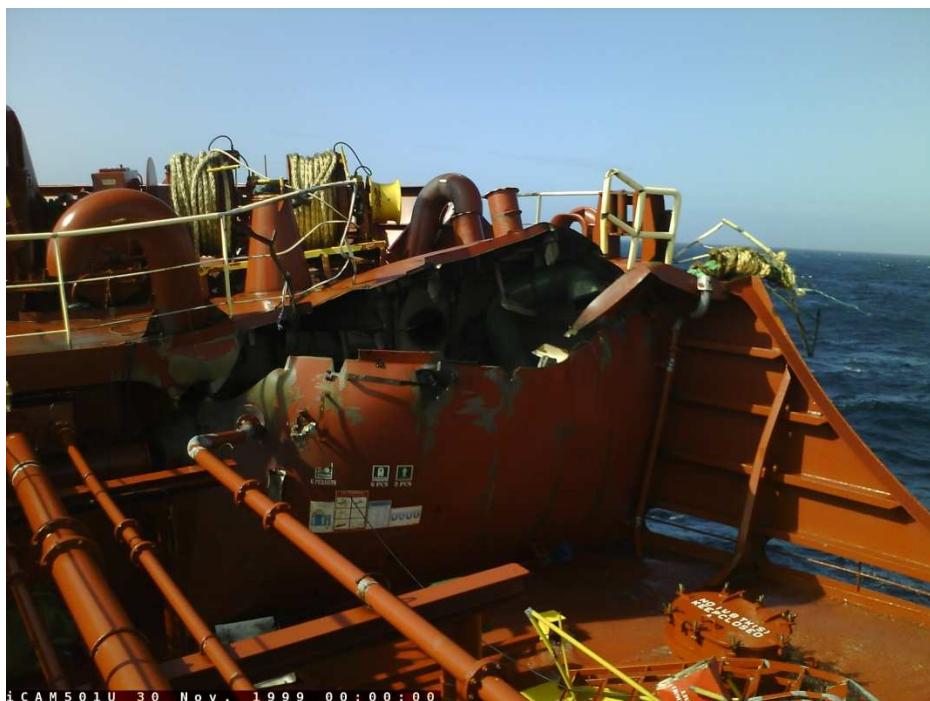




The Bahamas Maritime Authority

THE COMMONWEALTH OF THE BAHAMAS



“HARBOUR KRYSTAL”
IMO Number 9330020
Official Number 8001246

**Report of the investigation into the explosion
and fatality on the 6th March 2013**

The Bahamas Maritime Authority investigates incidents at sea for the sole purpose of discovering any lessons which may be learned with a view to preventing any repetition. It is not the purpose of the investigation to establish liability or to apportion blame, except in so far as emerges as part of the process of investigating that incident.

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

Date of Issue: 30th August 2013

Bahamas Maritime Authority
120 Old Broad Street
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United Kingdom

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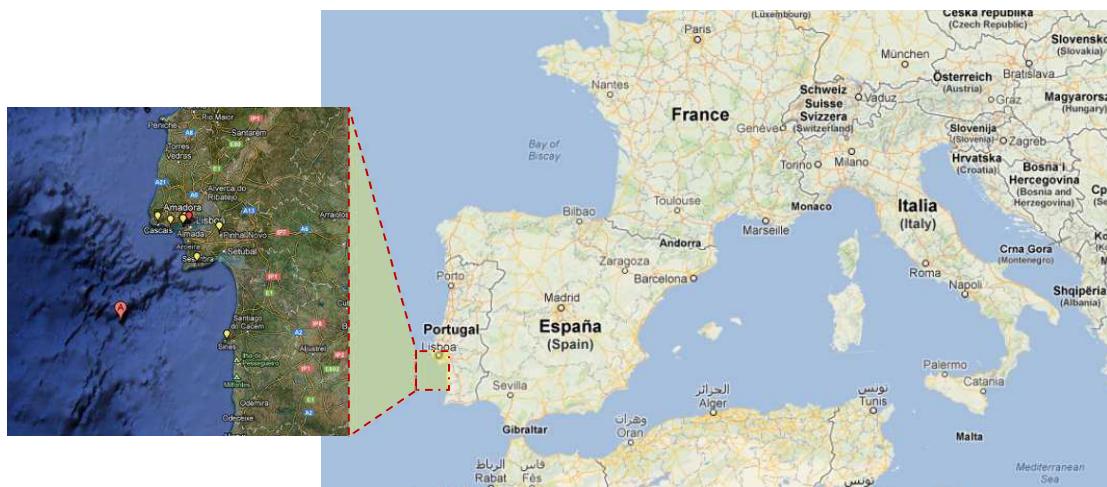
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Document 07.03.10-01 – Deck Spaces Gas Check Record

1 SUMMARY

- 1.1 The HARBOUR KRYSTAL was undertaking a scheduled voyage between Lavera (France) and Amsterdam (The Netherlands) loaded with 11,8987.40 m³ of naphtha
- 1.2 On the 6th March 2013 the vessel was underway with no dense traffic heading north towards the Finisterre area in Spain. Visibility was good with westerly winds of force 6 and sea 5.



- 1.3 At 09:12 hrs while the bridge was attended by 3rd officer on his watch an explosion was heard and smoke was seen on the forecastle. The Master was on the bridge at the time.
- 1.4 Immediately after the explosion the crew was mustered and accounted for with the Bosun reported missing.
- 1.5 The on-bard search for the Bosun was started while fire teams were preparing.
- 1.6 The vessel's heading was deviated east towards Lisbon, Portugal, and the local coastguard (ROCA Control) was contacted to report the accident.
- 1.7 At 09.35 hrs, after checking vessel's stability, Master decided to flood the forecastle area with water to avoid spread of smoke and fire
- 1.8 By 09.46 hrs Bosun was confirmed missing and ROCA Control was contacted with the position and time of accident and details of the missing person.

- 1.9 ROCA Control confirmed they would take over search & rescue operations.
- 1.10 By 10.35 hrs the first helicopter was confirmed to be in the area to search for the missing person.
- 1.11 The fire was declared extinguished at 11.30 hrs.
- 1.12 Several checks were made on ballast tanks and cofferdams for signs of flammable gases with negative results.
- 1.13 No pollution was reported.
- 1.14 The Master asked for port of refuge in Setubal.
- 1.15 Vessel was ordered to remain drifting offshore Portugal while authorities approved vessel's entry into Lisbon.
- 1.16 By 18.16 hours the vessel remained drifting waiting for instructions from Portuguese Authorities
- 1.17 At that stage, and in view of the fact that the vessel was yet not allowed to enter Portuguese territorial waters, the Bahamas High Commission was requested to contact the Portuguese Embassy to request for the port of refuge following the accident.
- 1.18 BMA also contacted the Portuguese delegation at IMO for the same purpose.
- 1.19 At around 19.00 hrs the vessel was allowed to enter the inner anchorage area of Setubal although heavy swell suspended pilotage and vessel remained drifting at 12 NM of the coast.
- 1.20 On the 7th December 2013 at 09.05 hrs a meeting was held with all port authorities and vessel was ordered to approach to 3 nautical miles of pilot station.
- 1.21 At 10.53 hrs the vessel entered the Port of Setubal escorted by two (2) tugs.
- 1.22 Vessel dropped anchor at inner anchorage area at 11.45 hrs and one tug remained alongside on standby.

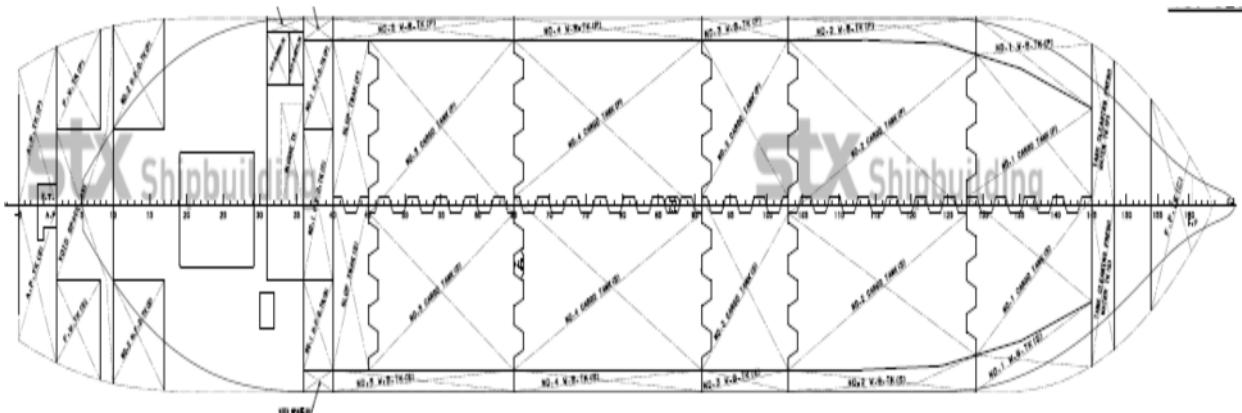
2 PARTICULARS OF HARBOUR KRYSTAL

2.1 “HARBOUR KRYSTAL” was a gearless oil/chemical tanker registered at Nassau, Bahamas, of welded steel construction having a raised forecastle. The accommodation and machinery spaces were situated aft. She had the following principal particulars:

1. Official Number - 8001246
2. IMO Number - 9330020
3. Length overall - 116.50m
4. Length BP - 109.36m
5. Breadth - 20.00m
6. Depth - 11.71m
7. Gross Tonnage - 7,687 t
8. Net Tonnage - 3,266 t
9. Deadweight - 11,262 t
10. Call Sign - C6VS7

2.2 She was powered by a STX MAN B&W slow speed main engine that developed 4,440 kW (6,060 bhp) and which drove one right turn fixed bladed propeller.

2.3 The cargo was carried in twelve (12) tanks distributed in five pairs and one pair of slop tanks on the aft. The total capacity of the tanks is of 12,498.20 m³ and when fully loaded to 98% of the total capacity, 12,248.00 m³.



2.4 The vessel was built in Busan, South Korea at STX Shipbuilding Co. Ltd. in 2006. At the time of the explosion she was owned by KRYSTAL SHIPPING

CO. LTD. of Bahamas and managed by NORDIC TANKERS MARINE A/S of Denmark.

- 2.5 The vessel was entered with American Bureau of Shipping Classification Society as a Double Hull Oil and Chemical Carrier with Class Notation □A1, Chemical Carrier, Oil Carrier, □ AMS, □ ACCU, VEC, TCM, RES for unrestricted service. At the time of the casualty it complied with all statutory and international requirements and certification. The vessel is issued with an International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk (IBC Code)
- 2.6 “HARBOUR KRYSTAL” was last subjected to a Bahamas Maritime Authority Annual Inspection at the Port of Lavera, France, on 02nd March 2013 with no observations made.
- 2.7 The vessel underwent PSC Inspections at the Port of New York, USA on the 02nd February 2012 and at the Port of Buenaventura, Colombia on the 15th May 2013. Neither of these inspections recorded any deficiencies.



- 2.8 Following the explosion, and as a condition to enter a Portuguese port of refuge, the vessel received a PSC inspection on the 7th March 2013 while still outside Setubal with the following observations/remarks, all of which were given a code 17 (Rectify before departure)

- i 01305 Log Book/Compulsory entries missing: Deck log book filled in since 06 Mar 08:05 until 24:00. Master statement of facts not presented
- ii 02106 Hull damage: Forecastle area deck plate heavily damaged/bent. Bulkheads collapsed. Emergency fire/bow thrusters room full of water. Bosun store frames deformed.
- iii 07101 Fire detection & alarm system: Missing with fwd area isolated.
- iv 04103 Emergency switchboard not as required: earth system found under earth fault.
- v 12106 Instrumentation not as required: sensor fault
- vi 08111 Alarms: Overfill/high level alarm disconnected
- vii 12109 Special Requirements: Gas sampling system found with areas isolated.
- viii 08107 Machinery control marks malfunctioning: Engine control room alarm log printers not properly printing

3 NARRATIVE OF EVENTS

- 3.1 All times noted in this narrative are given in the style of the standard 24 hour clock without additional annotation. Local time used on-board the HARBOUR KRYSTAL was UTC+1
- 3.2 The vessel discharged in the Port of Gaeta, Italy a parcel of Fatty Acid Methyl Ester (FAME) and Gas Oil. Following completion of discharge, on the 20th February 2013, the Master received orders to clean tanks and proceed to Lavera, France, for further instructions.
- 3.3 Cleaning of tanks was started on the 20th February 2013 at 13:00 hrs with sea water at 25°C for sixty (60) minutes, sea water at 80°C for two (2) hours followed with ten (10) minutes of fresh water at 60° C.
- 3.4 Following cleaning with water, all the tanks were ventilated for five (5) hours and dried for thirty (30) minutes. Tank cleaning was completed same day at 24:00 hrs.
- 3.5 While venting of tanks at sea on the 27th February 2013 the vessel was ordered to proceed to Lavera to load isomerate (naphta) intended for the Port of Amsterdam, The Netherlands.
- 3.6 On the 27th February 2013 at 19.30 hrs inerting of tanks with nitrogen gas commenced.
- 3.7 Inerting was completed on the 28th March 2013 at 23.30 hrs in reaching an oxygen level of below 7%
- 3.8 The “HARBOUR KRYSTAL” arrived at Lavera, France on the 01st March 2013 and dropped anchor at 05:12 hrs with all tanks ready for loading. All tanks were inerted.
- 3.9 The pilot arrived on-board on the same date at 24:00 hrs and vessel finally berthed on the 2nd March 2013 at 01.10 hrs.
- 3.10 Pre-Safety checks held jointly with cargo and terminal surveyors were started upon arrival and completed at 03:00 hrs and loading commenced at 04.10 hrs.
- 3.11 During loading operations the BMA annual inspection took place with no deficiencies or observations made apart from one verbal observation referring to a provision crane securing shackle and wire which was found in fair condition and which was requested to be renewed as soon as possible.
- 3.12 Loading operations were completed on the same day at 20.00 hrs
- 3.13 Safety checks and ullages were taken jointly with terminal surveyors.

- 3.14 Cargo tanks were loaded to 97.5% of their maximum capacity as follows,

Tank No.	Capacity (m ³)	
	100%	Loaded
No. 1 Port	743.1	731.80
No. 1 Stbd	751.8	737.06
No. 2 Port	1,521.7	1,486.80
No. 2 Stbd	1,519.3	1,484.49
No. 3 Port	756.2	739.58
No. 3 Stbd	756.3	741.98
No. 4 Port	1,628.6	1,589.14
No. 4 Stbd	1,630.8	1,591.06
No. 5 Port	1,254.6	1,231.56
No. 5 Stbd	1,256.1	1,229.01
Slop Port	336.3	0.00
Slop Stbd	343.2	335.92
TOTAL	12,498.2	11,898.40

- 3.15 On the evening of the 2nd March 2013 a number of crew joined the ship although did not familiarised themselves with the ship since it was too late. Familiarisation was scheduled for the following day.
- 3.16 The “HARBOUR KRYSTAL” sailed from the Port of Lavera, France on the 2nd March 2013 at 23:50 hrs loaded with 11,8987.40 m³ of isomerate (naphta) for the Port of Amsterdam, The Netherlands, with a sailing distance, pilot to pilot of 2,135 nautical miles estimated to be covered in 7 days and 2:48 hours at 12.5 knots.



Planned voyage of HARBOUR KRYSTAL from Lavera, France to Amsterdam, The Netherlands

- 3.17 The draft during the voyage was of 7.20m forward and 7.60m aft.
- 3.18 Vessel familiarisation was made as scheduled, on the 3rd March 2013 by the safety officer with the newly-boarded messboy, oiler and cadet.
- 3.19 During the familiarisation the new crew went to the bosun's store and to the emergency fire pump to learn how to start it locally.
- 3.20 When opening the forecastle the oiler noticed a smell. During subsequent interviews the smell was described as being cargo or paint. The oiler consequently asked the 3rd Officer if the ventilation mushroom was open and to start venting the area.
- 3.21 When opening the door, lights were already switched on. Ventilation was switched on and crew waited for 5 minutes until the smell was gone.
- 3.22 The crew entered the bosun's store around 13:00 hours and walked down to the emergency pump room. They were inside for about 15 to 20 minutes for familiarisation with the starting of the emergency fire pump.
- 3.23 Upon completion of familiarisation with the emergency fire pump all crew left the forecastle area and closed the door behind them.
- 3.24 The voyage through the Mediterranean along the Spanish Coast was reported to be good and with calm weather.
- 3.25 While approaching the Straits of Gibraltar, and in view of weather picking up slightly, the Master asked to ensure all openings and vents on the forecastle were closed.
- 3.26 The Bosun, one Able Seaman and one Ordinary Seaman went on the 5th March 2013 to the forecastle area in order to secure all vents and openings.

- 3.27 On the 5th March 2013 the Nitrogen system was used in order to top up the pressure in cargo tanks. The system was used for about fifty (50) minutes at 09:51 hrs.
- 3.28 On the 6th March 2013 at around 07:10 hrs the Bosun came to the bridge to discuss the day's work, and another matter referring to garbage, with Chief Officer.
- 3.29 At 07.50 hrs the Master went to the bridge to deal with e-mails and paper work.
- 3.30 At around 08:00 hrs the 3rd Officer took over the watch from the Chief Officer who then left the bridge.
- 3.31 Before 09:00 hrs the Bosun returned to the bridge with a shackle to confirm the SWL of a crane with 3rd Officer
- 3.32 The weather at this time was:
- i Wind direction West – Force 6
 - ii Sea 5
 - iii Swell 3 metres
- 3.33 Meanwhile the Chief Officer noted, as confirmed during the subsequent interview, that pressure on tanks 5 port, 5 starboard and slop tank starboard was low hence he instructed the engine department to start the nitrogen inerting system. Delivery of nitrogen started at 08.47 hrs.
- 3.34 At around 09:05 hrs the 3rd Officer was on the chart table on the starboard side looking forward into the radar and another ship in the distance. The Master was also on the bridge looking aft on the port side typing e-mails.
- 3.35 At 09.12 hrs a loud explosion was heard followed by vibration and an impact on the bridge.
- 3.36 The exact location of the explosion could not be seen due to hose crane stowage position although smoke was seen emanating from the forward part of the vessel.



HARBOUR KRYSTAL view from bridge window

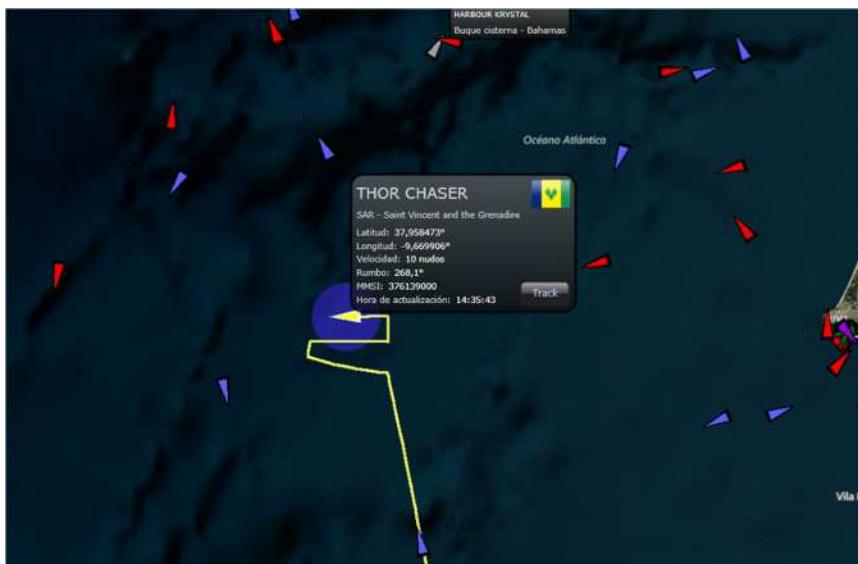
- 3.37 The Master moved immediately, looked forward and activated the general alarm thinking of a collision with a submarine or some other floating object.
- 3.38 All crew mustered within a minute and were accounted for except that the Bosun was reported missing. The Fitter immediately informed that the Bosun had gone forward towards the forecastle.
- 3.39 The Chief Officer and two other crew members went forward to start fire monitors and check for the Bosun. Meantime a fire team was getting ready.
- 3.40 Master was asked to start the main fire pumps. Black smoke started to appear from the bosun's store.
- 3.41 The Chief Officer asked the Captain to alter course to direct smoke away from deck and the fire team. Accordingly the course of the vessel was deviated to starboard to clear the smoke from main deck.
- 3.42 A total of five hoses and one fire monitor were used to fight the fire while the Master decided to flood the forward compartment. After checking on stability ballast pumps were started and lines opened towards the forecastle area.
- 3.43 At 10.35 hrs a SAR helicopter was reported to be in position.
- 3.44 At the same time ROCA control in Portugal was contacted for assistance reporting a man was missing. Roca control replied immediately and took over the SAR operations
- 3.45 The following SAR message was sent on NAVTEX

RA06
MONSANTORADIO
060909 UTC MAR 13

NAV. WARNING NR 560/13
 PORTUGAL-CONTINENTAL PORTUGAL-
 WEST COAST
 MERCHANT VESSEL
 HARBOUR KRISTAL REPORTED
 EXPLOSION ON BOARD AND A
 MAN OVERBOARD IN THE VICINITY OF
 THE POSITION
 38-04.15N - 009-44.70W AT 0812Z.
 WIDE BERTH REQUESTED.
 REQUEST ALL SHIPS IN VICINITY TO
 KEEP SHARP LOOKOUT AND REPORT
 ANY SIGHTS TO MRCC LISBOA
 NNNN

- 3.46 Among other ships, a number of passing vessels were noticed to have carried out SAR operation in the area given by the NAVTEX message. Despite the efforts none of them reported finding the Bosun

Ship Name	IMO	Flag	
CMA CGM HERODOTE	9360142	United Kingdom	Vessel turned around
YARA FROYA	9345350	Norway	Vessel turned around
SCI NHAVA SHEVA	9290414	Liberia	Deviated course
THOR CHASER	6710358	St. Vincent	SAR operation while underway



- 3.47 After an hour, when the density of smoke decreased a couple of hoses were introduced through the forward hatch.
- 3.48 One AB wearing breathing apparatus went down to the bosun's store and reported a fire on the starboard side and hoses were re-directed towards the fire.
- 3.49 After 10 minutes the fire was extinguished and an AB confirmed that the fire was extinguished so ventilation was started.
- 3.50 The Bosun's shoe was found about 1 metre from the forecastle entrance door.
- 3.51 At 11:10 hrs the Chief Officer and two crew members went down again to search for the Bosun although the lower forward compartments were flooded.
- 3.52 At 15.30 hrs the Master decided to pump out the flooded forward compartments to extend the search for the Bosun.
- 3.53 It was reported by the Chief Officer that Bosun was not found inside the forecastle.
- 3.54 At 18:00 hrs all water from forecastle and forward compartments had been pumped out.
- 3.55 With the bow thrusters' room almost empty a final check was made by the Chief Officer although the Bosun was not found. Search and rescue continued being co-ordinated by ROCA control.
- 3.56 On the evening of the 6th the vessel was not allowed into Lisbon roads and instead was asked to remain drifting pending approval to enter anchorage/port while being shadowed by a Portuguese naval vessel.
- 3.57 At 19:00 hours the vessel was notified that Setubal Harbour Master had authorised the vessel to enter the inner anchorage under the following conditions
1. One tug to be on standby near the vessel with fire system fully operational
 2. Hot work strictly forbidden
- 3.58 Anchorage entrance was delayed due to heavy weather and the vessel entered the inner anchorage of Setubal on the 7th March 2013 at 10:53 hrs.

4 DAMAGES AND CASUALTIES

4.1 The Bosun disappeared overboard due to blast and despite a wide Search and Rescue operation has not been found and is presumed deceased.

4.2 The following ship damages were observed during the investigation

Hull: All Hull plating buckled outwards due to explosion pressure inside the forecastle space. Starboard side shell plating noted with burn marks



Hull damaged with burning marks



Hull buckled between frames and reinforcements

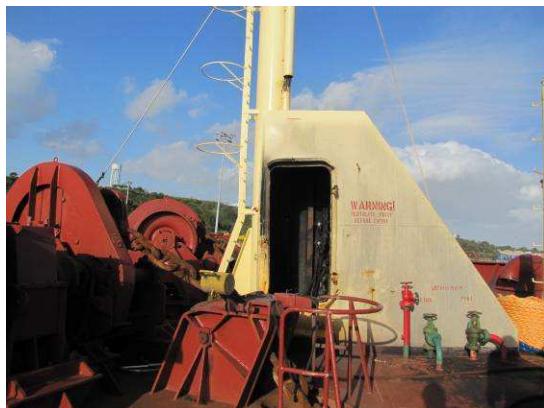


Hull buckled between frames and reinforcements



Hull damaged with burning marks

Forecastle Deck: All deck plating deformed due to explosion pressure inside the forecastle deck space. Entrance doors and hatch covers were ripped out and detached.



Forecastle entrance door missing



Inflated forecastle deck port side



Forward port square hatch missing. Ripped out from counter weight



Inflated forecastle deck on starboard side

Upper Deck: Deck plating deformed due to explosion pressure inside the forecastle deck spaces. Entrance doors and hatch covers ripped out and detached.



Bulkheads pushed outwards due to explosion pressure



Bosun's store port side

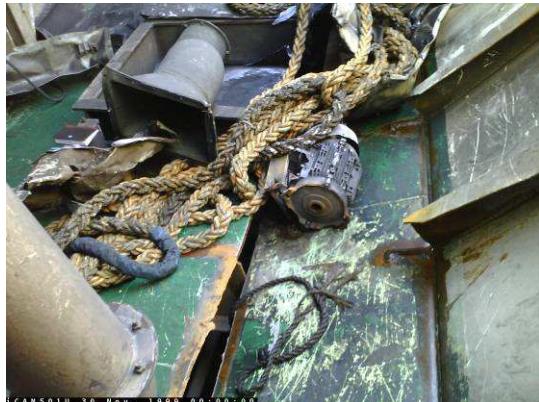


Bosun's store starboard side



Bosun's store centre line forward

De-humidifier Room: Deck plating deformed due to explosion pressure. De-humidifier unit disintegrated into small pieces.



Deck pushed and broken. Motor from de-humidifier



Fan with black soot



De-humidifier panel on aft bulkhead



De-humidifier base with one air flow line



De-humidifier panel on starboard side



Aft bulkhead pushed outwards

2nd Deck: Deck plating and bulkheads deformed due to explosion pressure.



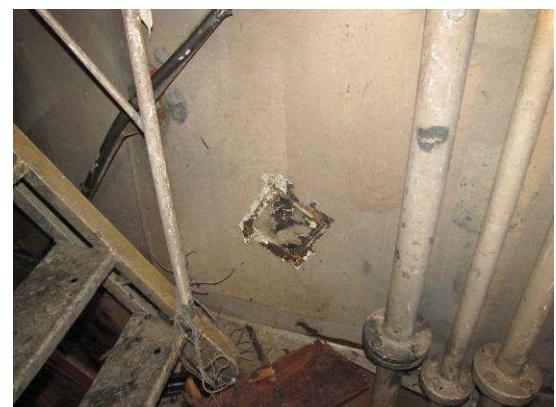
Top deck (Upper deck) inflated/broken



Top deck (Upper deck) inflated/broken



Aft bulkhead buckled towards the aft

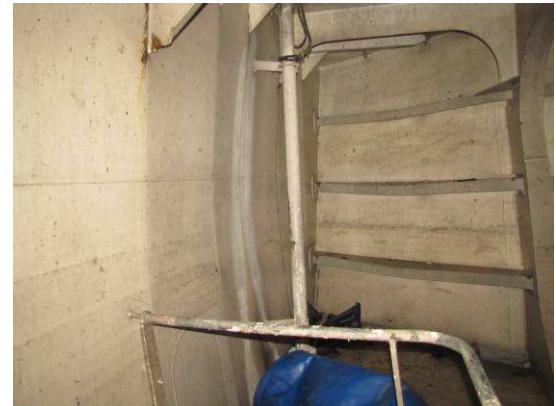


IMO sign burned

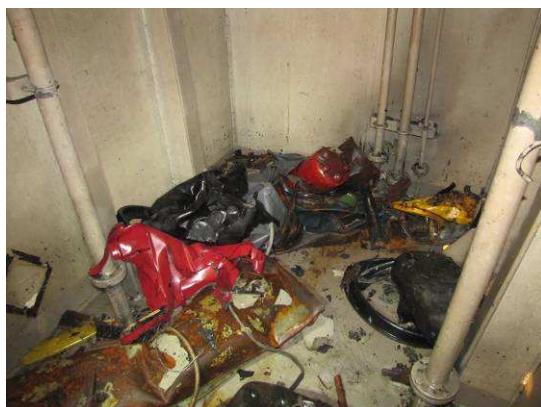
1st Deck: Deck plating deformed due to explosion pressure inside the forecastle space. Entrance doors and hatches ripped out.



Empty drums distorted, broken fire extinguisher



Aft bulkhead buckled towards the aft



Aft bulkhead buckled towards the aft. Plastic affected by heat



Debris left on deck

Bow Thruster Deck: All electrical boxes broken. Signs burned. Hull framing bent.



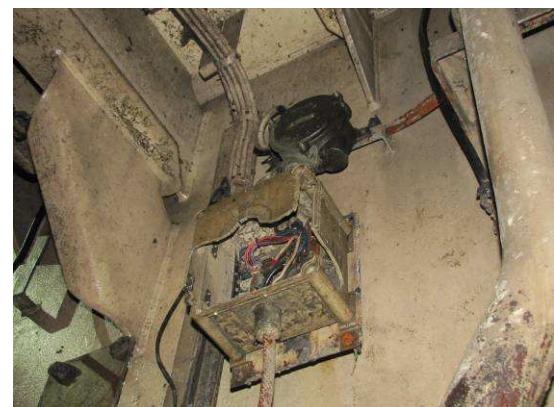
Emergency fire pump and electrical panel



Telephone base



Distorted Hull frame



Broken electrical connection box

5 ANALYSIS

SAFETY MANAGEMENT SYSTEM

- 5.1 The company SMS Doc 07.03.08, revision 0 effective from 01.10.10 “*TANK VENTILATION*” estates: (emphasis added)

Par. 1 – The objective of this procedure is to provide instructions on tank venting

Par. 2 – It is the responsibility of the Master to ensure that this procedure is followed.

It is the responsibility of the Chief Officer to ensure that this procedure is compiled with.

Par. 3.2 – Gas freeing operation: Natural or forced

- *Where the cargo tanks are gas freed by means of one or more permanently installed air blowers or nitrogen systems, all connections between the cargo tank system and the blowers should be blanked immediately upon completion of gas freeing. If air dryers are used upon completion of the gas freeing operation the air dryer lines should be blanked immediately after the tanks are dry.*
- *If the tanks are connected by a common venting system, each tank should be isolated to prevent the transfer of gas to or from other tanks.*

- 5.2 Observations

- 5.2.1 All tanks on the HARBOUR KRYSTAL were connected with a common venting system and considering the amount of gas which leaked into the dehumidifier room and the forecastle area there are reasons to believe that either one valve had been left open or several valves were not closed properly

- 5.2.2 Upon completion of air dryer operation the line should have been blanked immediately. During the investigation, and the close inspection of all the fixed venting lines, no blank was found. Hence it is concluded that the piping line had not been blanked after drying tanks.

- 5.2.3 Paragraphs 5.2.2 and 5.2.3 infers that SMS procedures were not fully complied with.

- 5.3 The company SMS Doc 06.02.02, revision 2 effective from 31.10.12 “*JOB DESCRIPTION. CHIEF OFFICER*” estates: (emphasis added)

Par. 3.1 – General

It shall be the responsibility of the Chief Officer to [inter alia]:

- *Supervise the seafarers-deck and all activities executed by the deck maintenance, and handle the cargo and ballast, as well as proper deck maintenance, including cargo spaces and ballast tanks.*
- *That cargo operations, tank cleaning/hold cleaning are executed in accordance with safe work procedures, in order to control hazards and avoid pollution to the environment.*

5.4 Observation

Tank valve hydraulic pressure tests carried out on the 13th April 2013 revealed that a number of valves were not tight. This evidence supports the conclusion that either several valves had leaked into the vent line leading to the forecastle deck through the de-humidifier or one or more valves had been not properly closed. There are reasons to believe that no proper supervision of deck seafarer's activities were implemented since the venting operation was left to the Bosun/Pumpman hands and responsibilities only.

5.5 The company SMS Doc 06.02.03, revision 2 effective from 31.10.12 "*JOB DESCRIPTION. SECOND OFFICER*" estates: (emphasis added)

Par. 3.1 – General

It shall be the responsibility of the Second Officer to amongst others:

Assist the Chief Officer in port with Cargo Operations

5.6 Observation

The Second officer has no responsibility for tank cleaning or venting.

5.7 The company SMS Doc 06.02.04, revision 2 effective from 31.10.12 "*JOB DESCRIPTION. THIRD OFFICER*" estates: (emphasis added)

Par. 3.1 – General

The third officer's responsibilities shall include but not to be limited to the following:

- Assist the Chief Officer in port with Cargo Operations

5.8 Observation

Third officer has no responsibility on tank cleaning or venting.

5.9 The company SMS Doc 06.02.23, revision 1 effective from 01.04.11 "*JOB DESCRIPTION - PUMPMAN*" estates: (emphasis added)

Par. 3.1 – General

It shall be the responsibility of the Pumpman to, amongst others:

- Assist the Chief Officer in planning and execution of all cargo related operations, such as: loading, discharging, tank cleaning, inerting, gas freeing etc*

Par. 3.2 – Special Tasks

Execute assigned tasks in conformance with safe work procedures and in accordance with instructions giving by the supervising officer.

5.10 Observation

The Pumpman executed all the cargo related operations such as manual hand valve operation for drying of tanks and line preparation for inerting. From subsequent interviews it was established that no supervision of those last operations prior loading had been made.

5.11 The vessel holds a P&A Manual approved by ABS on the 16th August 2006. Appenx C related to the ventilation procedures does not cover any aspect of the Air-Drying System, although an Air-drying system diagram is attached into among other line diagrams.

CARGO DESCRIPTION

5.11.1 Product Detail - Low Boiling point modified naphta/Alkylate/Isomerate

5.11.2 Hazards - Toxic Extremely flammable

5.11.3 Physical and Chemical properties

Flash Point -40°C

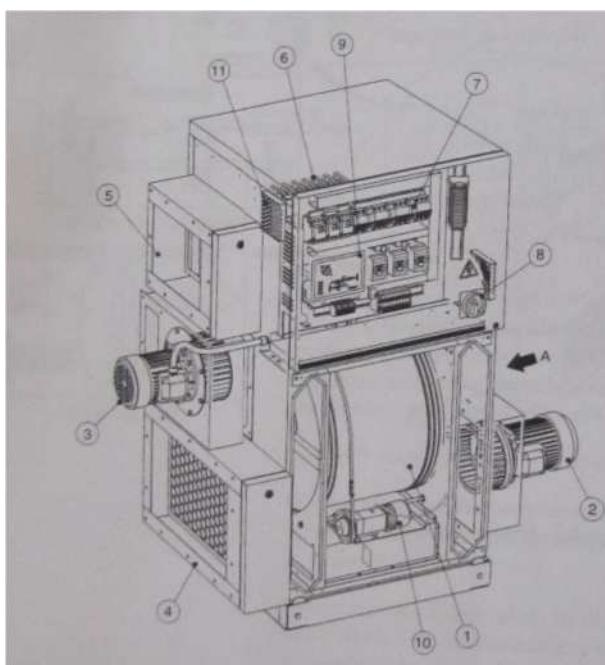
Explosion Limits: Lower 1.4% Vol
Upper 8.0% Vol

Density at 15°C 0.7-0.74 g/cm³

Vapour Density at 20°C 3-4

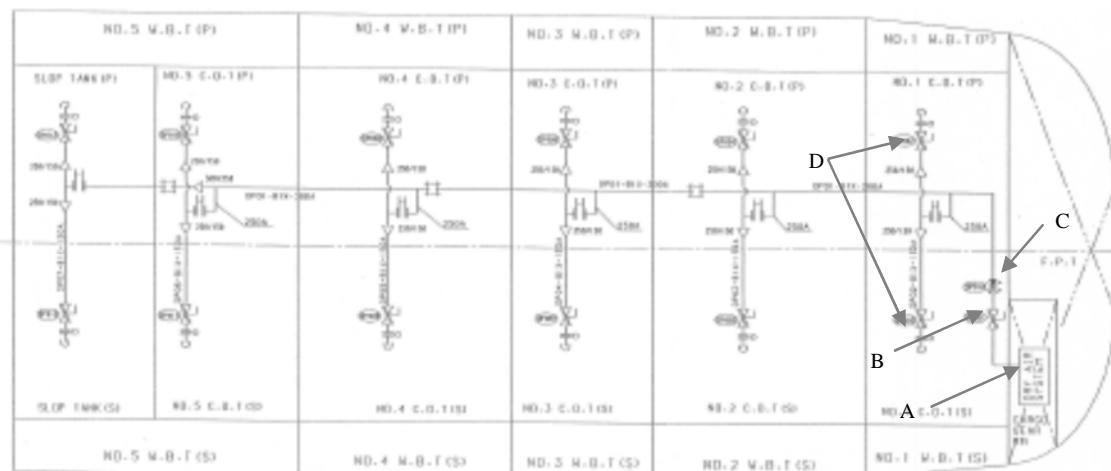
DE-HUMIDIFIER SYSTEM DESCRIPTION

- 5.12 The system consists of a dehumidifier manufactured by MUNTERS in Korea, type MX7600 intended solely for the dehumidification of air for many applications and wide number of industries.
- 5.13 The unit was designed and manufactured by an EN-ISO 9001 accredited development and manufacturing organization, The units also conformed with the specifications in the machinery directive 98/37/EEC, the low voltage directive 73/23/EEC as amended by directive 93/68/EEC and the EMC directive 89/336/EEC as amended by directive 92/31/EEC and 83/68/EEC.
- 5.14 The dehumidifier is designed to process airflows of 7600 m³/hr. All the functional components are enclosed in a case.



1. Rotor
2. Process air fan and motor
3. Reactivation air fan/motor
4. Process air filter
5. Reactivation air filter
6. Reactivation heater
7. Electric control panel
8. Mains power isolator
9. Switch panel ad temp. display
10. Rotor drive motor
11. Cooling fan

- 5.15 The system is designed to deliver dry air into and air pump which pressurises the line leading to deck.
- 5.16 The unit is connected in line with a fan manufactured by a Norwegian company, NYBORG AS.
- 5.17 While the fan was seen to be built to an explosion proof type, the de-humidifier was not seen to be Ex proof type



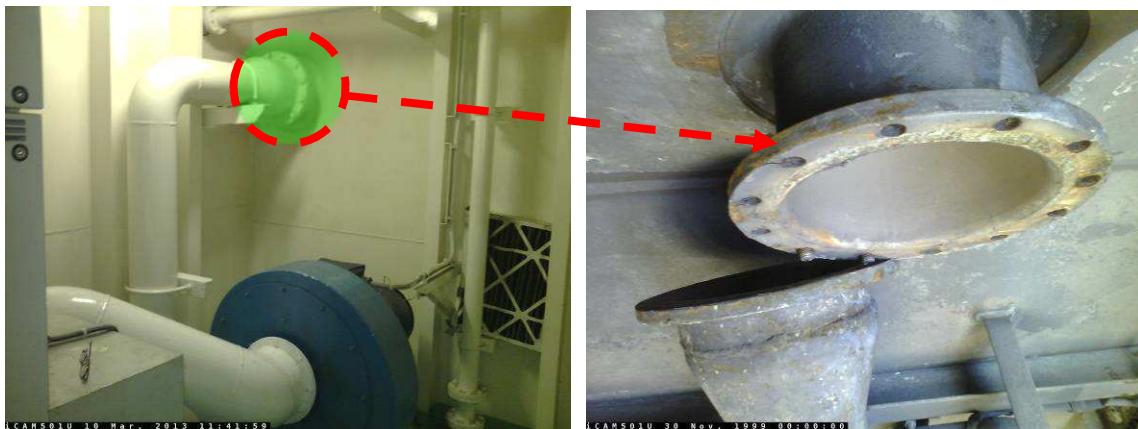
Item	Description		
A	De-humidifier and air fan in bosun's store		
B	Hand -operated isolation valve		
C	Non-return valve		
D	Manually operated tank valves		

- 5.18 The de-humidifier (A) is built inside the bosun store in the starboard aft end. The unit is connected to an air fan which is directly connected to the dehumidifier line. The de-humidifier line is fitted with two safety valves, one hand operated isolating valve (B) and a non-return valve valve (C) to avoid leaking into the de-humidifier room. Additionally, the line is fitted with a small hand operated valve (D) fitted on each individual tank

- 5.19 It was confirmed by the operators that a safety warning was already sent to keep the line blanked with the non-return valve (spool piece) removed due to foreseen dangers of vapours leaking into the room. The email print out was posted onboard.
- 5.20 Despite the email sent and post-it on the control room the non-return valve (spool piece) remained in position and was reported to never been removed.

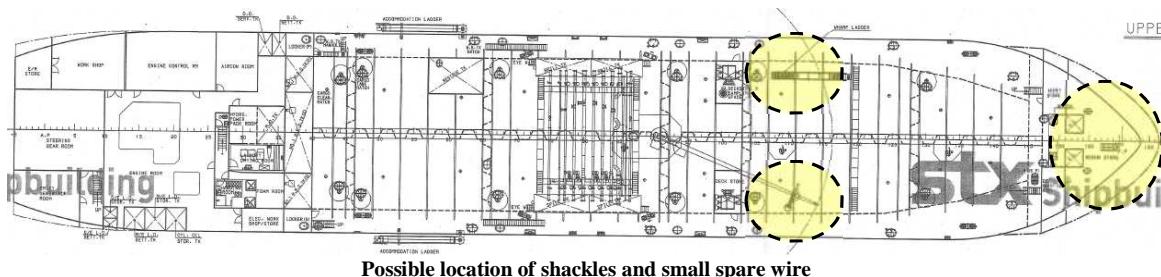
CLEANING PREPARATION OF TANKS FOR LOADING

- 5.21 The tanks were cleaned at sea prior arrival to the Port of Lavera, France with sea water for 1 hour through the fixed tank washing nozzle.
- 5.22 Cleaning was then followed by 2 hours of hot water at a temperature of 70° C. Water is heated with deck steam heat exchangers. Cleaning was then completed with 10 minutes of hot fresh water. After completion of cleaning operations, the tanks were dried for 5 hours with the de-humidifier.
- 5.23 Drying of tanks was done with the de-humidifier fitted on the aft starboard side of the bosun store.
- 5.24 The dehumidifier was locally started and switched off locally from the dehumidifier room by the Bosun. Chief Officer was said to be normally in the Cargo Control Room
- 5.25 Upon completion of tank drying, the Nitrogen system was started to inert the tanks.
- 5.26 The dehumidifier system lines were also used to by-pass tanks for quicker innerting flow between tanks.
- 5.27 It was said by the Chief Officer during the interviews that a thin sheet of copper was used to isolate the pipe from inside the dehumidifier room although he never saw such blank. No traces of copper were seen on the damaged line



PRE ACCIDENT

- 5.28 On the 3rd March 2013 a number of crew were undergoing familiarisation with the vessel and at around 13:00 hrs prior to entering the bosun's store they sensed a cargo/paint smell at the time of opening the forecastle entrance. The crew was being guided by the safety officer. There is no evidence that this odour was reported either to the Chief Officer or the Master.
- 5.29 Daily readings of O₂, HC and H₂S in several locations, including the forecastle area/bosun store are recorded as shown in Document 07.03.10-01 "Deck Spaces gas check Record" (see Appendix 1). However, sheets are not signed and feature only a hand annotation with one time recorded the day before the accident.
- 5.30 Information derived from statements indicated that checks were normally carried out daily at the same time. During familiarisation four crew members entered the forecastle around same time as gas checks but no abnormal readings were recorded despite the smell reported.
- 5.31 During the interviews it was mentioned that a number of tanks were losing pressure at a considerable rate hence the need to top up pressure with the nitrogen system.
- 5.32 On the 5th March 2013 the nitrogen system was used to inert top up pressure
- 5.33 The tanks 5 port, 5 starboard and slop tank starboard low pressure alarms were activated hence the need to top up on the 6th March 2013
- 5.34 Prior the explosion the Bosun was supervising the making of a pilot ladder on the aft deck and the repair of the provision crane securing shackle by two able seamen.
- 5.35 While repairing the shackle the Bosun mentioned to the able seamen that he would go to get a new shackle to replace the one they were working with. It is unknown where the Bosun went to pick up the shackle but a common place would have been either on the deck storage house situated port or starboard side forward of the manifold or the forecastle deck.



5.36 While the Bosun went to look for a piece of wire and the shackle, the two crew members, sat and talked while watching their watches in view of tea time.

5.37 There were no indications that the bosun store and any area of the forecastle area were being used to stow chemicals or paints. All chemicals seen onboard were stowed midships on deck in blue plastic barrels.



Location of chemicals onboard

5.38 It is likely that the Bosun went to the forecastle, opened the door and found the forecastle lights on, which were confirmed to be always switched on. He stepped in and closed the door behind him. Immediately after closing the door he switched on ventilation since it is assumed that he would have noted a strong smell inside.



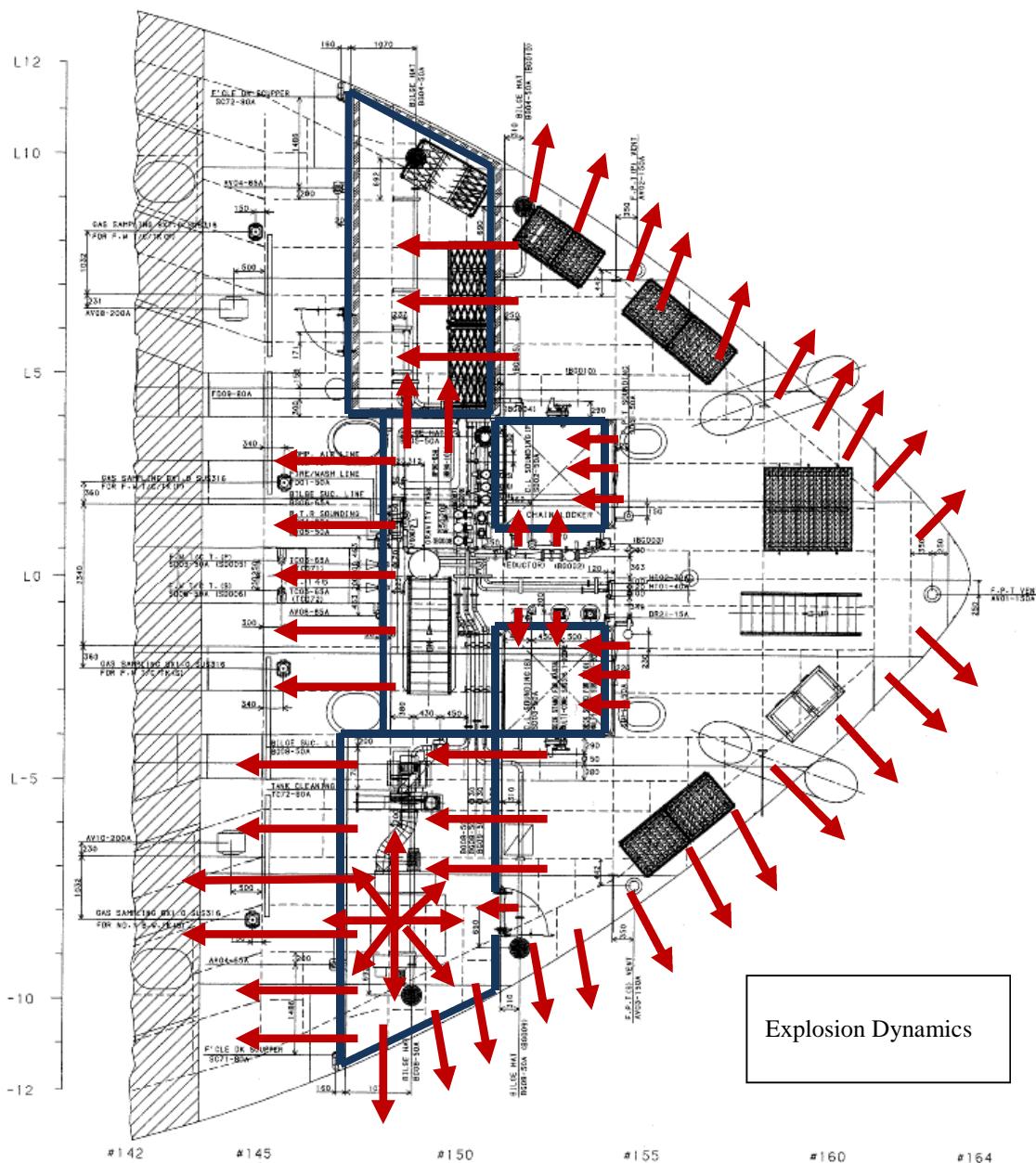
Entrance to forecastle as viewed from upper deck

View of switches easily reachable from inner side of entrance

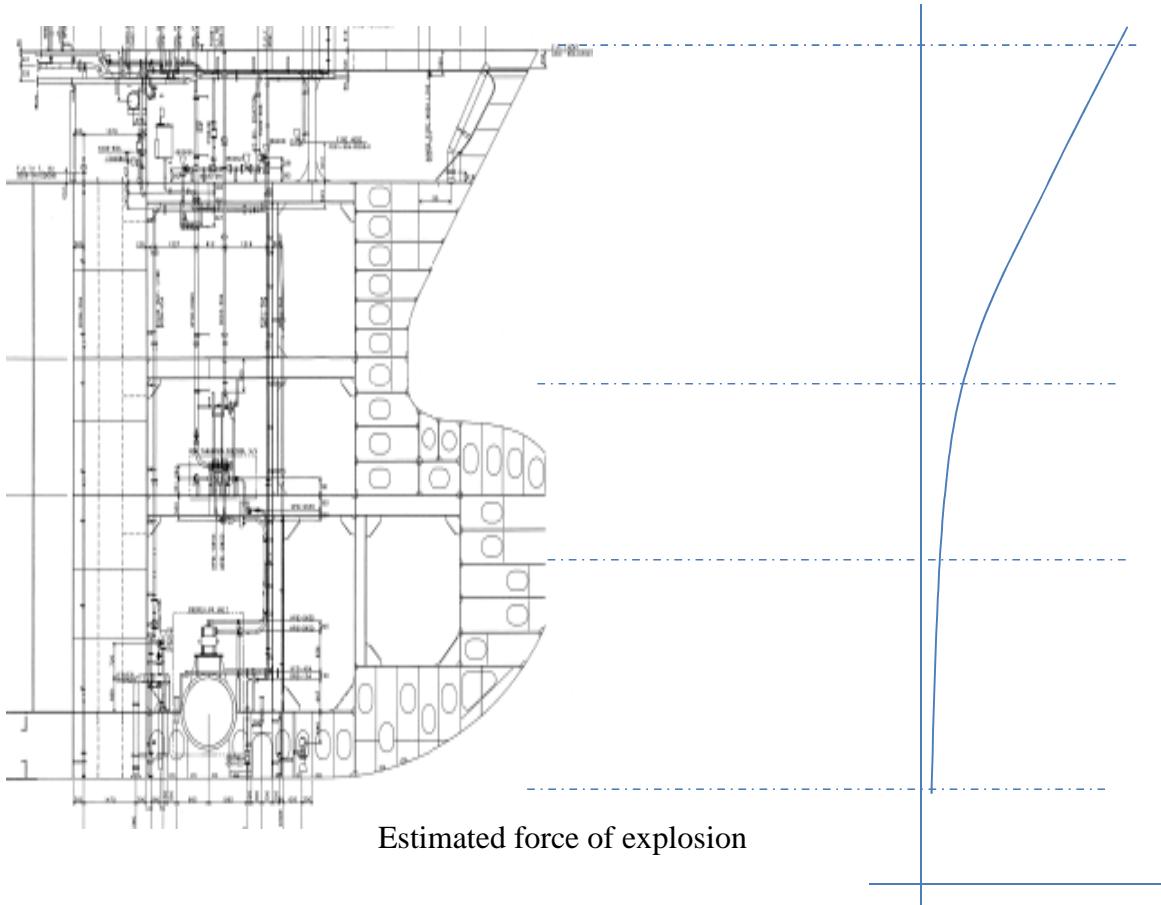
5.39 The ventilation fan was confirmed to be composed of a non-explosion proof electrical motor.

EXPLOSION DYNAMICS

- 5.40 The below diagram shows the force vectors showing the path of the explosion. The direction of travel and the burned material on the starboard side denotes that the starting point of the explosion or the ignition point was in way of the ventilator motor fitted at frame #157 near the centre line to the port side.
- 5.41 The explosion moved towards the interior of the de-humidifier where the second gas pocket caused the second explosion, disintegrating the de-humidifier. It was confirmed by several officers and crew that two consecutive explosions were heard, however other testimony differs on this point.



- 5.42 The force of the explosion was greater on the upper deck and gradually decreases its pressure towards the bottom decks. Therefore gas vapours were mostly concentrated on the upper levels.



- 5.43 The force of the explosion seems to be more powerful towards the upper deck starboard side.

POST EXPLOSION

- 5.44 From the muster station, Chief Officer and 2 crew members went forward to search for the missing Bosun on deck.
- 5.45 While mustering most of the crew were expecting a second explosion at any time due to the nature of the cargo. Despite fears of a second explosion and the type of cargo being carried the crew behaved in a very professional and co-ordinated way.
- 5.46 The Master altered the course of the ship to clear the smoke from upper deck. However, no search for the Bosun in the water was initiated since at that time it was assumed he was possibly inside the forecastle.

- 5.47 Once the forecastle area was safe to be entered further search for the Bosun was made inside with negative results. The Bosun was not found.
- 5.48 Only the Bosun's safety shoe was found on the starboard side of the forecastle deck.
- 5.49 All deck valves were hydraulically tested on the 13th April 2013



Isolating valve under testing



Tank valve leaking during test

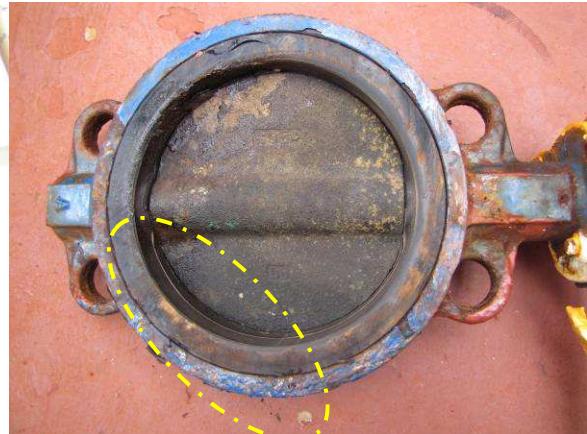


Non-return valve heavily leaking without pressure

- 5.50 The hydraulic tests concluded that all the tank hand valves were seized and could not be properly closed. The main manually operated valve could not close watertight and the non-return valve was not tight and fit for its purpose.



Isolating valve in closed position but not watertight



Tank valve in closed position with gap as marked



Isolating valve in closed position but in line with colours



Tank valve in closed position not at right angle to line

- 5.51 At the time of removal of the valves many were seen to be not closing properly and this could be seen either because the indicator was not parallel to the close position or the valve was not at a right angle to the line.
- 5.52 All light fittings on the forecastle area were of an explosion proof type. However the ventilator motor, de-humidifier and other electrical panels fitted on the forecastle were not explosion proof.

6 CONCLUSIONS

- 6.1 The only possible source of the vapour to cause the explosion was the cargo. Cargo vapours had to flow while tanks were pressurised through the de-humidifier line passing the small individual tank valve, the common non-return valve and the main common isolating hand valve. Additionally it would have to leak through a blank, traces of which were never seen hence concluded in all probability to be not in place at the time of the incident.
- 6.2 Although all tank lines were said to be closed, valve tests revealed that a number of those tanks were leaking and their condition was fair. Valves were confirmed by the workshop as not closing properly without excessive force.
- 6.3 Despite the safety email sent on December 2007 from the operator requesting all ships in their fleet fitted with similar de-humidifier system to remove the spool piece (non-return valve), the piece was in place and was confirmed as never having been removed. In fact removing the spool piece is not an easy job due to its high position and weight.
- 6.4 It was claimed that a blank was inserted by the Bosun on the line in the interior of the de-humidifier room. No evidence of a copper blank in the line was observed on the de-humidifier line. The installation of such a blank was never verified by an officer.
- 6.5 None of the valves were included in the maintenance system. Hydraulic tests on valves revealed that they were all partially seized due to lack of maintenance and that valves from 1 Port, 1 Stbd, 2 Port, 3 Stbd, 5 Stbd, main isolation valve and non-return valve were leaking.
- 6.6 All work carried out by the Bosun, also acting as pumpman was not properly supervised by an officer.
- 6.7 From the observed damage and the destructive nature of the explosion it was clear that this was a chemical explosion characterized by the presence of a fuel vapour. The elevated pressures that pushed all bulkheads and ripped off the hatches were created by the rapid burning of the fuel and the rapid production of combustion by gas and oxygen.
- 6.8 The speed of the flame and the propagation of the same seem to determine that the reaction was of a detonation type. Detonation is a reaction that propagates at supersonic speed of more than 335 metres per second. On the other hand a deflagration type travels at subsonic speeds and is more easily vented. The speed of the detonation is faster and cannot be vented because of the reaction speed.
- 6.9 The fact that a safety shoe is found on the forecastle deck and that the door was completely gone implies that it is likely that the Bosun opened the forecastle door, stepped in and immediately closed the door behind him turning on the ventilation which most likely caused the explosion.

- 6.10 The effect of the explosion had likely pushed the Bosun into the door and ripped off the door overboard. Hatch covers and closing vent pipe hatches were also ripped off.
- 6.11 The fact that one shoe is found is due to the fact that crew tend to have a larger shoe size to slip off their shoes when entering the accommodation clean areas without touching the shoe knot. This habit was observed among the crew onboard. They were able to take off their shoes hardly touching the safety boot.
- 6.12 The de-humidifier operations manual does not issue any warning on the use of the equipment with explosive atmospheres.

7 RECOMMENDATIONS

To the Classification Society

- 7.1 Consider the need to include provisions for explosion-proof electrical equipment in areas or enclosed spaces into which explosive or flammable cargo vapours may escape from cargo systems/tanks.
- 7.2 Consider the need to include forecastle areas containing de-humidifier units within the fixed gas detection system.

To the Company

- 7.3 Consider the difficulty in removal of the spool piece (non-return valve) posed by the weight and position and install improved access and lifting points/equipment.
- 7.4 Initiate a safety campaign among the officers, ratings and crew in view that the smell noted on the 3rd March was not notified and that other number of safety issues were not properly followed.
- 7.5 Include all valves in the Planned Maintenance System and review the PMS for the de-humidifier system e.g. the de-humidifier (“air drier of tank ventilation”).
- 7.6 Review and audit the implementation of the Safety Management System related to oversight, safety checks, work standards, maintenance, inspections and duties onboard.

Appendix 1

Deck Spaces Gas Check Record

Chapter : Shipboard Operations - Cargo Topic : Deck Spaces Gas Check Record		07.03.10-01 Page 1 of 1										
Safety Management System												
Vessel:	HARBOUR KRYSAL		Date: 03.03.2013									
			Voyage No. 110									
Date	03.03.13			04.03.13			05.03.13					
	Result	O2 %	HC	TOXIC GAS		TOXIC GAS		O2	HC	TOXIC GAS		
Name				ppm	O2	HC	Name			ppm	Name	ppm
Store Name												
BOSUN STORE	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
DEHUMIDIFIRE R.	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
BOW THRUST R.	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
PAINT LOCKER	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
HEATER ROOM	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
SAMPLE STORE	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
SEMPREP ROOM	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
DECK STORE STS	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
CO ₂ ROOM	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
SAFETY LOCKER	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
CARGO AREA 1PYS	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
CARGO AREA 2PYS	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
CARGO AREA 3PYS	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
CARGO AREA 4PYS	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
CARGO AREA 5PYS	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
CARGO AREA SLOP	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
MANIFOLD PORT S.	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
MANIFOLD PORT F.	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
Comments	12.28'											
Signature												
Issued Date : 03.03.10	Issued by : SVT	Office/Visser : /COSS										
Revision Date : 31.03.12	Approved by : SVT											
Review No. : 3												

Chapter : Shipboard Operations - Cargo Topic : Deck Spaces Gas Check Record										DOCUMENT 07.03.10-01		
Safety Management System										Page 1 of 1		
Vessel:	HARBOUR KRYSYAL				Date:	06.03.2013						
					Voyage No.	110						
Result	Date		06.03.2013		07.03.2013		08.03.2013					
	O2 %	HC	TOXIC GAS		O2	HC	TOXIC GAS		O2	HC	TOXIC GAS	
			Name	ppm			Name	ppm			Name	ppm
Store Name												
BOSUN STORE												
DEHUMIDFIRE R.												
BOW THRUST R.												
PAINT LOCKER	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	G
HEATER ROOM	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
SAMPLE STORE	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
SEMPEP ROOM	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
DECK STORE STS	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
CO ₂ ROOM	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
SAFETY LOCKER	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
CARGO AREA 1P/S	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
CARGO AREA 2P/S	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
CARGO AREA 3P/S	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
CARGO AREA 4P/S	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
CARGO AREA 5P/S	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
CARGO AREA SLOP	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
MANIFOLD PORT S.	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
MANIFOLD PORT F	20.9	0	H2S	0	20.9	0	H2S	0	20.9	0	H2S	0
Comments												
Signature												

Issued Date : 01.10.10
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