Report on the investigation of the

escape of Vinyl Chloride Monomer onboard

Coral Acropora

Runcorn, Manchester Ship Canal

10 August 2004

Marine Accident Investigation Branch
Carlton House
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Southampton
United Kingdom
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Report No 4/2005
March 2005

Extract from

The Merchant Shipping

(Accident Reporting and Investigation)

Regulations 1999 – Regulation 4:

"The fundamental purpose of investigating an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 1999 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."

NOTE

This report is not written with liability in mind and is not intended to be used in court for the purpose of litigation. It endeavours to identify and analyse the relevant safety issues pertaining to the specific accident, and to make recommendations aimed at preventing similar accidents in the future.

CONTENTS

GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AB	-	Able Seaman
BA	-	Breathing apparatus
Bar	-	A unit of pressure, equal to the sea-level pressure of Earth's atmosphere; 1 bar = 0.987 atmosphere = 101,300 pascals = 14.5 lbs/square inch = 100,000 Newtons per square metre
Barg	-	The abbreviation for **bar gauge**, a common unit of pressure in engineering. The term "gauge" means that the pressure has been read from a gauge that actually measures the difference between the pressure of the fluid or gas and the pressure of the atmosphere.
CCR	-	Cargo Control Room
CDI	-	Chemical Distribution Institute
COMAH	-	Control of Major Accident Hazards (COMAH) Regulations 1999
DNV	-	Det Norske Veritas
ESD	-	Emergency Shutdown
EVC	-	European Vinyls Corporation
HHLA	-	High High Level Alarm, set on this vessel at about 98% tank volume
HLA	-	High Level Alarm, set on this vessel at about 95% tank volume
HSE	-	Health and Safety Executive
HSL	-	Health and Safety Laboratory
ICS	-	International Chamber of Shipping
IGC Code	-	International Gas Carrier Code
IMO	-	International Maritime Organization
ISM	-	International Safety Management
MARVS	-	Maximum allowable relief valve setting, set on this vessel at 9.3barg
OCIMF	-	Oil Companies International Marine Forum

OOW	-	Officer of the watch
PHAST	-	Process Hazard Analysis Software Tool
PPE	-	Personal protective equipment
PPM	-	Parts per million of vapour-in-air by volume
RPE	-	Respiratory Protective Equipment
SCBA	-	Self contained breathing apparatus
SIGTTO	-	Society of International Gas Tankers and Terminal Operators
SIRE	-	Ship's Inspection Report
SMPEP	-	Shipboard marine pollution emergency plan
SOPEP	-	Shipboard oil pollution emergency plan
TLV	-	Threshold Limit Value of a gas in air is the required concentration of a substance to cause damage to living tissue, including impairment of the nervous system. TLVs in most countries' advisory systems are republished annually and updated in light of new knowledge.
TWA	-	Time Weighted Average is the concentration of vapour in air which may be experienced for an 8-hour day or 40-hour week throughout a person's working life.

SYNOPSIS

The gas carrier *Coral Acropora* was alongside the EVC berth at Runcorn on the Manchester Ship Canal when there was an escape of part of her cargo of Vinyl Chloride Monomer (VCM). At the time of the accident, she had been preparing to start to discharge her cargo into shore cargo tanks situated about 3 kilometres from the berth.

On arrival at the berth, a cargo surveyor had boarded the vessel and, after calculating the cargo quantity, he had asked the chief officer to run a cargo pump in each tank as he took cargo samples. The chief officer had not been aware of the need for sampling and he had not made preparations or planned for it. However, he acceded to the request without including the operation in the discharge plan. The chief officer opened the valves on the aft tank, which allowed recirculation of the cargo in that tank. He then started the aft tank cargo pump using local controls sited on the tank top.

The cargo surveyor began filling his sample cylinder from the designated tank sampling point. After a few minutes, the cargo alarm klaxon sounded on deck. The chief officer walked around the tank dome and, using a local control, stopped the klaxon from sounding. He assumed the alarm indicated that the cargo pump had tripped, but he could not be certain without going to the cargo office. A few moments later, the klaxon sounded again. The chief officer then noticed a large cloud of white vapour advancing down the deck towards him. He quickly ran aft, taking hold of the cargo surveyor and pulling him with him, hitting the emergency shutdown (ESD) button as he passed by. They managed to reach the shelter provided by the accommodation before the cloud overtook them.

A little under 600 kilograms of liquid and vapour VCM had erupted from the vessel's forward cargo tank mast riser after the forward tank had become over-pressurised.

Despite the vessel having, what appeared on paper to be, a good operations and safety management system, cargo valves had been habitually left in the open position and safety features had been routinely overridden. These practices resulted in cargo being transferred inadvertently from the aft cargo tank to the forward cargo tank during the sampling process.

The vessel's crew, the port agency representative, the cargo surveyor, two terminal staff who had been connecting the manifold, two people on the berth and a number of members of the public were exposed to VCM as the resulting gas cloud drifted downwind.

The Health and Safety Laboratory (HSL), an executive agency of the Health and Safety Executive (HSE), modelled the release of VCM and found the principal consequent risk to have been that of flash fire within about 50 metres of the escape. Their calculations showed no credible hazard from toxicity.

Soon after the accident, the MAIB issued a Safety Bulletin advising all tanker operators on the importance of ensuring that good tanker practice is observed at all times during cargo operations. Further recommendations have been made to the vessel's owners, the charterer and berth operator, SIGTTO, OCIMF and ICS. These are aimed at reinforcing the message that terminal and vessel operators should check and ensure that safety management systems are working in practice and that cargo operations, in particular, are always conducted in accordance with industry guidelines.

Figure 1

Coral Acropora alongside at Runcorn

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *CORAL ACROPORA* AND ACCIDENT (Figure 1)

Vessel details

Registered owner	:	Rederij MV "Coral Acropora"
Vessel manager	:	Anthony Veder Rederijzakeen BV
Port of registry	:	Willemstad
Flag	:	Netherlands Antilles
Type	:	Liquefied Gas Carrier
Built	:	1993 YVC Ysselwerf BV
Classification society	:	Bureau Veritas
Length overall	:	101.48 metres
Gross tonnage	:	3096
Cargo Volume	:	3219 cubic metres at 100%, 3154 cubic metres at 98%
Cargo tank deepwell pumps	:	Fwd tank pump – 200m³/hour Aft tank pump – 400m³/hour

Accident details

Time and date	:	1110 (UTC+1) 10 August 2004
Location of accident	:	Alongside the lay-by berth at Runcorn
Persons on board	:	11
Injuries/fatalities	:	At least 33 people exposed to vapour
Damage	:	None

1.2 BACKGROUND

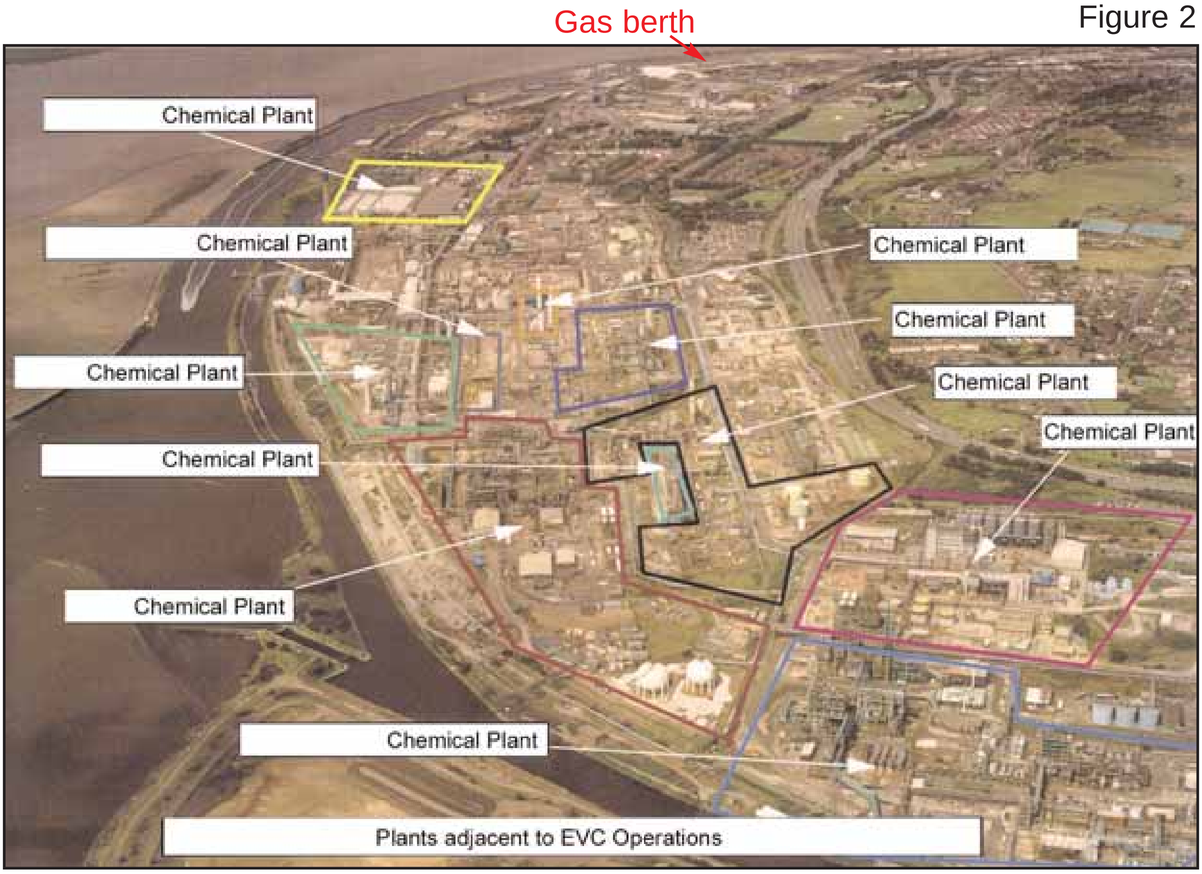
1.2.1 General

Coral Acropora was bareboat chartered by the vessel owners to a company in the Netherlands Antilles which, in 2002, time chartered her to EVC Ltd. This was the only vessel that EVC chartered. Due to a lack of marine chartering knowledge and expertise, EVC engaged the services of a logistics company named Agility to undertake the charterers' day to day functions in respect of the vessel. Agility's role included communicating the cargo requirements and scheduling to the master, arranging bunkers and appointing port agents.

EVC Ltd also owned and operated the terminal at Runcorn, situated on the south bank of the Manchester Ship Canal. The berth was originally a canal lay-by berth and the necessary infrastructure, such as gas piping, controls and security were added in 1998. The berth was about 3 kilometres from the EVC chemical plant where the storage tanks were located. The cargo was pumped via pipelines to and from the plant **(Figure 2)**.

The vessel was usually employed loading VCM from the EVC chemical plant in Runcorn and discharging the cargo into another EVC chemical plant at Barry, Glamorgan. At the time of the accident, due to shore maintenance at the plant in Runcorn, *Coral Acropora* was being used to import VCM from continental ports to build up the plant's VCM stock. It was the intention for *Coral Acropora* to return to the Runcorn/Barry route once the stock of VCM at Runcorn had been built to sufficient levels.

Figure 2



Aerial photo of MSC terminal and chemical plants

1.2.2 Gas carriage at sea

Gas carriers transport their cargo in tanks under a positive pressure to prevent air entering the cargo system and forming a flammable atmosphere. All gas carriers utilise closed cargo systems when loading or discharging, to ensure no vapour is vented to the atmosphere. Cargo release to the atmosphere is virtually eliminated by this system and the risk of vapour ignition is minimised.

Transportation of gas by sea carries a wide range of operational risks, therefore, gas carriers must comply with the international standards set by the IMO gas codes, as well as all safety and pollution requirements common to other vessels.

The potential for serious consequences resulting from an accident are obvious, however, the gas tanker industry has a very good safety record, underpinned by well-trained and experienced personnel and thorough operational systems.

1.2.3 *Coral Acropora*

Coral Acropora is a semi-pressurised gas carrier. For the previous 2 years the vessel has been exclusively serving EVC's shipping needs.

The total complement onboard at the time of the accident was 11 people, whose nationalities were Ukrainian, Latvian, Russian and Georgian. The common language spoken onboard was therefore Russian, although the officers and crew were also proficient in English which was the company established working language. The crew on the day of the accident comprised a master, chief officer, second officer, chief engineer, fourth engineer, a bosun, two ABs, an oiler, a cook and the wife of the second officer. The number of crew on board *Coral Acropora* was in excess of the safe manning certificate, which only required 7.

1.3 NARRATIVE

(All times are UTC+1)

Coral Acropora completed loading approximately 2804 tonnes of VCM at 0345 on 7 August 2004, and sailed from Rotterdam at 0810 the same day.

Upon completion of loading, many of the cargo valves which were not required to be open were not shut. This was the chief officer's normal operational procedure.

The vessel's two cargo tank loaded volumes were:

Tank	Volume	Sounding	98% alarm setting
Aft Tank (No 1)	98.10%	7403mm	7425mm
Forward Tank (No 2)	97.98%	7525mm	7557mm

The cargo temperature upon completion of loading was found to be 28°C, which was higher than the normal 20°C carriage temperature. The chief officer was therefore required to reduce the cargo temperature during the loaded passage to Runcorn. Each morning, during the loaded voyage, the chief officer ran the cargo refrigeration system taking vapour from the two cargo tanks, passing it through the liquefaction plant and returning the resulting condensate to the cargo tanks. The chief officer mistakenly believed, even after this process, that the forward tank was loaded to beyond the 98% alarm setting.

The vessel arrived at the entrance to the River Mersey on the evening of 9 August, and anchored at 2155.

The anchor was heaved up the next morning at 0455, and the vessel entered the River Mersey. The chief officer was called at about 0500, and went to the bridge at 0600 to take over the watch from the second officer. The vessel passed through the canal locks and into the Manchester Ship Canal, and began the transit towards her berth situated on the south bank of the canal.

The chief officer went on deck just prior to berthing to complete the usual pre-arrival cargo checks. He checked the 98% high-high level alarms (HHLA) on the aft tank by locally switching the pneumatic loading valve **D (Figure 3)** to the open position, and confirming the valve remained shut. The 98% alarm had been activated by the vessel's movement during the voyage and, at that time, had not been accepted and cancelled. The chief officer believed that this tank was loaded to below the 98% alarm setting, so he switched the local valve control back to the shut position, to stop the valve from opening once the 98% alarm was accepted and cancelled.

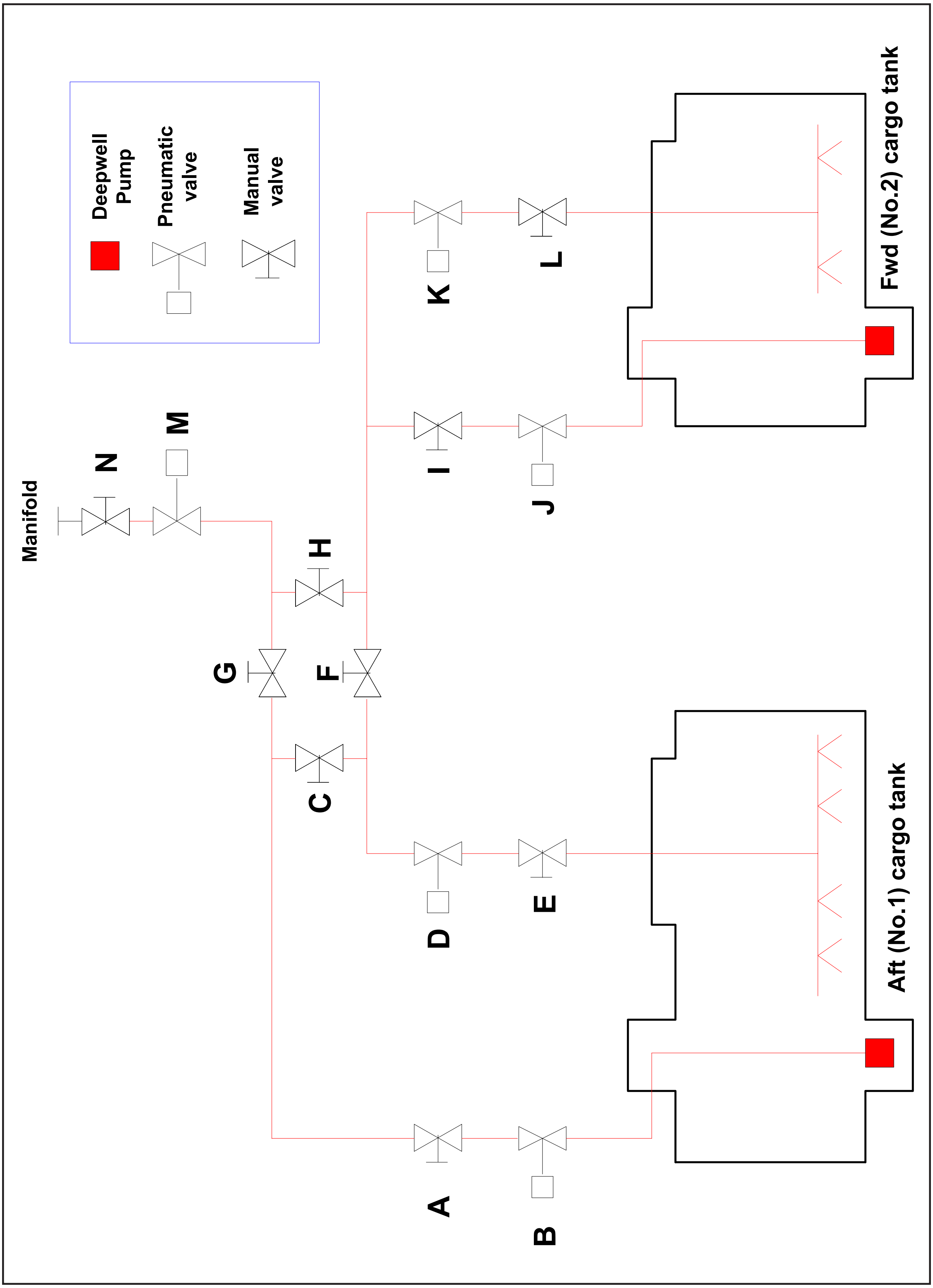
At the forward tank, the chief officer confirmed the pneumatic loading valve **K** remained shut when switching it locally to the open position. However, he left this valve control in the open position, because he wrongly believed the tank was loaded above the 98% alarm setting and therefore it would remain shut when the 98% alarm was later accepted and cancelled **(Figures 4 & 5)**.

The chief officer's usual practice was to leave many of the manual cargo valves open, and to operate the cargo system using the pneumatic cargo valves alone. At the time of the accident manual valves **A, C, E, F, G, H, I & L** were all open.

The chief officer went forward to his mooring station. The vessel was moored starboard side alongside the "lay-by" berth at Runcorn, and was all fast at 1030.

The chief officer then lowered the ullage floats to enable cargo gauging.

The vessel's gangway was rigged by the crew and a representative from the local port agency boarded her, along with a cargo surveyor. The agency representative went to the master's office to undertake the routine arrival procedures. The cargo surveyor went to the cargo office with the chief officer and began calculating the cargo quantity.



Relevent valve and piping arrangement - Basic

Figure 4

Forward tank pneumatic valve controls

Figure 5

Forward tank loading valves

It was found that the temperature of the cargo had been successfully reduced to about 20°C and the resulting cargo tank volumes were:

Tank	Volume	Sounding	98% Alarm setting
Aft Tank (No 1)	96.27%	7155mm	7425mm
Forward Tank (No 2)	97.45%	7439mm	7557mm

The chief officer did not notice that the forward tank was not loaded to over 98% as he had believed.

At 1046, the AB on deck watch went to the manifold and removed the manifold blank in preparation for the shore loading arm being connected **(Figure 6)**.

Shortly afterwards, two shore operators boarded the vessel and went directly to the manifold area and rigged the manifold gas alarm unit. At 1052, they swung the shore loading arm over the vessel and began connecting it to the vessel's cargo manifold **(Figure 7)**. The chief officer noticed that they were onboard and connecting the loading arm.

Upon completing the cargo calculations, the cargo surveyor advised the chief officer he wanted to take cargo samples from both cargo tanks, and that he also would require the individual tank cargo pump to be run to circulate the cargo in each tank as he obtained the samples.

The chief officer had not expected samples to be taken, or the cargo pumps to be run prior to cargo discharge operations, and he had not made preparations for it. However, he telephoned the engineer on watch in the engine room to advise him he required the use of the cargo pumps.

The chief officer then switched the forward cargo tank 98% HHLA to the override position (the alarm has a cargo pump interlock stopping the pumps while the alarm is active), so he could start the cargo pumps **(Figure 8)**. At about this time, he accepted and cancelled all the alarms on the cargo office mimic board that had been displayed during the sea passage. However, in doing so, he did not notice the forward cargo tank HHLA was accepted and cleared.

At about 1100, the chief officer and cargo surveyor proceeded to the deck to take the samples, starting at the aft cargo tank. The chief officer was not wearing breathing apparatus (BA), as required by the owner's instructions. The chief officer opened the aft cargo tank pneumatic loading valve **D** and pneumatic cargo pump discharge valve **B (Figure 9)** and started the aft tank cargo pump, with the intention of circulating the cargo around the aft tank **(Figure 10)**. The cargo surveyor began filling his sample cylinders.

Because other cargo valves were open, unbeknown to the chief officer, the actual cargo flow was as indicated in **Figure 11**.

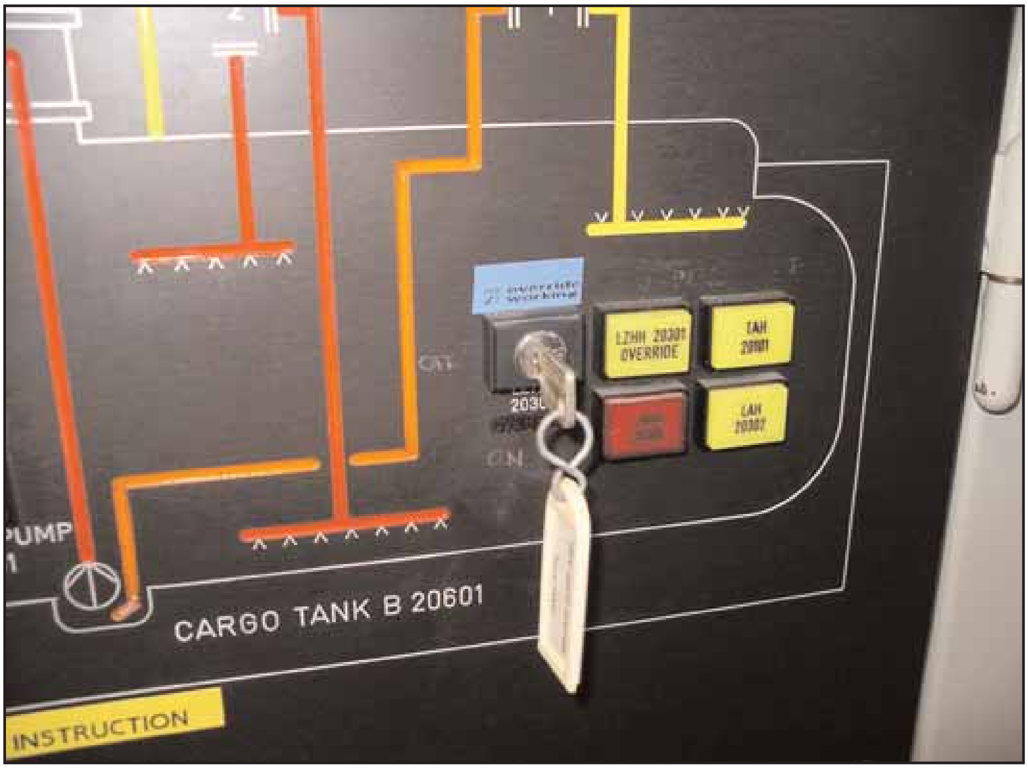
Figure 6

Crewman removing ships manifold blank

Figure 7

Two shore operators connecting the loading arm to ship's manifold

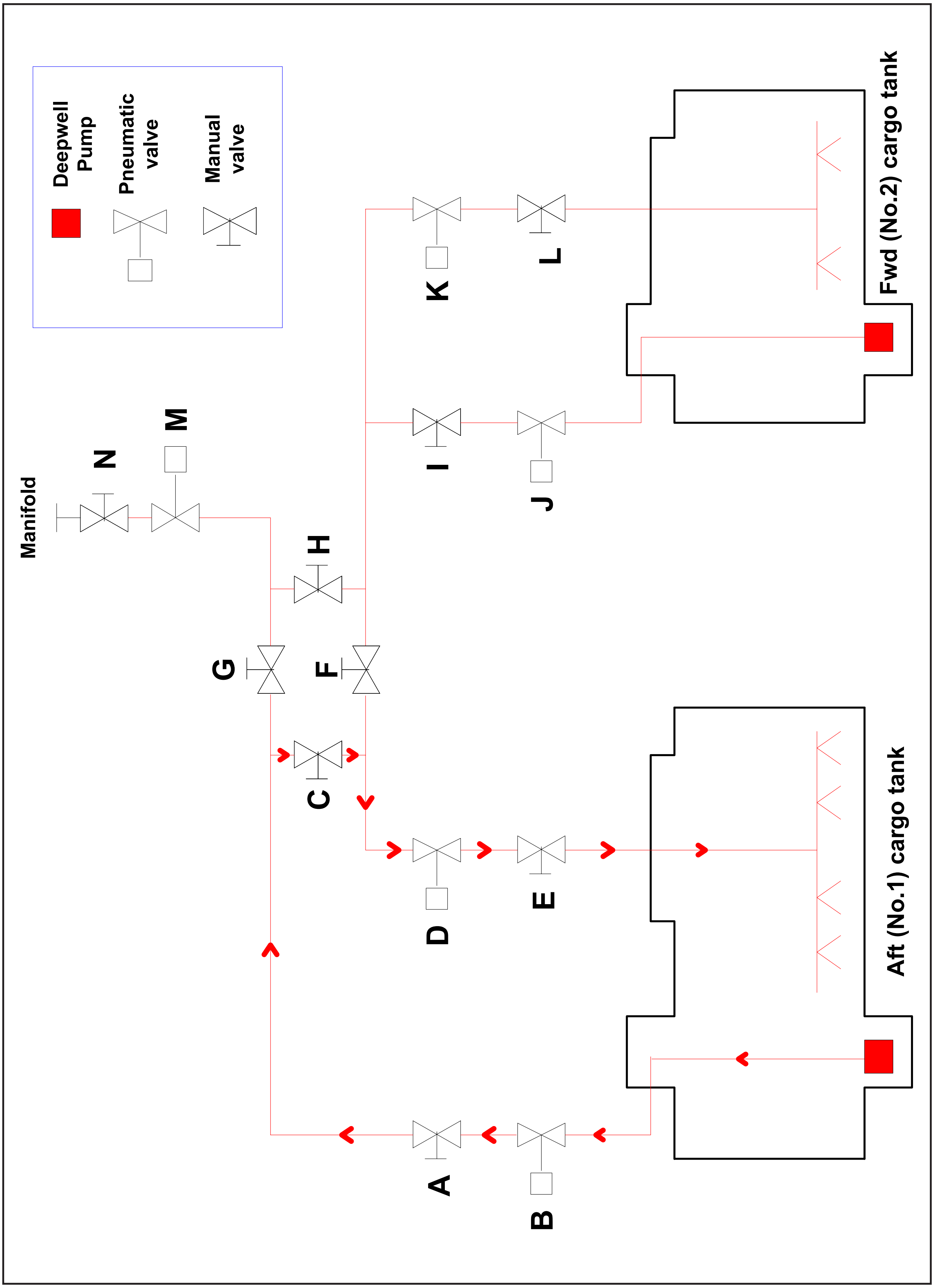
Figure 8



HHLA override key

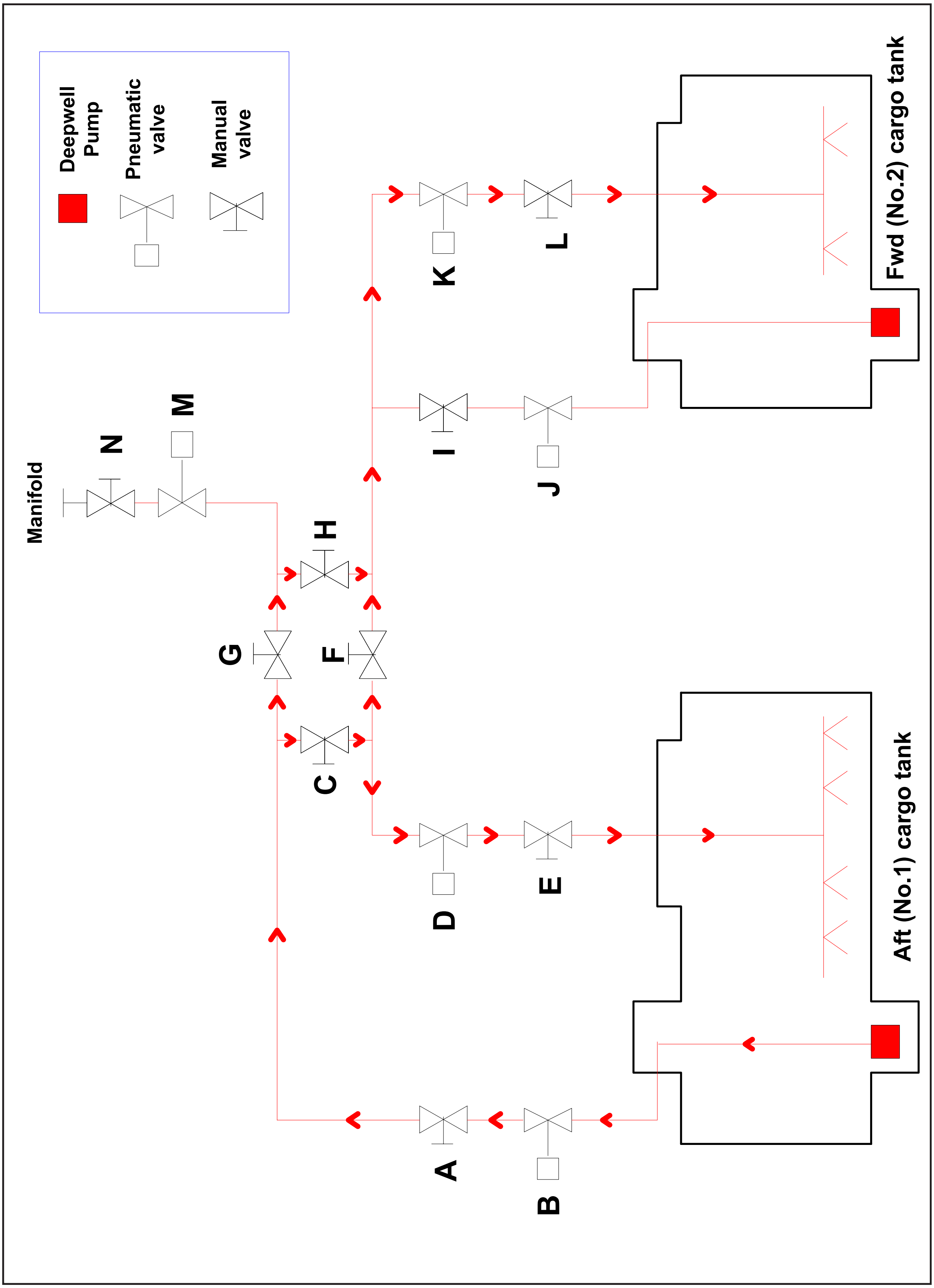
Figure 9

Aft tank discharge valves



Relevent valve and piping arrangement - Intended flow

Figure 11



Relevent valve and piping arrangement - Actual flow

A few minutes later, the cargo alarm deck klaxon sounded, signalling an alarm condition on the cargo consul in the unmanned cargo office. The chief officer thought that the alarm was probably due to the cargo pump tripping, so he locally stopped the klaxon from sounding[1]. A few moments later, the deck klaxon sounded once again[2]. The chief officer now became unsure what the alarms signified. Before he could check, he noticed a white vapour cloud advancing down the deck towards him. He ran aft towards the safety of the accommodation block, taking hold of the cargo surveyor and pulling him with him, and hitting the ESD switch as he passed by **(Figure 12)**. The chief officer and cargo surveyor entered through the starboard accommodation door, closing it behind them, seconds before the vapour cloud arrived.

The two shore operators were putting the bolts into the manifold connection when they noticed the vapour cloud approaching **(Figure 13)**, and they ran from the manifold area towards the gangway to reach safety. However, they were engulfed by the vapour cloud and had to run clear of the berth in visibility of less than 2 metres. Fortunately, both men managed to get away without becoming overcome by the effects of the gas by running upwind once they were ashore. The vessel was enveloped in the vapour cloud for a period of about 6 minutes **(Figures 14, 15 & 16) (Appendix C)**.

“Yellow box”

Figure 12

ESD switch

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[1] The MAIB believes this alarm was probably the forward tank 98% HHLA. The pump continued to run and valves remained open because the alarm safety features were overridden.

[2] The MAIB believes this alarm was probably the forward tank high-pressure alarm which was set at 8.3barg.

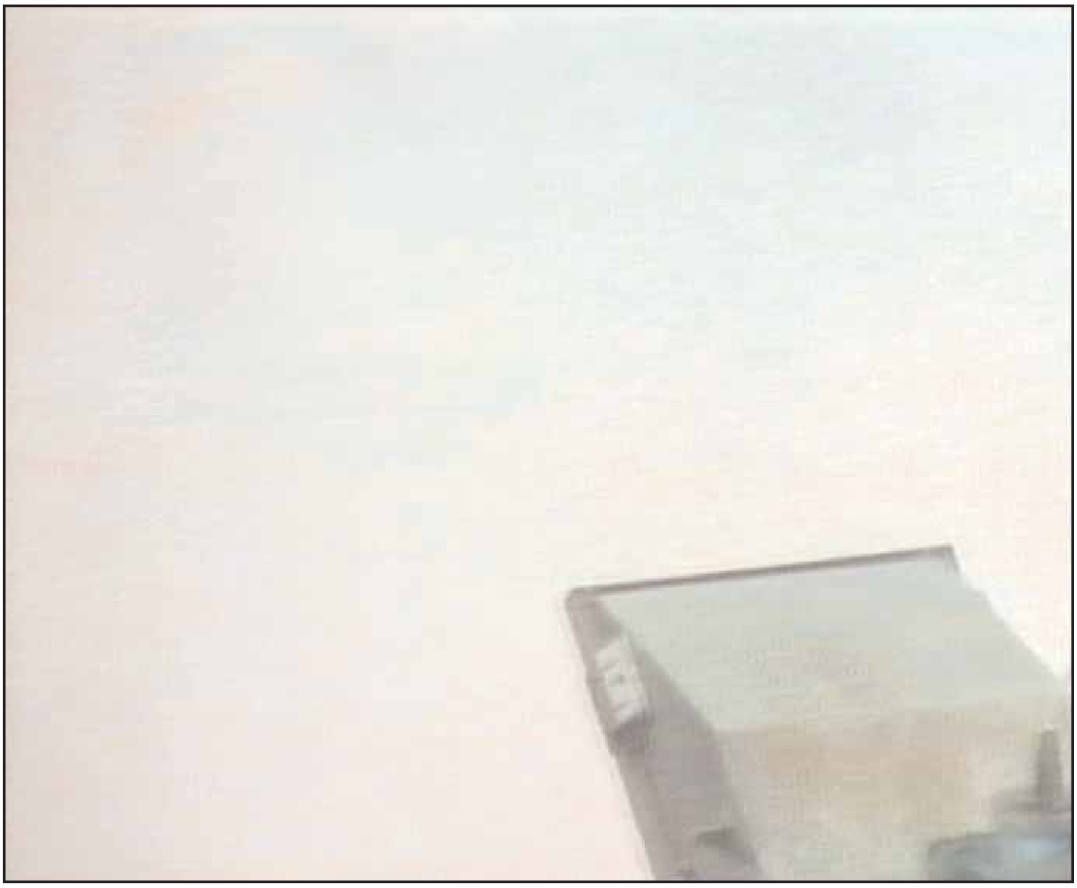
Figure 13

The moment cargo emitted from the mast riser

Figure 14

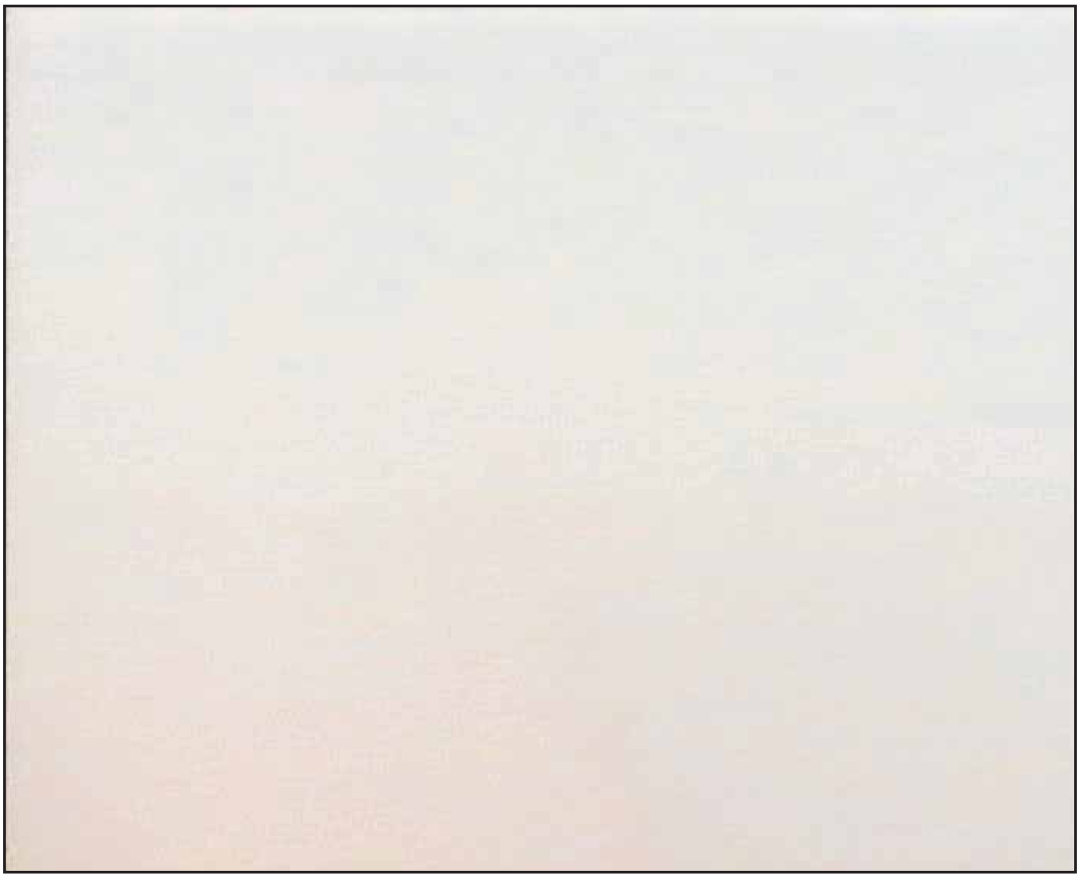
Vapour mist reaches manifold area

Figure 15



Vapour mist thickens

Figure 16



Vapour mist cloud at worst concentration

The chief officer stated that he saw the two shore operators running from the vessel. The deck watch AB also managed to reach the accommodation before the vapour cloud arrived.

At the time of the accident, the master had been completing arrival formalities with the agents' representative in his office. He decided to go to the cargo office to find out why the deck cargo alarms were sounding. On arrival there, the chief officer told him what he knew of the situation. The master noticed that the forward tank pressure readout was indicating 5.5 bar, instead of the usual 2 bar. He asked the chief officer to put on a BA set and investigate the situation on deck. The master then went to the bridge to phone the vessel's owner to inform them of the situation. As he passed his office, he informed the agency representative that there was a small problem on deck and that he should stay where he was in the office.

At 1116, the master telephoned the shipowner's emergency response number, but received no immediate reply. The master then telephoned the owner's normal operations number and reported that cargo had been released into the atmosphere but that the situation was under control. The master was not yet aware that a major emergency response was being activated ashore. The recipient of the call therefore advised the master to make a report and send it to him. The master began writing the report immediately.

At about 1120, the chief officer and the watch AB went on deck to assess the situation, wearing breathing apparatus **(Figure 17)**.

Figure 17

Vessels' chief officer checks deck

The chief officer noticed that the house flag being flown on the fore mast was frozen, and he deduced that cargo had been released through the forward mast riser **(Figure 18)**. He checked the valve positions and began to realise what had happened. The deck was coated in white crystals.

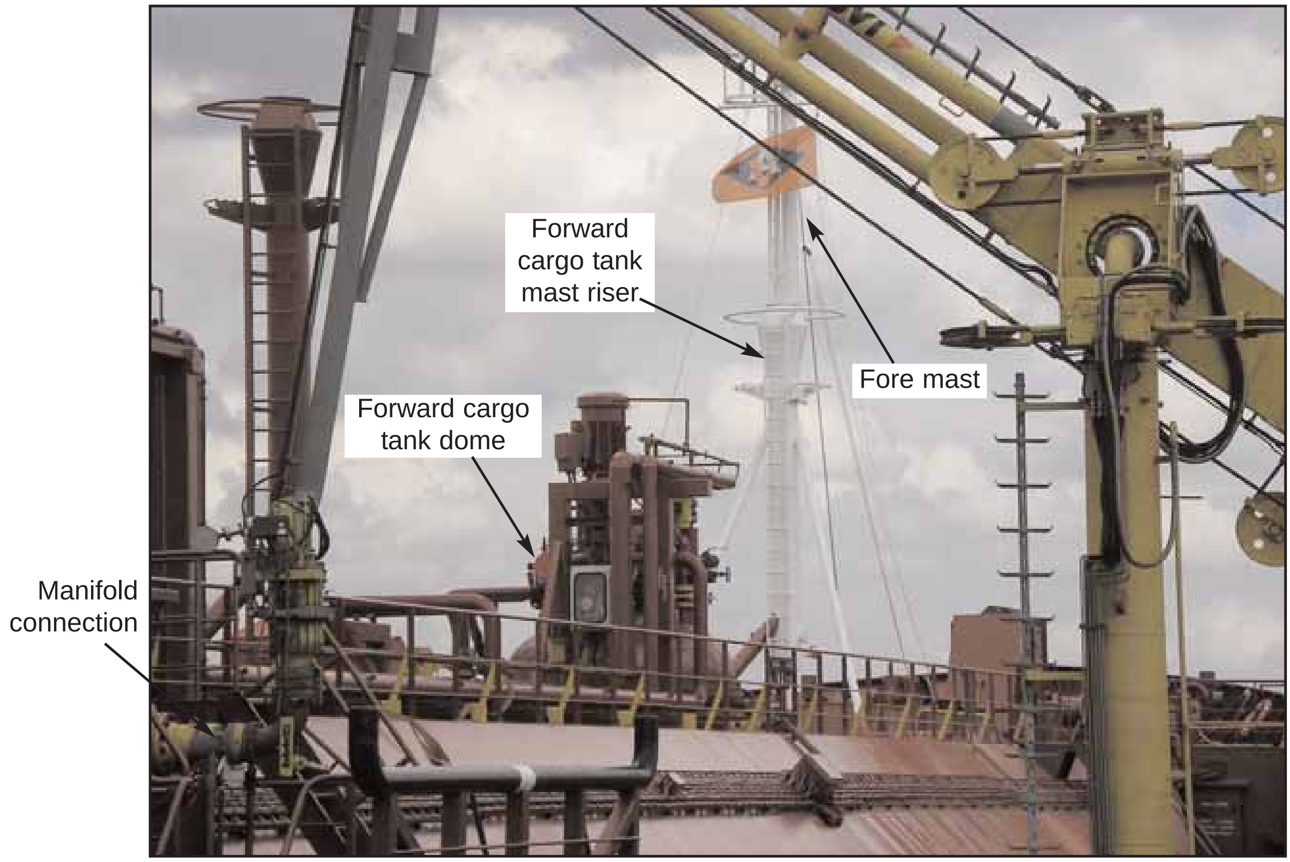
At about 1126, the first of the chemical plant and local emergency services began arriving at the berth **(Figure 19)**.

At 1128, the deck watch AB began hosing down the deck with a deck wash hose, possibly to disperse any liquid cargo on the deck, or to dilute any remaining gas **(Figure 20)**. The chief officer assumed that there was no more gas on deck and took his BA set off.

The vessel's second officer donned a 15 minute escape set and checked the internal accommodation for gas using a portable gas detector. He found gas levels of between 10 and 50ppm.

The agency representative, who was still in the master's office, noticed various members of the crew, some wearing BA, some not, walking past the door, checking the spaces with a portable gas detector. He thought that it might have been an emergency drill, but as everyone was speaking Russian, he was not sure, so he went to the bridge to find out.

Figure 18



View of mast riser, foremast and forward cargo tank dome

Figure 19

Emergency services arrive on berth

Figure 20

Crewman using water hose on deck

The master informed him there had been a small spillage of cargo, but that everything was now under control, but he should not go outside the accommodation housing. He was told to return to the master's office where he would be safe.

The agency representative followed these instructions, but contacted his operations department, who advised him to stay in the accommodation and follow the crew's instructions.

At about 1200, the harbourmaster contacted the agency representative by mobile telephone, informing him they had been unable to contact the vessel and asking whether he knew anything about the situation onboard. The agency representative returned to the bridge and passed on this request for information to the master. The master replied that they had some operational problems and cargo had been accidentally released, but that the situation was now under control. The agency representative relayed this information to the harbourmaster. The agency representative then stayed on the bridge and liaised between the master, the emergency services and the harbourmaster, using his mobile telephone.

At about 1400, the area was declared safe by shore staff, and the emergency services left the area. EVC personnel, the harbourmaster, and various other people boarded the vessel.

At about 1530, the vessel's P&I club inspector and ship's crew inspected the void spaces to ensure the cargo tanks had sustained no damage.

Further EVC personnel boarded the vessel during the night to ascertain from the crew what had happened, and what measures were being put in place to ensure the cargo discharge would be completed without further incident.

Cargo discharge was started the following day at 1325. It was completed without further problems, and *Coral Acropora* then sailed from the port.

1.4 ENVIRONMENTAL INFORMATION

At the time of the accident, the sky was overcast and it was raining. The wind was 10 knots from the north. *Coral Acropora* was lying alongside on a heading of 040° so the relative wind was about 40° on her port bow.

The rain stopped shortly after the accident.

1.5 *CORAL ACROPORA*

1.5.1 Manning

The officers and crew were employed and supplied by a ship's crewing agency based in Cyprus. Their certification, including gas endorsements, was checked and found to be in order.

The master was 38 years of age. He had sailed in Russian vessels from 1989 to 1997 as third and then second officer. Between 1997 and 1999 he sailed as second officer on various vessel types, including oil tankers. In 1999, he gained his first gas carrier experience. He was subsequently promoted to chief officer on oil tankers, until 2001, when he joined the Cypriot crewing agency. Between 2001 and 2004 he sailed on various gas carriers as chief officer, including 3 months on *Coral Acropora* in 2002. He joined the vessel once again on 31 May 2004, and after an extended handover period, was promoted to master on 18 June 2004.

The chief officer was 46 years of age. He joined his first vessel as a rating in 1989 at the age of 31. He was promoted to junior officer in 1991. He had held a chief officer certificate of competency since 1999 and had served on gas carriers as second officer from that time. He joined the Cypriot crewing agents in 2001, and sailed on gas carriers as second officer until 2003. He was promoted to chief officer and served on one vessel for 3 months before joining *Coral Acropora*, for his second trip as chief officer, on 18 June 2004. The person he relieved remained on board and was promoted to sail as master.

1.5.2 Ship management

Historically, *Coral Acropora*'s owners crewed their vessels with Dutch and Indonesian nationals. However, the available pool of experienced Dutch nationals has decreased over the years, to the point where it was not possible to obtain sufficient crew to staff the entire fleet.

The owners felt that they had no option but to employ other nationalities on some of their vessels. They considered the relative benefits of multi-national crews against those of a single nationality, or at least sharing a common language, and decided on a policy of employing crews which spoke a good common working language.

The ship owners kept a close check on the performance of the staff supplied to their vessels, and were keen to ensure that the officers and ratings returned to their fleet after their vacation periods. This helped to ensure that the vessels were staffed with experienced and competent people.

1.5.3 Cargo system

Coral Acropora had two cargo tanks, one aft (No 1) and the other forward (No 2), and their 100% capacities were 2208.74m³ and 1009.19m³ respectively. Each cargo tank was fitted with a deepwell cargo pump.

Because many of the cargo valves could not be operated remotely, the vessel had a cargo office, and not a cargo control room. The vessel's cargo system mimic panel, which was situated in the cargo office, showed the pipeline and valve arrangement. Some valves could be operated from the panel. Cargo tank pressure gauges and ullage indication could also be read in the cargo office, as well as details of all activated alarms. The 98% HHLA cargo tank override switches were situated on the mimic panel **(Figures 21 & 22)**.

Cargo pumps could only be started locally on deck in the vicinity of the tank top. The cargo pumps were electrically driven, and worked at a fixed speed. The pumping rate could be controlled by adjusting the position of the pump discharge valve **(Figure 9)**.

To protect against over pressurisation, each cargo tank was fitted with two pressure relief valves set to lift at 9.3 bar **(Figure 23)**.

If the pressure relief valves activated, cargo was released to atmosphere high above the deck through the mast riser **(Figure 18)**.

1.5.4 Deck water spray system

The vessel was fitted with a deck water spray system, which could be used as a fire extinguishing medium for liquefied gas fires. It could also be used to induce air movement into a vapour cloud and, thereby, deflect it from a source of ignition or help to dilute it. The deck water spray system was not used during the accident.

1.5.5 Cargo tank containment space

Each cargo tank onboard the vessel was situated within a cargo hold. The space around the tank and within the hold was the containment space. Onboard *Coral Acropora*, the containment space contained dry air kept at a positive pressure of about 50mb by continual supply from a designated compressor. The containment space had no fixed gas detection system, and therefore gas detection was achieved by use of the portable hand pump type gas detectors, described in 1.5.6 below.

As a result of the accident, the forward cargo tank was subjected to a pressure equivalent to the maximum allowable, which resulted in the operation of the pressure relief valve. The vessel's crew checked the containment space for signs of possible tank structural failure 4 hours after the accident. None were found.

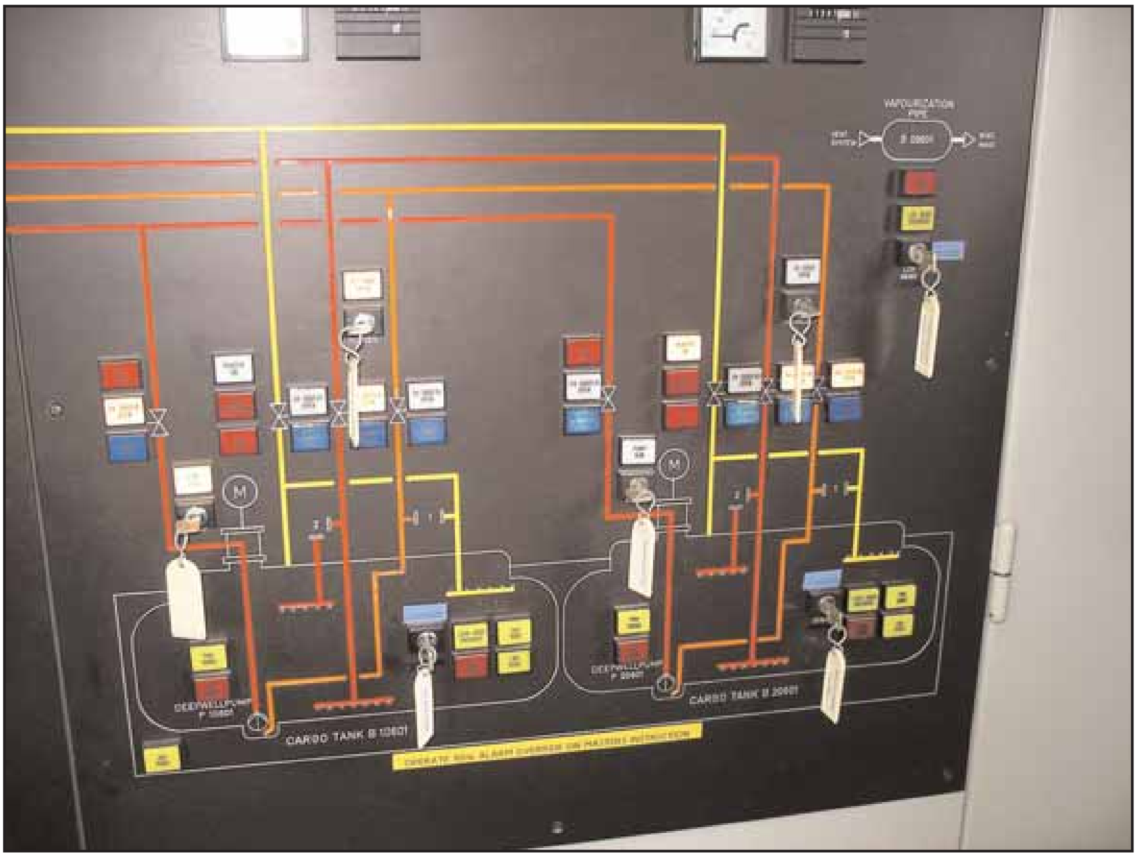
1.5.6 Onboard gas detection capability

Coral Acropora had no fixed gas detection system.

At the time of the accident, the vessel had two Dräger Pac III type portable gas detectors on board, in accordance with the owner's minimum standards **(Figure 24)**.

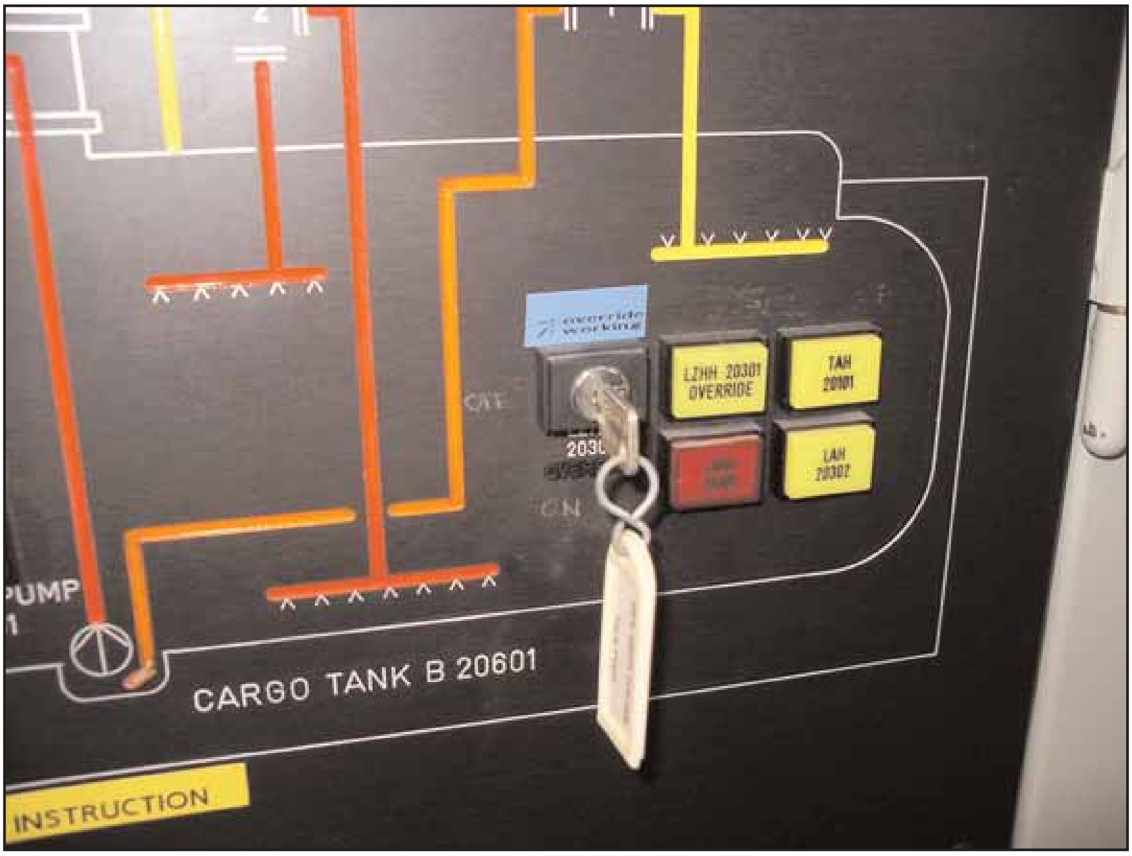
The vessel also had two Dräger hand pump units, for use with Dräger tubes. Additionally, the portable detectors could be fitted with sampling hoses for remote gas detection in containment or similar spaces.

Figure 21



Cargo office mimic board

Figure 22

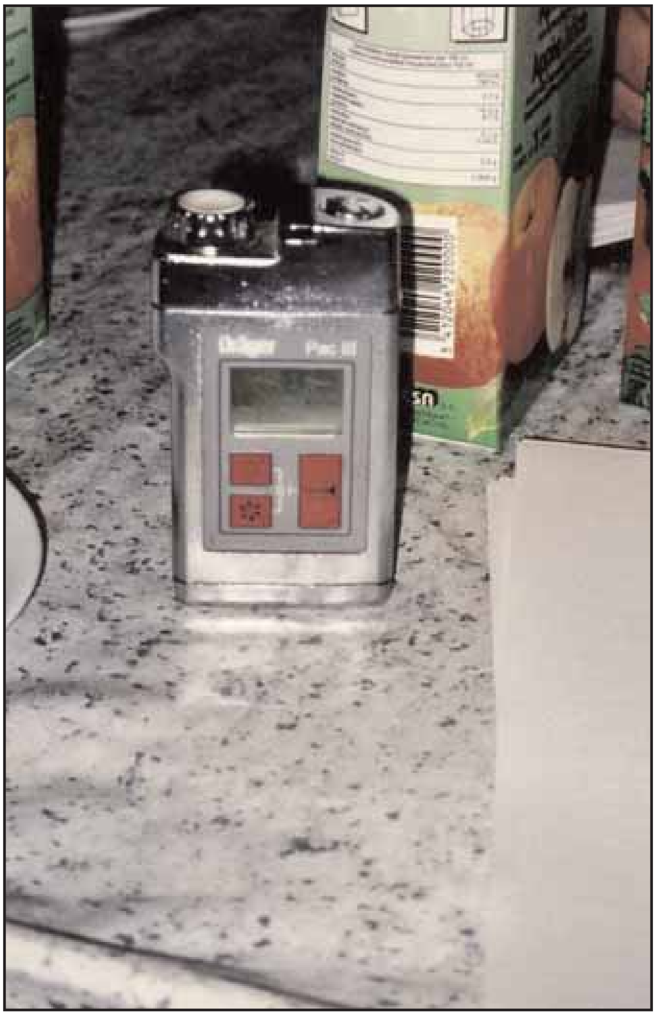


HHLA override switch and key

Figure 23

Forward cargo tank pressure vacuum valves

Figure 24



Portable gas detector

1.6 THE APPLICABLE INTERNATIONAL GAS CARRIER CODE

Coral Acropora was built in 1993, therefore, the International Maritime Organization's (IMO's) International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, the IGC Code [1993 Edition], applied.

1.7 VINYL CHLORIDE MONOMER [VCM]

A liquefied gas is a substance which, at ambient temperature, is a gas, but which, in order to be stored and transported economically under a much reduced volume, is liquefied by the application of pressure, by cooling or by a combination of both. Liquefied gas onboard *Coral Acropora* was carried under some pressure and cooled below ambient temperature. The cargo was carried at, or near the boiling temperature associated with its pressure.

Vinyl Chloride is a chlorinated hydrocarbon gas used in the manufacture of PVC. Worldwide annual production of Vinyl Chloride is about 20 million tonnes, of which 2 million tonnes is carried by sea. Typically, the flash point is -78ºC, flammable range is 4.0 to 33.0% by volume in air, and the auto-ignition temperature is 472ºC.

The present industry threshold limit value – time weighted average (TLV-TWA) for Vinyl Chloride stated in the International Chamber of Shipping (ICS) publication *Tanker Safety Guide*, is 2ppm.

The odour threshold limit is in the region of 250ppm.

The hazards to anyone exposed to liquid VCM are damage to skin and eyes, and frostbite.

The hazards to anyone exposed to vapour VCM are blurred vision and, possibly, frostbite. When inhaled, the acute effect is an inability to concentrate, numbness, burning or tingling of the feet, adverse effects to the central nervous system. Recovery is rapid in fresh air. There is a known narcotic effect in high concentrations. It is suspected that a chronic effect of long exposure to low concentrations is liver cancer. The substance may also adversely affect the spleen, blood and peripheral blood vessels, and tissues and bones of the fingers.

VCM gas is heavier than air, and may be blown along close to the ground, leading to a possibility of distant ignition.

VCM polymerises in the presence of oxygen, heat and air. The white crystals which formed on the deck and structure of the vessel were polymerised VCM.

As stated previously, the deck water spray system was not utilised to dilute or disperse the cargo spill. The able seaman used a fire hose in an attempt to dilute the gas and remove "ice crystals" from the deck, to reduce the gas content and stop any damage to the vessel's structure from thermal shock.

SECTION 2 - ANALYSIS

2.1 AIM

The purpose of the analysis is to determine the contributory causes and circumstances of the accident as a basis for making recommendations to prevent similar accidents occurring in the future.

2.2 OPERATIONAL PRACTICES ON *CORAL ACROPORA*

2.2.1 Overloading cargo tanks

Chapter 15 of the IGC Code states:

> *No cargo tank should be more than 98% liquid full at the reference temperature*.

A higher limit may be allowed by the Administration after taking into account the shape of the tank or some other criteria. However, this was not the situation onboard *Coral Acropora*.

The ship owner's cargo operations manual clearly endorses the international requirement and, additionally, it states:

> *Taking into account response time at the terminal and tonnes received after the order to stop loading is given in order to prevent overfilling and as an international standard a cargo tank is normally topped up until 97.8%*.

At Rotterdam, prior to the accident, the vessel's forward and aft cargo tanks were loaded to 97.98% and 98.10% respectively. Therefore, the filling limits were exceeded on the voyage.

The cargo report, completed by the chief officer at the discharge port on the previous voyage, was as follows:

> Forward tank 97.40%   Aft tank 98.05%

Again, the tank-filling limit had been exceeded.

It appears that the tanks onboard *Coral Acropora* were regularly loaded close to, or beyond the 98% alarm setting. Overloading the tanks led to the need to override safety features such as the 98% cargo pump interlocks.

The chief officer wrongly believed the forward tank to have been overloaded on this occasion.

2.2.2 Double valve segregation and valve operation

Cargo isolating valves should be fitted in accordance with the International Gas Carrier Code. Where cargo tanks have a maximum allowable relief valve setting (MARVS) greater than 0.7 barg, the principal liquid and vapour connections on the tank dome should be fitted with a double valve arrangement. In accordance with the Code, this shall comprise of one manually operated globe valve and a remotely operated isolation valve fitted in series. *Coral Acropora* was fitted with the manual valves and pneumatically operated isolation valves.

The fitting of double valves allows the tank or system to remain isolated if one valve leaks or fails. Double valve segregation is common on all types of tankers where high pressures exist in tanks or pipes, and where single valve leakage may cause a serious pollution hazard or adversely affect the pipe or tank integrity.

Double valve segregation also allows for one valve to be inadvertently left open, or opened due to misoperation without compromising the integrity of the system. The second valve will protect the system.

On board *Coral Acropora,* to save time, the chief officer generally left most manual valves open, and operated the cargo system by use of the pneumatic valves alone. Additionally, the manual valves immediately adjacent to the tank dome were considered by the chief officer to be stiff to operate, and he believed that it was not possible to maintain them as the tank could not be isolated. This, in fact, is incorrect, as the valves can be maintained without the need to remove them from the system.

The MAIB inspectors tested the valves, and they appeared to be free and required little effort to operate them.

2.2.3 Setting up the cargo system before arrival at the terminal and undue pressure to rush operations

When a tanker arrives alongside a terminal there is a lot of preparational work to do before she is ready to load or discharge cargo.

Time alongside terminals can be very costly. Vessel charterers and, to some extent, the owners therefore prefer to keep the time spent alongside to a minimum.

Pressure is sometimes put on the vessel's crew to complete cargo operations in the shortest time possible. If the crew can accomplish this without compromising safety, all parties will be satisfied with the performance.

The ship owner's operating instructions must be carefully written to avoid putting undue pressure on crews, since this could encourage them to rush cargo operations and to take unnecessary risks.

The cargo operating manual on *Coral Acropora* stated that:

> A *considerable amount of preparation work can be carried out prior to the ship's arrival at the berth,* and, *the time delay at the berth due to ship related delays is to be kept to a minimum*.

Although the *preparation work* referred to is not specified, the owners did not intend the crew to carry out potentially unsafe procedures such as setting up the cargo system ready for operations.

The chief officer onboard *Coral Acropora* felt pressurised to complete operations quickly, however, it could not be determined whether such a feeling was specific to the operation on this vessel, or a more generic one that had developed through his work on tankers.

It was found during the investigation that the chief officer left many, possibly all, manual cargo valves open at all times, for expediency. He did this despite the fact he was a relatively new chief officer and the cargo onboard was extremely hazardous. It is especially surprising that he had adopted these poor working practices so quickly after being promoted.

The chief officer had read and signed that he understood the ship owner's cargo operating instructions, which clearly stated:

> *All valves in the cargo system not required to be open for the operation are [to be] shut*.

2.2.4 The ship/shore liaison and checklist system

Coral Acropora had been trading between the same two ports almost continuously for 2 years. This should have led to a high standard of ship/shore compatibility and good integration of operational and emergency procedures.

SIGTTO states, in its publication, "Crew Safety Standards and Training for Large LNG Carriers":

> *It is essential that ship and shore cargo handling procedures be synchronised and compatible.*

The ship owner's operating procedures state:

> *Before any operation commences at a terminal, the whole operation is to be fully discussed with the terminal representatives.*

It continues by listing the items required to be discussed, and finishes by stating:

> *The principle items for discussion and agreement between the ship and shore must be included in a written form of agreement*.

A checklist system was available on board the vessel and covered the actions to be taken prior to the commencement of cargo discharge or loading operations. These included the shore operator and the chief officer completing the pre-operations checklist, and then handing the shore walkie-talkie to the chief officer before any cargo operations took place.

On the day of the accident, despite the cargo pumps being run for sampling, no checklists had been completed.

Two terminal staff had boarded *Coral Acropora* to fit the shore portable gas alarm, and then begin connecting the manifold to the loading arm. They did not inform the chief officer that they were onboard and were going to begin connecting operations. There should be an obligation for anyone who is going to work onboard a vessel to report to the chief officer or another responsible officer before they begin any work. Accordingly, a sign posted at the top of the gangway stated "visitors report to duty officer".

On the day of the accident, vessel and shore operations were being undertaken separately, with neither party being fully aware of the actions of the other. This might have been partly due to the fact that the vessel's staff had no single person from ashore with whom to liaise. Additionally, as the crew's first language was not English, there was a reluctance, on the part of the shore operators, to engage in lengthy discussions with them. This led to some operations occurring with only implicit agreement or consent.

In SIGTTO's guides to gas carrier operations, there are a number of references to *terminal supervisors* who are responsible for overall jetty operations. Such a person oversees the shore operation and can liaise with the cargo officer onboard. The berth in question does not employ a terminal supervisor, and the MAIB believes that, had it done so, many of the operational failures and poor operational practices would not have been allowed to develop.

The checklists adopted by the berth operator were based on IMO standard checklists, but were slightly altered to be more relevant to the specific operation. Despite the fact that checklists had not been completed in this case, the investigation indicated that the shore-based personnel had relied too heavily on the "expertise" of the vessel's staff with regard to marine matters. Perhaps because of this, the checking performed by the shore-based personnel merely confirmed that the vessel had undertaken its own checks, rather than the more comprehensive rigorous mutual checking suggested by the guidelines.

2.2.5 Ship/shore communications

It is important that good communications are maintained between the vessel and the shore, from the time the vessel is made fast, throughout the duration of cargo operations, to when the vessel finally departs the berth. This accident occurred in the period before cargo discharge had started, and no radio or other means of communication with the terminal had been supplied to the vessel.

The Dangerous Substances in Harbour Areas Regulations 1987 control the carriage, loading, unloading and storage of all classes of dangerous substances in harbours and harbour areas. In Part IV of those regulations, under the heading *General Duties of Persons Handling Dangerous Substances*, paragraph 44 requires:

> *During loading or unloading of dangerous liquids in bulk the berth operator should ensure that effective communication is maintained between people on the vessel, on the berth and at the storage installation in order that the transfer operation may be safely controlled.*

The MAIB believes that effective communication should be maintained **at all times** while the vessel is at the berth. Special radios which are normally supplied to the vessel before cargo operations begin, should be supplied as soon as the vessel arrives at the berth.

2.2.6 Connecting/disconnecting manifold hoses and loading arms

The ship owner's operating procedures state that prior to removing or fitting the manifold blank flanges:

> *Personnel involved should wear the protection equipment required for the cargo/cargo vapour in the system*,

and vessel's crew are also instructed to ensure that:

> *Similar precautions shall be taken by the shore side before the blank flange is removed from the hose/hard arm*.

The agreed personal protective equipment (PPE) to be used for this operation includes breathing apparatus (BA) or other respiratory protective equipment (RPI). Neither the shore operators, nor the vessel's crew, wore RPI while completing the operation, despite the fact that everyone involved was fully aware of the requirement. This is indicative of a poor safety culture onboard the vessel and in the terminal. As the shortfalls in safe operating practice would have been obvious to any observer, it also indicates that the vessel's senior officers and the terminal managers did not take a pro-active attitude towards safety.

The shore operators had boarded the vessel without informing the chief officer that they were onboard. They then began connecting the loading arm, probably believing the vessel was ready, as the vessel's manifold blank had already been removed.

The ship owner's standing operational instructions require a responsible person to be overseeing the connecting of the manifolds. However, this was not the case onboard *Coral Acropora* on the day of the accident.

In addition, at this time, no pre-operation checklists had been completed and one of the vessel's single speed cargo pumps was running and pressurising the vessel's pipeline system, including the manifold cross-over lines. The potential for a very serious accident was high.

2.2.7 Overriding of tanker safety features

The IGC Code requires cargo tanks to be fitted with high level alarms. *Coral Acropora* was fitted with 95% (HLA) and 98% (HHLA) alarms. The 98% alarm also incorporates other tank overfilling safety features such as cargo pump trips and automatic valve closing. When a cargo tank loaded volume is above the 98% alarm setting, cargo pumps cannot be started, and the pneumatic tank valves remain shut regardless of whether the valve operating control is switched to open or shut.

This can be problematic in the unusual situation where a cargo tank volume is over the alarm setting point, and it is not possible to start the cargo pump or open the valves to discharge the tank. To overcome this potential problem, vessels are fitted with a tank 98% cargo pump trip and valve closing interlock override switch **(Figure 25)**. The override switch must be used with great care, as the operator would be removing an important safety feature. The switch is operated by use of a key, and strict controls on its use are usually put in place. The usual practice onboard *Coral Acropora* was to leave the keys in position at all times, despite the ship owner's cargo operational procedures which state pre-operation checks shall confirm:

> …*any isolation / by-pass switches are in the active position and the operating key removed*.

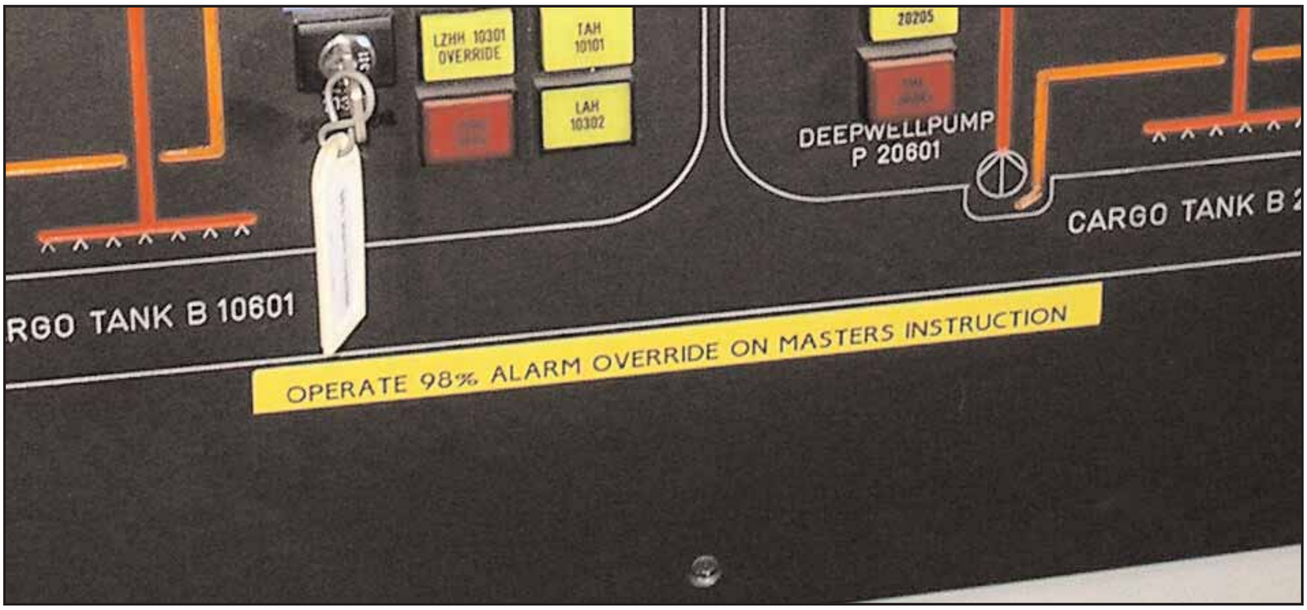
Coral Acropora's owners were fully aware of the necessity of controlling the use of this override switch, and procedures regarding the use of the override feature were posted in the cargo office. Records were also kept in the deck log when the switches were activated. A sign on the cargo mimic board also stated:

> *OPERATE 98% ALARM OVERRIDE ON MASTERS INSTRUCTION*

However, no evidence was found to suggest that this was, in fact, the normal operational procedure **(Figure 25)**.

The override switch is used throughout loaded passage voyages to stop the cargo system alarming as the vessel moves in a seaway. Further, as previous cargo records show, the cargo tanks were often above, or close to, the 98% alarm level setting, so it appears to have become a matter of common practice to use the override switch during cargo operations.

Figure 25



HHLA override warning instruction

2.2.8 Cargo control room/cargo office

Coral Acropora did not have a cargo control room, but cargo operations could only be monitored from a cargo office. Although many valves were not operable from the office, the MAIB believes it was important that this space was manned for the critical stages of cargo operations such as commencement or completion of operations, and changing over of tanks, as features such as the alarm system, tank levels and line pressures could only be viewed from there.

The chief officer left the cargo office unmanned when starting and running cargo pumps, despite the fact that he could have called the master – who had been the vessel's previous chief officer – or the second officer, to stand-by in the cargo office to monitor the cargo system. Had he done so, the person in the cargo office could have noticed the cargo being transferred from the aft tank into the forward tank, or might have realised what was happening when the forward cargo tank 98% high level and the high pressure alarms were activated.

2.2.9 Cargo sampling

SIGTTO has published a working group report on liquefied gas sampling procedures that recommends:

> *When the sample might have toxic risks* [as in this case] *then means should be provided to avoid release of the material to the atmosphere, e.g. a closed loop system may be provided, or obtained by connecting the container outlet valve to a vapour sample point or vent system.*

The cargo surveyor drew samples from the aft tank using a closed sampling procedure which involved three sample cylinders. He drew samples into one "working" cylinder, and transferred it into one of the other cylinders. He did not use "closed loop sampling", as the aft dome of the vessel's after tank is not equipped with sufficient sample points to do so.

The ICS publication Tanker Safety Guide contains details regarding cargo sampling that include:

- *The responsible officer should be present when any cargo sampling is carried out. He should be fully conversant with all aspects of the ship's sampling system including the operational characteristics of all valves. He should clearly recognise that the responsibility rests entirely with him for ensuring that sampling operations are conducted in a safe and efficient manner which will preclude any escape of cargo liquid or vapours to the atmosphere beyond that required by the sampling process, whoever is performing the actual sampling operation.*
- *If the cargo is toxic, self-contained breathing apparatus must be worn.*

The chief officer had not expected the cargo surveyor to take cargo samples. The reason for this is not clear, as the cargo had been loaded in a port not usually visited by the vessel, and had originated from a supplier not normally used. Under these circumstances, it would have been surprising if the receiving facility decided not to take samples.

The charterer had not informed the vessel that samples were to be taken at Runcorn. In hindsight, had the requirement for sampling been relayed to the vessel, including the fact that the cargo pumps would need to be run, the chief officer might have planned ahead and been better prepared.

Despite not being forewarned, the chief officer had a responsibility to stop any operation if he felt its continuation would adversely affect safety. He should have delayed the sampling until he could include the operation in the cargo discharge plan and get it agreed by the master **(see 2.2.10)**.

The chief officer did not wear a BA set during the sampling operation. This seems to have been his usual practice, despite the ICS guidelines quoted above. The chief officer had read, and signed that he understood the ship owner's cargo operational procedures that state:

> … *during the sampling process, all personnel involved must wear appropriate protective equipment. This should include protective clothing, gloves, goggles and when there is a risk from toxic gas, breathing apparatus*.

If cargo pumps are used during sampling, the risks will increase considerably. This means that no other operations, such as connecting the manifold, should take place simultaneously. The terminal and vessel both complete checklists prior to the start of operations, however, sampling generally falls outside the scope of *operations* in this context. Nevertheless, the MAIB believes ship/shore checklists should be completed before cargo samples are obtained whenever the operation requires cargo pumps to be run. There is also a strong argument for ensuring that sampling operations, where pumps are used, are completed prior to connecting the manifold, so that the shore cargo connection cannot be accidentally pressurised.

2.2.10 Changes to the planned operation

As previously stated, the cargo surveyor's request to run a cargo pump on each tank, while he took the samples, was not expected by the chief officer.

This operation required cargo valves to be opened and cargo pumps to be run in order to circulate the cargo within each tank. The chief officer was aware that most of the manual cargo valves were open, as it was his general practice to leave them so. However, he still went ahead and lined-up and started the pump on the aft tank, without closing any of the unnecessarily open valves, or calling someone else to double check he had set the system up correctly. He did this despite the fact that the ship owner's operating procedures stated:

> *All valves in the cargo system not required to be open for the operation are* [to be] *shut*:

and further:

> *The checks on the cargo system line up must be carried out by two persons independently*.

The normally accepted minimum safety requirement of at least a two valve separation was not maintained in this case.

The MAIB believes that the chief officer was too close to the operation to maintain an overall perspective. SIGTTO, in its best practice guide entitled Crew Safety Standards and Training for Large LNG Carriers, recognises this problem and recommends that:

> *Neither the chief officer nor the cargo engineer should act as watch keepers during cargo transfer*.

Despite *Coral Acropora* not being a large LNG carrier, the fundamental message stills holds true. In this case, the chief officer had allowed too many operations to proceed at once, and had become too personally involved. This, combined with the lack of any shore management/supervision, resulted in no-one maintaining an oversight of the cargo operations.

As stated earlier, the chief officer could have called someone else to assist him, which might have enabled him to recognise the dangerous situation that was developing.

2.2.11 Stopping cargo operations when in doubt

When the deck cargo alarm klaxon sounded, indicating an alarm on the cargo office control panel, the chief officer assumed it had been activated due to the cargo pump tripping. This assumption, and his decision not to go to the cargo office to determine what had caused the alarm, indicated an inappropriate level of safety awareness. At the time, the chief officer had no doubt in his mind as to the nature of the alarm, so felt no need to confirm his opinion. It was only when a second cargo alarm sounded that he began to realise something might be going wrong.

The ship owner's operational instructions state:

> *If at any time during the discharge operation … the chief officer … considers that a situation is developing which will place at risk the safety of the personnel or the ship the operation must be stopped immediately…*

The chief officer made a decision based on scanty information, and took no steps to stop the operation and/or ascertain the true nature of the alarm. Even at this late stage in the build up to the accident, if the chief officer had stopped the pump, the situation would have been safely resolved.

2.3 GENERAL TANKER SAFETY AND EMERGENCY PROCEDURES

2.3.1 Vessel visitors

During the accident, the port agency representative was left in the master's office and was given little information regarding the emergency situation. Despite having been onboard *Coral Acropora* many times previously, he had never been made aware of what action to take in the event of an emergency.

The ship owner's fleet instructions state:

> *The master will ensure that all visitors (including company officials) and contractors on board the ship while in port, receive instructions related to their muster location in case of an emergency.*

This was another example where a safe system existed on paper in the vessel's safety management system, but was not put into practice.

2.3.2 Shipboard emergency response

The master did not sound the emergency alarm, and he did not notify the terminal or the port that the accident had occurred, in contravention of his own vessel's emergency plans. He believed that the terminal was aware of the accident because its personnel had been on board at the time of the gas escape. However, this presumption did not obviate the master from his responsibility to notify shore authorities of the accident, especially as he was best placed to give them the most up to date information. In fact, members of the public had alerted the harbourmaster, the chemical plant and the shore emergency authorities, but these bodies did not know the true extent of the problem. They were informed that a gas cloud had been seen coming from the vessel. Some of the first reports were of an explosion. This was the information upon which some of the vital emergency response decisions were made. However, the chemical plant's response had been triggered by the gas detector near the mainifold alarming, and the plant's staff were able to gain a visual indication of the nature of the problem from CCTV cameras. It was not until at least 30 minutes after the accident, when the harbourmaster managed to raise the agent's representative on his mobile telephone, that information from the vessel started to filter through.

The vessel's International Safety Management (ISM) system listed the actions and response required in the event of an emergency, and gave detailed information regarding specific emergencies, such as cargo spills and gas vapour releases. The first action required of the master, in each case, is to sound the emergency alarm and muster the crew.

The master stated that he had not sounded the general alarm as he was worried that members of the crew would go to their muster stations situated outside the accommodation, and be exposed to the gas. He had been aware of this anomaly in the procedures before the accident. Apparently, the accepted method of allowing for this was to announce the nature of the emergency using the vessel's personal address system, at which time the crew would be instructed to proceed to a more protected muster station inside the accommodation. However, he did not do this on this occasion.

The ship owners operated a biennial fleet-wide emergency drill programme in their Fleet Standing Instructions, covering a wide range of emergency situations including cargo operations, collision, grounding and fire. The drill programme for

July 2004, the month before the accident, required a drill in the emergency procedures for a cargo liquid spill on deck. The drill for June 2004 covered the response required for a cargo vapour release. The master stated that the drills had been completed onboard *Coral Acropora* in accordance with these requirements.

The MAIB does not understand how these drills could have been carried out on all thirteen gas carriers in the owner's fleet without the anomaly about the external muster station being brought to the owner's attention. This is an indication that the fleet's ISM system was not operating effectively.

2.4 MANNING

At the time of the accident, the chief officer was on only his second trip in the rank, and the master had been promoted only at the beginning of the voyage.

The ship owner's stated policy was to ensure that newly promoted and relatively inexperienced masters and chief officers would not sail together. Every vessel was to have at least one experienced senior deck officer. However, the fleet personnel department did not notice the shortfall in experience on this occasion.

In accordance with the policy stated in section 1.5.2, the ship owners manned *Coral Acropora* with nationalities who spoke a common language, which in this case was Russian.

The owners had operated safely for many years by directly employing Dutch officers. The change to employing the entire crew through a manning agent, needed to be managed carefully to ensure that a high standard of safe operational practice was maintained. The owners were not aware of the unsafe practices that had apparently become normal routines on *Coral Acropora*. The technical and operation departments should have ensured the vessel was being operated and maintained in a safe manner. Closer monitoring of *Coral Acropora*'s performance was called for.

2.5 INSPECTIONS AND SHIP VETTING

The charterer has a responsibility to ensure that the vessel contracted to carry its cargo is able to do so in a safe and efficient manner. There is also a further responsibility to ensure that any vessel contracted under a time charter continues to perform according to the charter requirements, and in a safe manner. The berth operator also has at least a moral responsibility to ensure vessels visiting its berth do so in a safe manner.

In the case of *Coral Acropora*, EVC was both the charterer and the operator of the berths and the chemical plants between which the vessel traded. EVC, therefore, had a double responsibility to ensure the vessel operated safely.

EVC was in a good position to monitor the operation of the vessel. The EVC personnel who normally boarded the vessel when she berthed, were tasked with connecting her to the shore loading arm, and then leaving the vessel prior to any cargo operations beginning. At the end of the cargo operation, they returned to the vessel to disconnect the cargo arm. Arguably, these were missed opportunities to take note of the vessel's condition and to assess the operational capability of her officers and crew.

It is clear from the evidence gathered during the investigation, that other than an annual inspection accompanied by the owner, neither EVC, nor Agility, made any other vetting inspections. This might have been because neither EVC nor Agility employed permanent staff with marine gas carrier experience to call on to undertake such inspections. EVC and Agility relied heavily on the annual vessel inspections carried out by The Chemical Distribution Institute (CDI).

The last CDI inspection of *Coral Acropora* had occurred in December 2003. No major shortfalls were discovered at that time. A SIRE inspection of the vessel was completed in May 2004, and again no major shortfalls were uncovered. An external ISM audit was undertaken in December 2002 by Lloyd's Register, with an internal audit completed by the owners in May 2004, when again no problems were discovered. The fleet safety officer visited the vessel twice a year on average, once to carry out the ISM audit, and again as a general safety visit.

Most oil, gas and chemical tankers undergo frequent inspections and vetting including those carried out by major oil/gas/chemical companies to ensure that vessels carrying their cargoes are manned and operated safely. As *Coral Acropora* was time chartered to EVC, and normally operated between two EVC terminals, she had not been subjected to any other oil/gas/chemical company inspections.

The CDI and SIRE inspections took place annually at a date arranged by the owners. At other times, the ship owner alone was responsible for ensuring that the vessel's operation continued safely.

Coral Acropora was subjected to fewer inspections than many gas carriers could expect. The inspections that did occur, did not detect the poor operational practices that developed onboard. Had there been other operational checks by the charterer or experienced terminal personnel, the weak operational practices might have been noticed and action taken to improve them.

2.6 ENVIRONMENTAL POLLUTION

When VCM gas is released to the atmosphere, it forms a dense white mist. As the gas is heavier than air, it falls to the ground and polymerises, forming white crystalline deposits on the surfaces it touches.

As an initial emergency response, the use of a hose to disperse liquid spillage and prevent brittle fractures is completely acceptable. However, care should always be taken once such dangers have been negated, that any residual substance is disposed of safely.

The crew were unaware of what the white crystals/powdering on deck was, and it was usual practice to wash such deposits from the deck and structure of the vessel using wash hoses.

At the time of the accident, *Coral Acropora* was alongside a berth on the Manchester Ship Canal, so great care should have been taken when disposing of spilt substances.

A preferred approach, if the exact composition and pollution dangers of a substance are not known, would be to obtain advice from a body such as the National Chemical Emergency Centre, which staffs a 24 hour hotline, before attempting disposal.

2.7 GAS CLOUD MODELLING

In order to assist the MAIB with this investigation, the Health and Safety Executive (HSE) asked the Health and Safety Laboratory (HSL) to model the release in order to:

- Model the actual release of VCM; and
- Identify potential consequences of the release.

The modelling was carried out using Det Norske Veritas' (DNV's) Process Hazard Analysis Software Tool (PHAST) to model a near-instantaneous release of 600kg of VCM under the weather conditions that existed at the time **(see Appendix C for full report)**. The main findings were as follows:

1. The release had the potential to cause a flash fire (given a source of ignition) with potential fatal consequences for anyone caught on the vessel or ashore within about 50 metres of the mast riser.
2. No credible hazard from toxicity, jet fire, fireball or vapour cloud explosion was found.

2.8 FATIGUE

The vessel had just completed a two-day sea passage, and the master and most of the officers and crew were relatively well rested.

The chief officer had been keeping 4 on/8 off navigational watches on the bridge and overseeing the running of the liquefaction plant for another 4 hours each morning. He had therefore been working a total of 12 hours each day.

The chief officer's work/rest hours were entered into a computer programme which has been developed for the MAIB by the QinetiQ Centre for Human Sciences. The programme concluded that there was only a slight risk of him being fatigued at the time of the accident.

SECTION 3 - CONCLUSIONS

3.1 SAFETY ISSUES

1. Poor operational practices were identified on *Coral Acropora* including:

   - Cargo tanks were loaded in excess of the maximum allowable quantity of 98% during the voyage in question, and evidence was found indicating this had sometimes been the case during previous voyages. [2.2.1]
   - The chief officer habitually left manual valves open for expediency, and double valve segregation was therefore not maintained. [2.2.2]
   - The cargo system was lined up for discharge prior to the vessel's arrival at the berth. [2.2.3]
   - There was a poor liaison between the vessel's staff and those on the terminal, with both parties carrying out their roles in isolation. [2.2.4]
   - At the time of the accident, the vessel had no means of direct communication with the terminal. The shore emergency response was initially hampered by a lack of information from the vessel. [2.2.5; 2.3.2]
   - Personnel from both the vessel and the shore did not wear the proper personal protective equipment, including breathing apparatus, while removing manifold blank flanges, connecting the loading arm or carrying out cargo sampling. [2.2.6; 2.2.9]
   - Personnel from ashore were connecting up the manifold while, unbeknown to them, cargo pumps were running and pressurising the line. [2.2.6]
   - It was common practice to override safety features during cargo operations. [2.2.7]
   - The cargo office was not manned during the critical stages of cargo operations. This led to alarms not being positively and immediately identified. [2.2.8]
   - The chief officer did not have prior warning that cargo sampling, necessitating the use of cargo pumps, was required. Had he been warned, he could have planned ahead and been better prepared. [2.2.9]
   - Despite the fact that the sampling required the use of cargo pumps, checklists were not completed prior to the operation starting. [2.2.9]
   - The chief officer was fully involved in operations and not able to take an overseeing role. There were too many operations taking place at one time. He should have called another officer to assist him. [2.2.10]
   - The chief officer should have stopped the cargo pump when he became aware of the first deck cargo alarm. [2.2.11]

2. Visitors on board *Coral Acropora* were not instructed in the required action to be taken in the event of an emergency. [2.3.1]

3. The master did not inform the terminal/plant or port authority about the accident. [2.3.2]

4. The master did not sound the emergency alarm and muster the crew and visitors on board because the muster point was outside on deck and this would have put personnel at risk. [2.3.2]

5. Despite relevant drills being carried out throughout the owner's fleet of gas carriers in the two months prior to the accident, the anomaly of external muster points covering all emergencies was not reported. This calls into question the effectiveness of its ISM procedures. [2.3.2]

6. *Coral Acropora*'s master and chief officer were both inexperienced in the rank, contrary to the owner's stated policy of ensuring that every vessel had at least one experienced senior deck officer. [2.4]

7. *Coral Acropora* was subjected to fewer inspections than many gas carriers could expect. Had there been more operational checks by the charterer, or experienced terminal personnel, the vessel's weak operational practices might have been identified. [2.5]

8. The owner's inspection programme was not effective in uncovering and halting poor operational practices. [2.5]

9. Gas carrier inspections and vetting did not uncover the ship or shore deficiencies in the operational procedures. [2.5]

10. The vessel's crew washed white crystals into the canal, despite not knowing what they were. [2.6]

11. Modelling of the gas cloud has indicated the potential for a flash fire, with consequent serious risk of injury to any persons within about 50 metres of the mast riser. There was no credible hazard from toxicity. [2.7]

SECTION 4 - ACTION TAKEN

4.1 MAIB SAFETY BULLETIN

The MAIB issued Safety Bulletin 3/2004 on 27 August 2004. See Appendix A.

4.2 SHIP OWNER'S FLEET SAFETY BULLETIN

On completion of their initial investigation of the accident, the ship owners produced a "Safety Alert Bulletin" dated 20 August 2004. See Appendix B.

4.3 SHIP OWNER'S ACCIDENT INVESTIGATION REPORT

The ship owner produced an investigation report detailing the lessons learnt, and which included the following recommendations:

As the incident was caused by "an incorrect line up of the cargo piping system", the following recommendations are given to avoid recurrence:

1. *Maintain a maximum calculated filling limit of 97.8%.*

2. *Both EVC and Anthony Veder should reconfirm that their personnel adhere to the established procedures in order to safe-guard the following:*

    - *Means for (emergency) communication between the vessel and the terminal is established as first priority and emergency contact numbers are available before commencing any cargo operations including cargo sampling.*

    - *Cargo operations including sampling is to be discussed and agreed by the loading master and the chief officer prior to cargo operations.*

    - *The ship shore checklist is completed by the loading master and the C/O prior to cargo operations.*

    - *Separation by means of double valves in between all cargo tank(s) in order to avoid cargo transfer from one tank to the other as long as one of the 98% alarm and shutdown systems is placed in override position.*

    - *Separation by means of double valves should be maintained in between all other cargo tank(s) in order to avoid cargo transfer from one tank to the other when circulating on one tank.*

    - *Avoid transfer cargo to a tank with the 98% alarm / shutdown overridden.*

    - *During sampling of VCM cargo a BA set is to be worn all the time in compliance with company's specific instructions on VCM cargoes.*

3. *Evaluate the incident in close co-operation with the terminal and consider any recommendations of parties involved.*

4. *Present a "case study" on the accident during scheduled officer meetings to Anthony Veder personnel about the causes of the incident and the lessons learnt.*

5. *Evaluate the performance of the chief officer and establish further actions to monitor performance and / training needs.*

6. *Evaluate the performance of the master and establish further actions to monitor performance and / training needs.*

The report went on to list further consideration as follows:

As the investigation revealed several factors contributory to the incident or relevant to the follow up of the emergency situation the following recommendations are given for consideration:

1. *Avoid overriding the 98% alarm / shutdown system by limit full cargo allowance.*

2. *An "Emergency contact card" with port contacts should be posted in the wheelhouse upon arrival.*

3. *Company's emergency procedures with respect to the (toxic) gas release and the location of the muster stations should be reviewed and amended as deemed necessary.*

4. *Company's procedures and standing orders on "Cargo transfer operations" should be reviewed and amended as deemed necessary.*

5. *As no appraisal form was available in the office, company's procedures on "Appraisal of crew" should be reviewed and amended as deemed necessary.*

6. *Provide protective clothing for the crew and visitors to protect the crew from exposure of the skin to VCM in case the vessel is to be evacuated and a liquid spill is present on deck.*

7. *Investigate the feasibility of an additional "shutdown" of the cargo system in the event the 98% shut down system is overridden.*

8. *Have the vessel advised about cargo sampling prior to arrival.*

4.4 CHARTERER AND BERTH OPERATOR

EVC, who was the vessel's charterer as well as the berth operator, has taken the following action in light of the accident. It has:

- Adopted extra requirements that Dow Chemicals have in place for tankers carrying its cargoes.

- Introduced a temporary maximum cargo tank quantity loading limit.

- Considered the checking of tank level overrides on each of the vessel's cargo tanks.
- Undertaken training of supervisors in ship-based safety checks.
- Established a programme of inspections (ship and shore).
- Started to issue advance notice to vessel of voyage orders.
- Reviewed evacuation protocol for an accident.
- Has sent personnel on the Jetty Operators Course.
- Ensured sufficient time is planned for pre-operation checks.
- Re-enforced the need for full compliance with procedures by operations personnel.
- Included time for ship/shore checklist completion in vessel statement of facts.
- Undertaken training / revalidation of jetty team.
- Reviewed key parts of the vessel to shore checklist, including PPE requirements.
- Clarified management responsibility for jetty team and ownership of the vessel loading process and facility.
- Reviewed its approach to auditing / spot checks of ship/shore checklist, and recommended forward approach.
- Considered installing a local alarm that can warn local businesses of an emergency, and agreed the process for use / testing / information for local businesses with Manchester Ship Canal.
- Obtained a list of local businesses and contact numbers within Manchester Ship Canal land, and has formed and issued draft shelter advice.
- Updated emergency contacts in emergency procedures/duty managers files.
- Taken part in Halton Borough Council's review of emergency procedures.
- Re-established training of vessel's crew on VCM / jetty area.
- Determined future composition / content / attendance at review meetings with vessel's owner and the charter operators.

SECTION 5 - RECOMMENDATIONS

Anthony Veder Rederijzaken B.V. is recommended to:

2005/116 Review the frequency and scope of the company's current regime for ship visits by ship managers/superintendents with a view to providing senior management with incontrovertible evidence that its vessels are operating to acceptable safety standards, applying safe tanker practice and its fleet operating instructions are being adhered to at all times.

2005/117 Ensure that shipboard emergency checklists and procedures state that masters are under an obligation to inform the port state, coastguard, harbour authorities and/or terminal of any emergency situation on board their vessels.

2005/118 Take steps to improve feedback from vessel crews regarding deficiencies in the fleet ISM system.

2005/119 Establish improved procedures to ensure shipboard emergency drills are completed satisfactorily so as to enable vessel crews to respond effectively to an emergency situation.

2005/120 Provide its fleet with appropriate information on potential hazards and actions to be taken in the event of cargo spillage and/or pollution. Such information should be incorporated into shipboard emergency response plans and include guidance on how to obtain specialist advice, from bodies such as the UK National Chemical Emergency Centre, on how to dispose of potential pollutants.

European Vinyls Corporation is recommended to:

2005/121 Review existing terminal procedures to ensure the following:

- Improved co-ordination, communication and general liaison between ship and terminal staff.
- Direct means of communication between ship and terminal to be established on vessel's arrival.
- Personnel to wear appropriate PPE, including breathing apparatus, while removing manifold blank flanges, connecting the loading arm or carrying out cargo sampling.

2005/122 In its capacity as charterer, to establish a proactive ship vetting and inspection regime to ensure that vessels chartered in are operated in a safe manner.

SIGTTO and OCIMF are jointly recommended to:

2005/123 Review current guidelines and recommendations concerning gas carrier checklists and procedures with respect to sample operations requiring the use of cargo pumps.

Marine Accident Investigation Branch
March 2005

Safety recommendations shall in no case create a presumption of blame or liability

MAIB Safety Bulletin 3/2004

Safety Bulletin

Department for Transport

MAIB

MARINE ACCIDENT INVESTIGATION BRANCH

SAFETY BULLETIN 3/2004

Accidental release of Vinyl Chloride Monomer from Gas Carrier

Coral Acropora

while alongside at Runcorn

10 August 2004

Issued August 2004

MAIB SAFETY BULLETIN 3/2004

This document, containing Safety Recommendations, has been produced for marine safety purposes only, on the basis of information available to date.

The Merchant Shipping (Accident Reporting and Investigation) Regulations 1999 provide for the Chief Inspector of Marine Accidents to make recommendations at any time during the course of an investigation if, in his opinion, it is necessary or desirable to do so.

The Marine Accident Investigation Branch (MAIB) is carrying out an investigation into the accidental release of a hazardous substance onboard *Coral Acropora* that occurred on 10 August 2004. The MAIB will publish a full report on completion of the investigation.

Stephen Meyer
Chief Inspector of Marine Accidents

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Public Enquiries: 020 7944 3000
INTERNET ADDRESS FOR DFT PRESS NOTICES:
http://www.dft.gov.uk

Background

At about 1110 on 10 August 2004, 594 kilos of Vinyl Chloride Monomer (VCM) was accidentally released into the atmosphere from *Coral Acropora* a 3096grt Gas Carrier during a cargo sampling operation, prior to discharging cargo at the Runcorn Lay-By berth on the Manchester Ship Canal.

The vessel was loaded with 2829 Tonnes of Vinyl Chloride Monomer and securely moored starboard side alongside the Runcorn Lay-By berth on the Manchester Ship Canal. Shore personnel had boarded the vessel on arrival to connect the cargo manifold to the shore chicksan, and a Cargo Surveyor was trying to take samples from the vessels' cargo tanks. The vessel's Chief Officer was attempting single handedly to circulate cargo in the aft cargo tank by running the tank deepwell cargo pump at the request of the Cargo Surveyor. However, one valve on the full forward cargo tank had been opened and a second was inadvertently opened, with the effect that cargo was internally transferred into this tank. The pressure in the forward cargo tank rose as the tank filled, to such an extent that the tank pressure/vacuum valve lifted and cargo erupted from the forward tank mast riser.

The gas cloud directly affected all those on the ship and several persons in the terminal. A number of members of the public were also affected by the incident.

Safety Recommendations

Tanker operators demand and expect very high standards of safety. This accident suggests that, regardless of company procedures, practices onboard some vessels can deviate considerably from those expected. Thus all tanker owners and operators are recommended to ensure that good tanker practice takes place at all times on their vessels and that ship's personnel strictly adhere to company operating instructions and standing orders, and in particular the vessel's cargo operations manual.

In particular they should ensure that:

1. The vessels' Cargo Control Room is manned at all times when cargo pumps are running during any cargo operation.
2. During the operation of connecting the manifold to the shore chicksan or hoses, no other cargo operations are taking place, especially those involving operating cargo pumps.
3. During cargo operations good tanker practice is maintained, such as keeping double valve segregation, where fitted, and shutting all valves that are not required to be open.
4. When lining-up cargo systems a system of double-checking is implemented.
5. Safety features such as cargo tank 98% high volume alarms and interlocks are only overridden in exceptional circumstances when it is absolutely necessary, and then great care must be taken to continually monitor the situation.
6. If a ship's crew have any reservations with regard to the operational procedures adopted by a terminal or berth, such as lack of information, no direct communications with the terminal, or poor supervision or co-ordination, the crew make such reservations known to the terminal or berth operator and to the ship owner or operator. Operations must be suspended until safety concerns have been addressed.

APPENDIX B

Ship owners Safety Alert Bulletin, August 20th 2004

Anthony Veder Rederijzaken

Safety Alert Bulletin August 20th 2004

The incident

August 10th 2004 the M.T. "Coral Acropora" was involved in an "incidental cargo release alongside a terminal. Investigation of the incident revealed that "cargo sampling" was carried out while the cargo system was not properly lined up for Cargo sampling.

As both the filling valves of the No1 & No. 2 tanks were in open position, cargo was accidentally transferred from No1 to No 2 tank.

As the 98% high level alarm was overridden an overfill of the no.1 tank resulted in an estimated amount of 550 kg VCM was released through the forward vent riser. Cargo sampling was carried out despite the following:

- The cargo operations & cargo sampling was not discussed and agreed by the loading master and the C/O.
- The ship shore safety checklist was not discussed & completed by the loading master and the C/O.
- The means of communication between the vessel and the terminal was not established (radio equipment was not provided to the vessel upon arrival)

By activating the ESD system the cargo release was stopped, the port authorities were notified and the port emergency plan (including mobilisation of medical assistance, fire brigade and police) was activated.

No personnel of the vessel or terminal were injured.

Lessons learned

Among others, the following lessons can be learned from the incident :

- Separation by means of double valves should be maintained in between all cargo tank (s) in order to avoid cargo transfer from one tank to the other as long as one of the 98% alarm & shutdown systems is placed in override position.
- When circulating on one tank, separation by means of double valves should be maintained in between all other cargo tank (s) in order to avoid cargo transfer from one tank to the other.
- Do not transfer cargo to a tank with the 98% alarm / shutdown overridden.
- When alongside the terminal means for (emergency) communication between the vessel and the terminal should be established as first priority and before commencing any cargo operation including cargo sampling.
- Emergency contact numbers should be available before commencing any cargo operation including cargo sampling.

A comprehensive report on the accident will be forwarded to all vessels and the accident will be addressed as a "case study" during forthcoming office seminars.

APPENDIX C

HSE Lab Gas Cloud Dispersion Model Download pdf