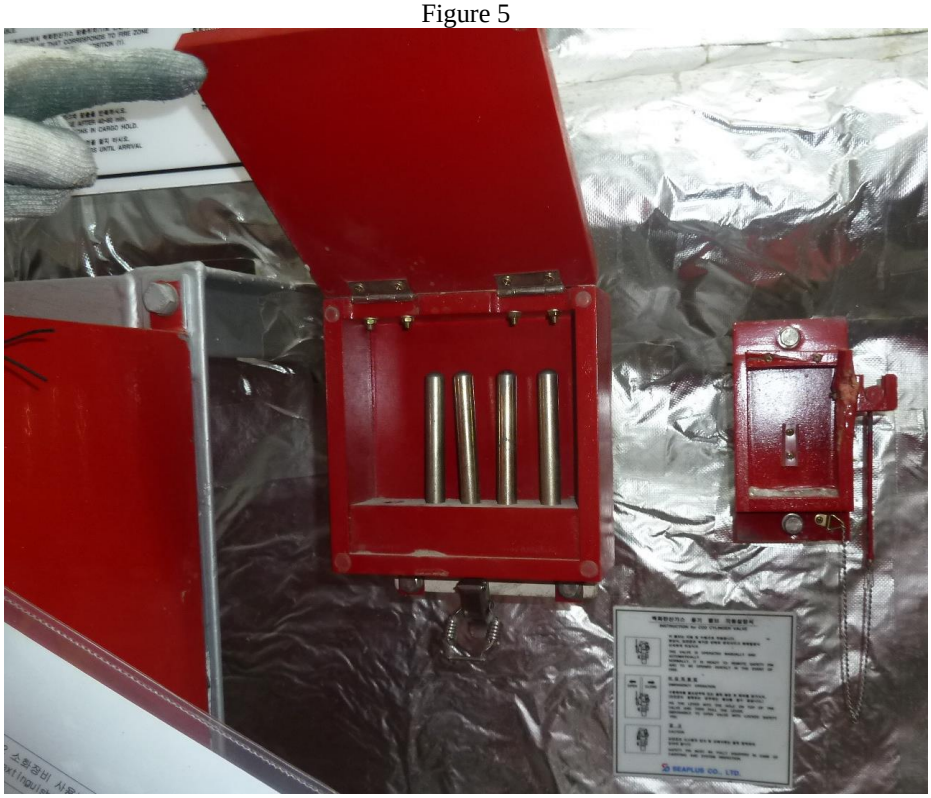
Figure 3

Section of CO_2 distribution manifold showing blue handled levers used to change over from smoke sampling to CO_2 delivery

Figure 4

Ball Valve Box for cargo hold open shows operating lever and micro-switch for alarm

Figure 5



Manual lever box showing CO_2 bottle manual actuating levers