Report on the investigation of the release of cargo vapours

resulting in two casualties on board the chemical tanker

Jo Eik

at the Vopak Terminal Teesport on

6 May 2009

Marine Accident Investigation Branch
Mountbatten House
Grosvenor Square
Southampton
United Kingdom
SO15 2JU

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Extract from

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2005 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame."

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AB	-	Able Bodied seaman
BA	-	breathing apparatus
BP	-	British Petroleum
BRS	-	Barry Rogliano Salles
CCR	-	Cargo Control Room
CCTV	-	Closed Circuit Television
CDI	-	Chemical Distribution Institute
CEAS	-	Cleveland Emergency Alarm Scheme
CST	-	Crude Sulphate Turpentine
DRT	-	Les Derives Resiniques et Tureniques
H_2S	-	hydrogen sulphide
IBC Code	-	International Code for the Construction and Equipment for Ships Carrying Dangerous Chemicals in Bulk
ICS	-	International Chamber of Shipping
IFIA	-	International Federation of Inspection Agencies
IMO	-	International Maritime Organization
ISGOTT	-	International Safety Guide for Oil Tankers and Terminals
ISM Code	-	International Safety Management Code
kW	-	Kilowatt
m	-	metre
MAIIF	-	Marine Accident Investigators' International Forum
MARPOL 73/78	-	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978
MCA	-	Maritime and Coastguard Agency
MSDS	-	Material Safety Data Sheet

mt	-	metric tonnes
OCIMF	-	Oil Companies International Marine Forum
OS	-	Ordinary Seaman
P&A	-	Procedures and Arrangements (Manual)
PPE	-	Personal Protective Equipment
ppm	-	parts per million
PV	-	Pressure/Vacuum
QCH	-	Cargo Handling Procedure
QEM	-	Quality Emergency Manual
QER	-	Engine Room Procedure
QMS	-	Quality Management System
QSA	-	Safety, Health and Environmental Protection Procedures
rpm	-	revolutions per minute
SIGTTO	-	Society of International Gas Tanker and Terminal Operators
SIRE	-	Ship Inspection Report Exchange
StS	-	Ship to Ship
TSA	-	Tank Storage Association
TSGC	-	Tanker Safety Guide Chemicals
UTC	-	Universal Co-ordinated Time
VOC	-	Volatile Organic Compound

Times: All times used in this report are UTC+1 unless otherwise stated

SYNOPSIS

On 6 May 2009 the chief officer and an AB on board the chemical tanker *Jo Eik* were overcome as they entered an area of the main deck which contained released cargo vapours. They were rescued and taken to hospital, where they made a full recovery.

Jo Eik loaded a cargo of MARPOL Category "X" Crude Sulphate Turpentine (CST) in Savannah, USA. Arrangements were made for a Ship to Ship (StS) transfer with the chemical tanker *Puccini* while alongside the Vopak Terminal at Teesside. Following the StS transfer, *Jo Eik* carried out a mandatory MARPOL pre-wash using portable washing equipment because the majority of the fixed washing systems were defective. The washing machine water supply hose was passed through P10 cargo tank inboard Butterworth hatch, which remained open. As the cargo tank was washed, water mist containing cargo vapours escaped through the open hatch as the tank's atmosphere was agitated. The vapours accumulated around the Butterworth hatch in what was an unidentified enclosed space. The on watch AB entered the area to isolate the cargo pump hydraulic motor valves. He was immediately overcome and lost consciousness. The chief officer and another AB attempted to rescue the unconscious AB. Neither was wearing breathing apparatus. The chief officer was rapidly overcome. The AB also suffered the effects of vapour inhalation/oxygen depletion, but managed to escape unaided.

There were two Material Safety Data Sheets (MSDS) in circulation for the CST. The cargo specific MSDS held by *Jo Eik* identified hydrogen sulphide (H_2S) as a constituent part. The other MSDS passed to the terminal staff and to *Puccini* did not. The CST cargo hazards were not recognised by the chief officer of *Jo Eik* because proper reference was not made to the MSDS and the crew were not informed because a Teesside pre-arrival conference was not carried out. This contributed to inadequate risk control measures being established.

Some areas on the deck of *Jo Eik* fell into the category of enclosed spaces as defined by the International Maritime Organization (IMO). This was not recognised by the crew, so the appropriate safety precautions were not taken. There was also a complacent attitude regarding the need for respiratory protection during cargo operations. The requirement was not enforced and this put the crew at risk.

Jo Tankers AS has established a range of measures to address its organisational shortcomings. These include instructions for management of unfamiliar cargoes, including those containing H_2S, surveying the deck to identify and label areas falling into the enclosed space category, the use of personal gas detectors and repair of the fixed tank washing systems.

A number of recommendations have also been made to Jo Tankers AS. These include actions to ensure pre-arrival conferences are carried out which identify the cargo risks and safety measures required, for the diligent completion of cargo operation checklists, and for enforcing the use of respiratory protection in accordance with the ship's Quality Management System (QMS).

An MAIB safety flyer covering the circumstances of the accident has been distributed to the chemical tanker and related industries.

Jo Eik

SECTION 1 - FACTUAL INFORMATION

1.1 Particulars of *Jo Eik* and accident

Ship details

Registered owner	:	Zippora Pte Ltd, Singapore
Manager	:	Jo Tankers AS, Norway
Port of registry	:	Bergen
Flag	:	Norway
Type	:	Chemical tanker - IMO Type I, II and III
Built	:	1998 at S.A. Juliana Constructora Gijonesa, Gijon, Spain. Yard No 359
Classification society	:	Det Norske Veritas
Construction	:	Steel – double hull
Length overall, breadth	:	148.44m, 23.00m
Gross tonnage	:	12249
Displacement	:	25696 tonnes
Engine type, power and propulsion	:	Single, 5 cylinder MAN B+W 5S50MC, 2 stroke engine. Power output 7134kW. One controllable pitch propeller and a single 626kW bow thruster
Service speed	:	14.75 knots

Accident details

Time and date	:	1213 on 6 May 2009
Location of incident	:	54º 36.32'N 001º 9.58'W at the Vopak Terminal Teesport, United Kingdom
Persons on board	:	24, all Filipino crew
Injuries/fatalities	:	Chief officer and one AB hospitalised following inhalation of cargo vapours emitted from P10 cargo tank
Damage	:	None

1.2 BACKGROUND

1.2.1 Ship overview

The double hulled, Norwegian registered *Jo Eik* was one of a fleet of 21 chemical tankers managed by Jo Tankers AS based in Bergen, Norway. The ship was manned by an all Filipino crew of 24, most of whom had extensive chemical tanker experience and had served with Jo Tankers for a number of years.

Jo Eik was constructed with 34 cargo tanks of part corrugated and part flush stainless steel bulkhead design. She had a total cargo capacity of 19424m^3 at 98% full, spread across 20 centre and 14 wing tanks.

A general arrangement drawing of *Jo Eik* is at **Figure 1**.

1.2.2 Contractual arrangements

This accident related to a cargo of Crude Sulphate Turpentine (CST) that was loaded in Savannah USA together with a cargo of Tall Oil Fatty Acid, known as Sylfat.

The CST was manufactured by the Georgia-Pacific Corporation of Atlanta, Georgia, USA. Paris based Barry Rogliano Salles (BRS) was the cargo broker, and nominated the cargo on behalf of Les Derives Resiniques et Tureniques (DRT), based in Dax in France, who was the head charterer and final customer. DRT's American office, DRT America Inc, based in Saint Augustine in Florida, was the cargo shipper.

1.2.3 Jo Tankers' actions in preparation for loading turpentine cargo

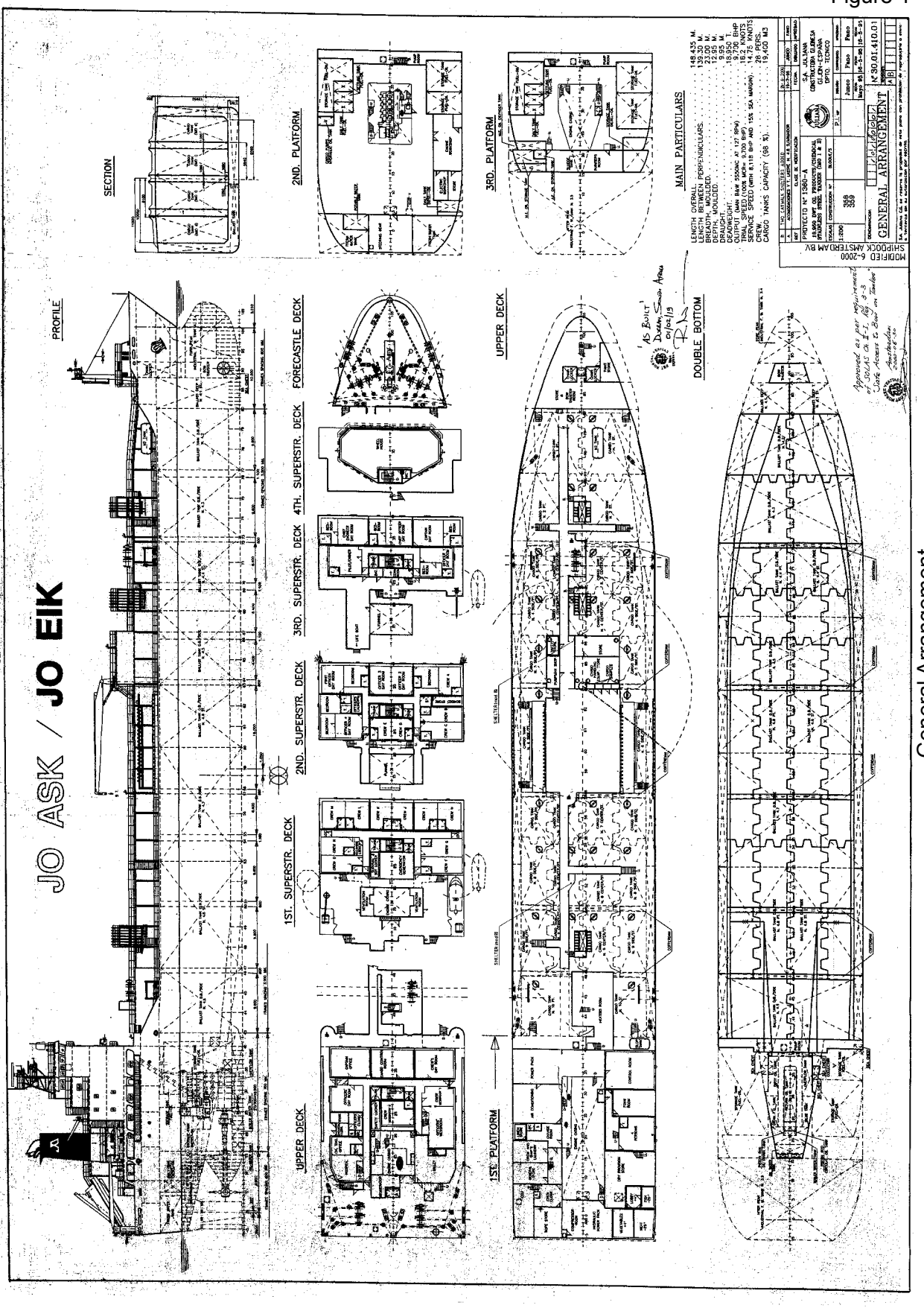
On 17 February 2009 Jo Tankers' chartering department confirmed the shipment of approximately 2000 metric tonnes (mt) of CST with BRS. The cargo was planned to be shipped to Bayonne in France for Ship to Ship (StS) transfer. In accordance with normal practice, Jo Tankers requested a copy of the cargo Material Safety Data Sheet (MSDS). BRS obtained an MSDS – Essence de Papeterie dated 22 November 2004 **(Annex A)** from DRT in Dax and forwarded it to Jo Tankers. The chartering department did not forward the MSDS on to *Jo Eik*.

1.3 NARRATIVE

1.3.1 Savannah 15 – 21 April 2009

Prior to arrival in Savannah the chief officer carried out a pre-arrival conference as required by the Quality Management System (QMS), Cargo Handling Procedures (QCH) Section 2.16 **(Annex B)**. The conference covered the loading requirements for the expected Sylfat and CST cargoes. The crew had wide experience in handling Sylfat cargoes. While none had previously handled CST on board *Jo Eik,* the chief officer had dealt with the cargo while serving on board a previous ship. While the MSDS for Sylfat was held on board, that for CST was not, and so the conference covering the CST cargo was conducted in general

Figure 1



General Arrangement

terms covering closed loading, tank loading sequence and terminal emergency alerting procedures, but not the precautions for handling CST or information regarding its constituents.

Jo Eik arrived in Savannah at 0300 on 16 April 2009 in preparation to load 2000mt CST and 10250mt of Sylfat.

As preparations were made for closed loading of the CST cargo some of those involved looked for the MSDS to check on the hazards associated with the cargo because they had no experience of it. It was not until just before cargo loading started that the chief officer was passed the cargo specific MSDS - Georgia-Pacific GP-S08 dated 13 February 2003 **(Annex C)** by the shipper's representative. The MSDS, which listed hydrogen sulphide (H_2S) as a component of the CST, was posted in the alleyway outside the Cargo Control Room (CCR) so that the crew could consult it, but the chief officer did not specifically draw the attention of the crew to the MSDS.

On 17 April a Chemical Distribution Institute (CDI) inspection started, which completed on 19 April.

Having finished cargo loading, *Jo Eik* sailed from Savannah for Bayonne at 1530 on 21 April. On completion of the StS transfer in Bayonne it was planned to berth at the Vopak Terminal at Teesport to offload 1200mt of the Sylfat cargo. A copy of the cargo stowage plan on leaving Savannah is at **Figure 2**.

1.3.2 Events leading up to berthing alongside the Vopak Terminal Teesport

At 1000 on 28 April the chief officer produced a discharge plan in preparation for the StS transfer of the CST cargo in Bayonne. He also carried out a pre-arrival conference at 1000 on 29 April which covered the crew's duties and general precautions to be adopted. It did not mention the specific hazards associated with the CST cargo. The chief officer recorded in the Deck Logbook that the conference had been carried out.

Following the request for the StS transfer, the Bayonne harbourmaster carried out a risk assessment. This identified that the traffic density within the harbour limits could compromise the safe transfer of the cargo, so permission for the StS transfer was refused.

As a result, Caspar Shipping, the ship's agent based in Middlesbrough, approached the Vopak Terminal and the Teesport harbourmaster on 30 April to request an StS transfer of the CST cargo. The receiving ship was to be the Cypriot registered chemical tanker *Puccini*, and the StS transfer was requested to take place on completion of the discharge of Sylfat cargo to the Vopak facilities.

JO TANKERS

Stowage plan

At departure of SAVANNAH

Vessel : Jo Eik
Name : 121.1
Generated : 06-Apr-2009

P10 (996) (SS) 121:04:121:04 30/TURPENTINE / 852.635 - - -/- - - / X-No -	P09 (485) (SS) 121:03:121:03 34/TALL OIL (CRUDE AND DISTILLED) / 427.345 60 - 72/60 - 72 / Y-No -	P08 (535) (SS) 121:02:121:02 34/TALL OIL (CRUDE AND DISTILLED) / 488.747 60 - 72/60 - 72 / Y-No -	P07 (365) (SS)	P06 (837) (SS) 121:01:121:01 34/TALL OIL (CRUDE AND DISTILLED) 598.966 30 - 30/30 - 30 / Y-No -	P05 (363) (SS)	P04 (374) (SS) 121:03:121:03 34/TALL OIL (CRUDE AND DISTILLED) / 326.03 60 - 72/60 - 72 / Y-No -	P03 (310) (SS) 121:03:121:03 34/TALL OIL (CRUDE AND DISTILLED) / 277.739 60 - 72/60 - 72 / Y-No -	P02 (935) (SS) 121:02:121:02 34/TALL OIL (CRUDE AND DISTILLED) / 865.365 60 - 72/60 - 72 / Y-No -	P01 (666) (SS) 121:02:121:02 34/TALL OIL (CRUDE AND DISTILLED) / 614.778 60 - 72/60 - 72 / Y-No -
	CP09 (576) (SS)	CP08 (607) (SS) 121:02:121:02 34/TALL OIL (CRUDE AND DISTILLED) / 563.028 60 - 72/60 - 72 / Y-No -	CP07 (413) (SS)	CP06 (967) (SS)	CP05 (414) (SS) 121:02:121:02 34/TALL OIL (CRUDE AND DISTILLED) / 381.367 60 - 72/60 - 72 / Y-No -	CP04 (440) (SS) 121:02:121:02 34/TALL OIL (CRUDE AND DISTILLED) / 404.216 60 - 72/60 - 72 / Y-No -	CP03 (413) (SS) 121:03:121:03 34/TALL OIL (CRUDE AND DISTILLED) / 363.548 60 - 72/60 - 72 / Y-No -		
S10 (997) (SS)	CS09 (577) (SS) 121:03:121:03 34/TALL OIL (CRUDE AND DISTILLED) / 526.237 60 - 72/60 - 72 / Y-No -	CS08 (614) (SS)	CS07 (420) (SS) 121:04:121:04 30/TURPENTINE / 362.655 - - -/- - - / X-No -	CS06 (968) (SS) 121:04:121:04 30/TURPENTINE / 784.735 - - -/- - - / X-No -	CS05 (420) (SS)	CS04 (454) (SS) 121:02:121:02 34/TALL OIL (CRUDE AND DISTILLED) / 417.619 60 - 72/60 - 72 / Y-No -	CS03 (420) (SS) 121:03:121:03 34/TALL OIL (CRUDE AND DISTILLED) / 373.257 60 - 72/60 - 72 / Y-No -	S02 (929) (SS) 121:02:121:02 34/TALL OIL (CRUDE AND DISTILLED) / 864.606 60 - 72/60 - 72 / Y-No -	S01 (660) (SS) 121:02:121:02 34/TALL OIL (CRUDE AND DISTILLED) / 612.205 60 - 72/60 - 72 / Y-No -
	S09 (485) (SS) 121:03:121:03 34/TALL OIL (CRUDE AND DISTILLED) / 434.176 60 - 72/60 - 72 / Y-No -	S08 (535) (SS) 121:02:121:02 34/TALL OIL (CRUDE AND DISTILLED) / 486.755 60 - 72/60 - 72 / Y-No -	S07 (365) (SS)	S06 (837) (SS) 121:01:121:01 34/TALL OIL (CRUDE AND DISTILLED) 602.939 30 - 30/30 - 30 / Y-No -	S05 (363) (SS)	S04 (374) (SS) 121:02:121:02 34/TALL OIL (CRUDE AND DISTILLED) / 344.362 60 - 72/60 - 72 / Y-No -	S03 (310) (SS) 121:03:121:03 34/TALL OIL (CRUDE AND DISTILLED) 277.496 60 - 72/60 - 72 / Y-No -		

TANK LEGENDA

TANK (Volume at 98%) (Lining)
Voy no : Cargo no
USCG / Commodity
Ship figure (metric tons)
Voy °C min/max - Discharge °C min/max
Marpol - Nitrogen blancket

CARGO

Voy	Car	Trade name	Ships figures	B/L figures	Loading port	Discharge port	Marpol	IMO	UN no.	Stowage
121	01	TALL OIL (CRUDE AND DISTILLED)	1201.925	1200	SAVANNAH	TEESPORT	Y			P06,S06,
121	02	TALL OIL (CRUDE AND DISTILLED)	6043.048	6000	SAVANNAH	SANDARNE	Y			CP08,P01,P02,P08,S01,S02,S08,CP04,CP05,CS04,S04,
121	03	TALL OIL (CRUDE AND DISTILLED)	3005.83	3000	SAVANNAH	SANDARNE	Y			CS09,P09,S09,CP03,CS03,P03,P04,S03,
121	04	TURPENTINE	2000.025	2000	SAVANNAH	BAYONNE	X	3	1299	CS06,CS07,P10,
		Totals:	12250.828	12200						

DEADWEIGHT FIGURES (mt)

Winter :		
Summer :	X	
Tropical :		
Fixed :	200	
Fresh water :	100	
Bunkers :	1000	+
Total of non-cargo :	1300	
DWT of vessel :	19062	
Total of non-cargo :	1300	
Cargo :	12251	
Correction :	0	-
Remaining for cargo :	5511	

Tanks dischargerd at the Vopak Terminal, Teesport

Figure 2

Cargo stowage plan at departure from Savannah

The harbourmaster checked his cargo database and found that during the past 7 years, CST had been carried by three ships, but only as a transit cargo. There were no records of StS transfers of CST cargoes. While the harbourmaster did not have the cargo specific CST MSDS, he did consult the Turpentine Chemdata sheet- 000372F1-0001B939 **(Annex D)**, and on 30 April he conditionally approved the StS transfer **(Annex E)**.

The Vopak Terminal staff also had no experience of handling CST cargoes. They approached the ship's agent for a copy of the CST MSDS to determine if any special safety measures were required when facilitating the StS transfer. The agent obtained the MSDS that had been supplied by BRS, from Jo Tankers in Bergen, and passed a copy to the Vopak Terminal. The agent retained a further copy which was to be passed to *Puccini* on her arrival. On 1 May, Vopak, in accordance with its work practices, approached the harbourmaster for permission to carry out the StS transfer. Later that day the harbourmaster approved the request.

Jo Eik took on bunkers at Portland overnight on 2-3 May and anchored off Teesport at 1515 on 4 May, to await the availability of her berth. In the meantime the chief officer prepared the cargo discharging programme for the Sylfat and StS transfer of the CST **(Annex F)**. However, the pre-arrival conference required by the QMS was not carried out.

During the morning of 5 May an Intertek OCA cargo surveyor, who had been nominated to survey both the *Jo Eik* and *Puccini* cargoes, sought advice on the risks associated with the CST cargo. His area manager was the only surveyor in the Teesport Intertek OCA office to have dealt with the cargo, and that was 20 years previously. He warned the surveyor of the cargo's strong smell and instructed him to wear respiratory protection during his cargo surveys. Intertek OCA did not hold an MSDS for CST and the surveyor decided to research the product via the internet to check if any precautions were necessary. His research confirmed the need for respiratory protection against organic substances. However, the possibility that the inorganic H_2S could be a component of the cargo was not identified. Based on the information he had discovered, he equipped himself with a full face respirator fitted with an EN 141 A2 filter.

Jo Eik berthed alongside No2 Jetty at the Vopak Terminal at 1424 on 5 May, at which time a Maritime and Coastguard Agency (MCA) surveyor attended the ship to carry out a Port State Control inspection.

1.3.3 Cargo operations

At 1500 the Intertek OCA surveyor and the Vopak loading master met with the chief officer. The surveyor was accompanied by an AB from *Jo Eik*, who opened up the Butterworth hatches of cargo tanks P6 and S6 for Sylfat cargo sampling. He then took samples of the CST from cargo tanks CS6, CS7 **(Figure 3)** and P10. During sampling the surveyor wore his full face respirator. The AB wore no respiratory protection.

Figure 3

Cargo tank CS7 Butterworth hatch

As the sampling was carried out the chief officer completed the first of the ship specific Cargo Checklists 1, 6, 7 and 8 **(Annex G)**. He then conducted the unloading conference and completed the Sylfat pre-cargo operations checks with the terminal staff, as specified in the terminal's Cargo Information Book. A copy of the completed book, which included emergency routines, was placed in the ship's Cargo Control Room (CCR).

After the Sylfat cargo sampling and calculations had been completed, the transfer hose was connected from the jetty to the ship's discharge manifold and cargo unloading started at 1625.

The Port State Control inspection completed at about the same time, with no significant defects being identified.

At 2300, discharge of the Sylfat cargo was completed and soon afterwards the Intertek OCA surveyor inspected and accepted that tanks P6 and S6 were empty. The Sylfat discharge hose was then blown through, purged with nitrogen and disconnected at 2330.

With the first stage of cargo operations now finished *Puccini* was permitted to go alongside *Jo Eik* at 0055 on 6 May. *Puccini* was met by the agent, and the MSDS, which had been obtained from Jo Tankers, was handed to the

chief officer. The pre StS transfer checks contained in the Cargo Information Book were carried out between Vopak Terminal Staff and the master and chief officer of *Puccini*. A separate set of Cargo Information Book checks was then carried out with the chief officer of *Jo Eik* as the delivery ship. It was noted that, because CST was a Category X cargo, a MARPOL pre-wash was required of *Jo Eik*'s CST cargo tanks on completion of the transfer. A pre-loading conference was held between the chief officers of *Puccini* and *Jo Eik* to agree the StS transfer procedure. The MSDSs held by *Jo Eik* and *Puccini* were not cross-checked, and although *Puccini*'s chief officer was surprised that the terminal did not require a vapour return line to be fitted, she did not pursue the point.

The CST transfer started at 0245 at which time the crews of both ships and the Vopak jetty personnel immediately identified a strong pungent smell.

At 0640 the harbourmaster's office received a report from Tees Dock about the smell. The harbourmaster's staff made several enquiries to try to identify the source, but without success. "Mutual Aid Messages" were posted on the Cleveland Emergency Alarm Scheme (CEAS) system at 0703, and again at 0757, requesting information regarding the source of the smell. There were no responses and the harbourmaster's staff closed the incident at 0900.

At 0941 the Vopak Operations Room also raised a Mutual Aid Message stating:

> *"Strong gaseous smell on site. Checked our site, nothing apparent. Any info?"*

Once again there were no responses from recipients of the message.

The StS completed at 1055. At 1120 the Intertek OCA cargo surveyor, wearing his protective respirator and accompanied by an AB, who was again unprotected and who opened the Butterworth hatches, confirmed from deck level that cargo tanks CS6, CS7 and P10 were well drained. He then issued his "Ship Tanks After Discharge Report" – Report Number 6269 **(Annex H)**.

The StS cargo transfer hose was disconnected at 1130. The slop hose was then connected from *Jo Eik*'s manifold in preparation to transfer the washing residues from the three CST cargo tanks into Vopak's receiving system ashore.

1.3.4 CST cargo tank MARPOL pre-washing operations

The two on watch ABs, pumpman and bosun connected the cargo tank portable washing equipment to the saltwater supply manifold. A single washer and hose were passed into each of CS6 and CS7 tanks through their individual Butterworth hatches. The manifold discharge valves and sea water wash valves were opened and, at 1246, the 12 minute wash cycle was started.

In the meantime, two portable washers were rigged with salt water supplies to clean P10 cargo tank through the tank's two Butterworth hatches[1]. The hoses were passed through the hatches and the outboard hatch cover was then dropped onto the hose. The inboard hatch cover was left in the fully open position **(Figure 4)**.

Figure 4

Cargo tank P10 open inboard Butterworth hatch

At about 1155 the cargo watch changed. The on-coming second officer went to the CCR to take charge of the cargo operations. He was advised by the off-going third officer that the pre-wash was almost complete. The afternoon watch AB and OS went onto the deck and immediately noticed a strong pungent smell. They were told by the two off-going ABs, that CS6 and CS7 tank cleans had just been completed. The portable washers and hoses had been removed, the tanks stripped of washing residues and the Butterworth hatch covers closed. The pumpman and bosun told the on-coming AB and OS that the sea water pre-wash of P10 had finished and that the final fresh water wash, to flush the discharge pipework, was underway. They then left the deck to go to lunch, leaving the afternoon watch AB and OS on the deck.

[1] Each portable washer needed to be used for 6 minutes each to satisfy the minimum 12 minute wash period specified in the ship specific Procedures and Arrangements Manual.

The on watch AB went up to the walkway immediately aft of P10 inboard Butterworth hatch **(Figure 5)** and noted that the pungent smell was stronger than he had previously noticed. A vertical plume of water mist came up from the Butterworth hatch and extended above his head height. To avoid getting wet he moved to the port side of the walkway.

Figure 5

Walkway aft of P10 inboard Butterworth hatch

As the pre-wash had almost finished the chief officer instructed the second officer to go on deck to take the draught mark readings while the chief officer supervised the final stages of the pre-wash operations. Soon afterwards, the chief officer stopped the pre-wash fresh water pump. At the same time, the AB on the walkway, and the OS, who was adjacent to the P10 outboard Butterworth hatch, heard the tone of the cargo/stripping pump change indicating that the pump had lost suction and that the tank pre-wash residue had been discharged ashore.

The OS started to remove the washing equipment from the outboard Butterworth hatch as the AB went down the ladder to the inboard Butterworth hatch. As he descended the ladder, the AB was no longer aware of the strong smell he had noticed earlier. He then stepped over the deep deck longitudinals to shut the cargo/stripping pump hydraulic motor supply valves in readiness for the final task of opening the 7 bar compressed air line to strip the pump and associated pipework of any remaining residue.

At about 1213, the AB completed shutting the pump hydraulic motor supply valves. Immediately afterwards he gasped for breath as he lost consciousness and slumped across the open Butterworth hatch.

The OS completed removing the washing equipment from P10 outboard Butterworth hatch and went to see if the AB needed help. As he looked down from the walkway, into the confined area of P10 inboard Butterworth hatch, he saw the unconscious AB. He shouted to him, but there was no reply.

1.3.5 Post accident actions

The OS immediately banged on the CCR window which was directly behind him and screamed into his radio to alert the chief officer that the AB had collapsed. At about 1215 the chief officer ran onto the walkway and saw the collapsed AB. He then ran to the officers' mess room and informed the master. The master immediately went to the bridge and, at 1216, sounded the general alarm. He followed the alarm with a broadcast instructing that a stretcher and breathing apparatus (BA) were required at P10 cargo tank. A short time later he informed the ship's agent and the company's management team in Bergen of the accident.

The chief officer noticed the strong smell. He decided that it would be unwise to go down the ladder near to the casualty because he did not know why the AB had collapsed. The chief officer decided to approach the unconscious AB from the port side of the main deck **(Figure 6)**. He was not wearing a BA. He struggled to get through the pipework which blocked his way, but managed to get close to the AB. He noticed the crew assembling on the walkway above him and called for help to recover the AB. As he got closer to the AB, the chief officer suddenly lost his motor ability. He could not move from his kneeling position, he lost his sense of smell and was unable to speak. In the meantime one of the ABs from the forenoon watch took a number of large gulps of fresh air, held his breath and went down the ladder to try to move the AB, but without success. Having inhaled the atmosphere in the vicinity of the collapsed AB, he managed to get back to the walkway, where he felt sick and stumbled badly.

1.3.6 Recovery

The ship's agent, having been alerted to the emergency, contacted the harbourmaster's office to advise that two crew members appeared to have been overcome by cargo vapour inhalation. At 1225 the harbourmaster alerted the Cleveland Fire and Rescue Service.

At the same time, one of the Vopak Terminal jetty operators noticed the commotion on the deck of *Jo Eik* and reported it to the day supervisor in the Terminal's operations room. The jetty's closed circuit television (CCTV) cameras were directed towards the ship and the unfolding rescue was recorded.

Figure 6

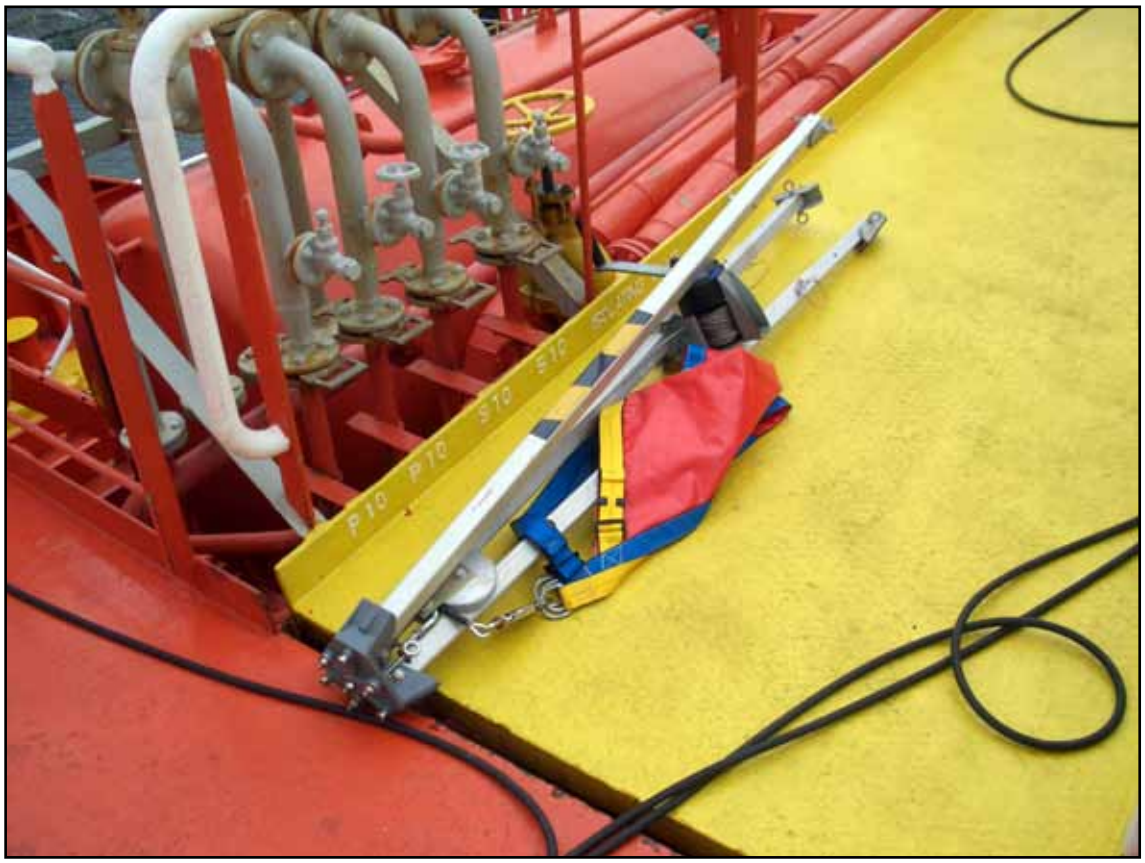
Route taken by the chief officer

The supervisor immediately alerted the Vopak management team who were attending an on-site, Vopak sponsored, safety seminar. The seminar broke up as the On-Site Emergency Plan was initiated. The supervisor also dialled the emergency services and was advised that two ambulances, an air ambulance and the Cleveland Fire and Rescue Service were being dispatched. One fire tender was being used at the safety seminar and was quickly on the scene.

On board *Jo Eik* the portable BA trolley was brought to the accident site from its stowage at the forward end of the flying bridge. At the same time, some of the ship's crew donned BA sets and made their way down to the area where the chief officer and AB were located. Other crew set about rigging a portable rescue tripod equipped with a block, tackle and sling **(Figure 7)**. A short time later the chief officer was recovered to the walkway immediately above P10 inboard Butterworth hatch. The AB was then recovered, also to the walkway. Both casualties were removed using a sling attached to a gantry fixed to the forward bulkhead of the superstructure **(Figure 8)**, which proved faster than rigging and using the portable rescue tripod. The chief officer, who was barely conscious, was supported by crew members. The unconscious and violently shaking AB was placed on a stretcher and given cardiopulmonary resuscitation while awaiting the arrival of the emergency services.

At this point the rescuers, casualties and observers remained on the walkway.

Figure 7



Portable rescue tripod

Figure 8

Gantry arrangement used for rescue

Very soon afterwards the Vopak on-scene controller arrived on board equipped with an “Entry Rae” PGM-3000 Multi Gas Monitor. He was not wearing respiratory protection. As he approached the accident site his gas monitor alarm sounded. He noted an H_2S reading of 4-5 parts per million (ppm) and a Volatile Organic Compound (VOC) reading of 10-15 ppm on the walkway where the crew had assembled. As he lowered the monitor below the walkway to his elbow level an H_2S reading of 25 ppm and a VOC level of 411 ppm were recorded. Because of the continued danger of vapour inhalation the on-scene controller instructed the ship’s staff to move forward, away from the danger area. At 1226 the first fire tender arrived and the firefighters administered further first-aid to both casualties, and to the AB who had become affected by the vapour during his rescue attempt.

The Vopak Terminal initiated a CEAS Incident Report at 1232 to advise other organisations and sites in the area of the accident and in particular of the imminent arrival of an air ambulance.

By 1245 the air ambulance, two road ambulances, more fire tenders and the marine police were on site. As a precautionary measure the fire officer-in-charge advised the master to evacuate the ship until the cause of the vapour release was identified. However, it was conceded that a small skeleton crew could remain on board for ship safety purposes. As *Puccini* was still alongside *Jo Eik*, the master of *Puccini* was advised by the Vopak on-scene controller to keep all crew clear of the upper deck until the area was confirmed to be safe. At 1300 Vopak’s operations room staff instructed the master of *Jo Eik* to fully secure the tanks and systems which had contained the CST cargo.

Following stabilisation of both casualties, arrangements were made to take them to the James Cooke University Hospital in Middlesborough. The chief officer was transferred by road and the AB was airlifted to hospital at 1315.

After confirming that the H_2S and VOC readings had subsided to normal levels the crew were allowed back on board at 1325. The Marine Accident Investigation Branch (MAIB) was informed of the accident and the emergency services were stood down. The Vopak Terminal closed off the CEAS incident at 1352.

The chief officer made a rapid recovery and was allowed back on board during the early evening of 6 May. The AB spent 4 days in intensive care receiving respiratory therapy, and returned to the Philippines on 15 May 2009.

Jo Eik sailed late on 8 May for Sandarne in Sweden to offload her remaining Sylfat cargo.

1.4 ENVIRONMENTAL CONDITIONS

At the time of the accident the ship was in sheltered waters. The wind was south-south-westerly force 5 (17-21 knots) and, although cloudy, the visibility was good (8 miles). The barometric pressure was 1010.0 millibars and the air temperature was 14.2ºC.

The wind direction in relation to the ship's position at the Vopak Terminal's No 2 jetty is shown in **Figure 9**.

1.5 CRUDE SULPHATE TURPENTINE (CST)

CST is a fluid obtained by the distillation of resin from trees, mainly pine trees. The product is manufactured by steaming pine chips or by condensing the vapour collected during burning of pine trees for other manufacturing purposes.

CST is brownish-yellow in colour and has an extremely pungent smell due its sulphur compound and methyl mercaptan (also known as methanethiol) content. The exact components of CST vary with the origin of the trees and the manufacturing process used.

1.6 MATERIAL SAFETY DATA SHEETS (MSDS)

1.6.1 Purpose

The purpose of an MSDS is to provide information for the safe handling of the material concerned. It includes physical data e.g melting point, boiling point, and flash point. The MSDS also provides information on the product's toxicity, health effects, first-aid requirements, reactivity, storage, disposal, need for protective equipment, and spill handling procedures.

1.6.2 MSDS passed to Jo Tankers

Section 2 of the MSDS forwarded to Jo Tankers stated that the product comprised 97.5% – 99.5% turpentine. The remaining 0.5% - 2.5% was made up of the dimethyl sulphide, dimethyl disulphide and mercaptans. Section 3 – Hazards Identification stated that the product could be harmful through inhalation. Section 8 – Exposure Controls/Personal Protection recommended the use of respiratory protection.

1.6.3 MSDS passed to *Jo Eik*

Section 2 - "Composition/Information on Ingredients" of the MSDS passed to *Jo Eik* stated that 99% of the product was turpentine with the remaining 1% being made up from hydrogen sulphide, dimethyl sulphide, dimethyl disulphide, methyl mercaptan.

Section 3 – "Hazards Identification", stated that the product had an offensive sulphurous odour and could be harmful, or fatal, if inhaled, swallowed or absorbed through the skin.

Figure 9

Wind direction at the Vopak Terminal

Section 6 – Accidental Release Measure – Special Procedures stated:

> *"The use of monitoring equipment is recommended when entering confined spaces that may contain turpentine vapours or liquid. Additional monitoring may also be needed for sulphur compounds, such as dimethyl sulphide, dimethyl disulphide, methyl mercaptan and hydrogen sulphide."*

Section 8 –"Exposure Controls/Personal Protection" recommended the use of respiratory protection.

1.7 REGULATION, GUIDANCE AND INSPECTION

1.7.1 International Code for the Construction and Equipment for Ships Carrying Dangerous Chemicals in Bulk (IBC Code)

The purpose of the International Maritime Organization's (IMO) IBC Code is to provide an international standard for the safe carriage, in bulk, by sea, of dangerous chemicals and noxious liquid substances as detailed in Chapter 17 of the Code. The Code also prescribes the construction and equipment standards so that the risks to the crew, the ship and environment are minimised.

The type of cargo that a ship may carry is designated by ship type I, II or III. A type I ship design is the most stringent and may carry cargoes that pose the most severe risks. *Jo Eik* was designated as an IMO ship type I, II and III. The requirements for a ship type to carry a particular cargo are laid out in Chapter 17 of the Code.

A copy of page 98 of the Chapter 17 table, relating to the carriage of turpentine, is reproduced at **Annex I**. The Code designated turpentine as a Category X cargo (column c) as defined by the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78). Column "j" of the table requires that the tanks are fitted with a "Restricted" tank gauging device for measuring cargo levels.

Section 13.1.1.2 states:

> *"Restricted device: which penetrates the tank and which, when in use, permits a small quantity of cargo vapour or liquid to be exposed to the atmosphere. ……..."*

1.7.2 MARPOL 73/78

MARPOL 73/78 is an international marine environmental convention which aims to minimise pollution of the seas, including dumping, oil and exhaust pollution.

Annex II of the convention lays out the Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk. Annex II, Regulation 6 – Categorization and Listing of Noxious Liquid Substances and other Substances defines the four categories to which noxious liquid substances are allocated **(Annex J)**. The IBC Code stated that turpentine is a Category X substance. This is defined in MARPOL 73/78 as follows:

" Category X: Noxious liquid substances which, if discharged into the sea from tank washing or de-ballasting operations, are deemed to present a major hazard to either marine resources or human health and, therefore, justify the prohibition of discharge into the marine environment".

The regulation means that a pre-wash is necessary after discharging a CST cargo. The wash residues are normally discharged to a shore facility for processing and disposal. After a pre-wash has been completed to the satisfaction of a MARPOL surveyor, a tank certificate is issued. The ship may then complete routine washing of the tank at sea, discharging the residues into the sea using an underwater discharge. This is conditional on the ship being 12 nautical miles from land, in a minimum depth of water of 25m and with the ship proceeding at 7 knots or more.

Every ship certified to carry Category X, Y or Z substances is required to have a Procedures and Arrangements (P&A) Manual on board in accordance with MARPOL 73/78 –Annex II, Appendix 4.

Jo Eik's P&A Manual was approved by Det Norske Veritas. It identified the physical arrangements and operational procedures with respect to cargo and slops handling, tank washing, cargo tank ballasting and de-ballasting which had to be followed in order to comply with the requirements of MARPOL Annex II.

The Note accompanying Table B1/B2 in the P&A Manual stated:

"*Normally the fixed tank washing machines are to be used for the pre-wash"*

1.7.3 International Chamber of Shipping (ICS) guidance

The ICS is a voluntary organisation comprising national shipowners' associations. It is an international shipping industry trade association and represents about two thirds of the world's tonnage. The ICS has IMO consultative status and has wide interests including safety, ship design and construction and pollution prevention.

The ICS sponsors the Tanker Safety Guide Chemicals (TSGC) (Third edition 2002) and the International Safety Guide for Oil Tankers and Terminals (ISGOTT) (Fifth edition 2006). Although ISGOTT is directed towards the oil tanker industry, both publications represent best practice and are recognised as the principal chemical and marine oil industry reference manuals.

1.7.4 Inspection

Apart from national inspection requirements such as Port State Control inspections, *Jo Eik* was subject to two other main industry body inspections. The Chemical Distribution Institute (CDI) and the Oil Companies International Marine Forum (OCIMF) are voluntary organisations with the aim of improving the safety and quality performance of bulk liquid shipping.

The purpose of both the CDI and OCIMF inspections is to check a ship's overall status against legislation, industry best practice and chemical and oil industry requirements for ships intended for charter. Both organisations monitor trends and overall performance of the world's chemical and oil fleets, but do not evaluate individual reports. Individual charterers use the inspection reports to measure compliance of the ships with their individual minimum safety criteria for the cargo to be carried.

1.8 CARGO TANK ARRANGEMENTS

1.8.1 General overview

Each of *Jo Eik*'s stainless steel cargo tanks was fitted with its own cargo transfer system and an independent Frank Mohn hydraulically driven deepwell cargo pump. The pump took its suction from a shallow well to maximise cargo and washing stripping residue removal. Each pump was fitted with a 7 bar compressed air system used to strip the pump and associated pipework back to the manifold. The tanks were protected from over pressurisation and from excessive negative pressures by individual tank pressure/vacuum valves. Four of the tanks were fitted with thermal oil heating arrangements; the remainder were heated using hot water.

Each tank was provided with a main tank hatch which provided tank access. There was at least one, 350 mm diameter Butterworth hatch for each tank through which portable tank washing equipment could be passed. The hatch also allowed for direct cargo sampling and tank surveying before and after cargo operations. A hermetically sealed tank level measuring system was fitted to each tank.

A Hamworthy Moss nitrogen generating plant provided the cargo inert gas requirement.

1.9 TANK WASHING SYSTEMS, WEATHER CONSIDERATIONS AND RISK ASSESSMENT

1.9.1 Fixed tank washing machines

Tank washing was based on using the 65 Gunclean 7000S fixed tank washing machines mounted in all tanks[2] **(Figure 10)** as specified in Section 2.9 of the ship's P&A Manual. The 13mm nozzle units discharged 21 m^3/hr at 10 bar and could be adjusted to rotate between 1-2 rpm on the X-axis as the washing head rotated about the Y-axis. The washing medium of hot/cold fresh water, including washing additives where appropriate, or cold sea water was supplied via a hose connection to the washer head. The washing medium also provided the washer's rotational motive power. The washer drive head was fitted with a speed adjustment, rotational indicator and manual override **(Figure 11)**.

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[2] *Jo Eik* and *Jo Ask* are the only two ships in the Jo Tanker fleet to be fitted with Gunclean 7000S fixed tank washing equipment.

Figure 10

Gunclean 7000S fixed tank washing machine

Figure 11

Gunclean 7000S fixed tank washing machine drive head arrangement

1.9.2 Portable tank washing equipment

There were 12, Cloud 700, portable tank washing machines also carried on board **(Figure 12)**. The machines were fitted with 9.5mm nozzles that also discharged 21 m^3/hr of washing medium at 10 bar. The machines and hoses were lowered through the Butterworth hatches using a natural fibre rope, and progressively secured at a number of pre-determined levels to ensure complete cleaning.

Once the washer was secured, with the weight of the machine supported by the hose, the hose was often reported to be crimped against the top of the Butterworth hatch coaming because hose guides were not carried on board. Butterworth hatches were then normally dropped onto the hose to form a partial seal. However, it was reported that the hatches were sometimes left in the fully open position.

Figure 12

Cloud 700 portable tank washing machine

1.9.3 Pre-wash timings

Jo Eik's P&A Manual contained detailed pre-wash requirements and calculations for determining the duration of tank cleans to satisfy the MARPOL 73/78 requirement. Tables had been produced which calculated the minimum wash

time for each tank when using either fixed or portable washing equipment. In this case the minimum wash time, using the portable equipment, for CS6, CS7 and P10 tanks should have been 11.5, 8.8 and 11.6 minutes respectively.

1.9.4 Fixed washing equipment reliability

The chief officer had served on board *Jo Eik* since March 2009. He reported that many of the tank fixed washing machines had been defective when he joined the vessel, and that there had been a long history of unreliability.

At the time of the MAIB investigation it was reported that only 7 out of the 65 fixed washing systems were fully operational. To better understand the problems MAIB inspectors arranged a functional test be conducted of P10 cargo tank fixed washing system. The findings are discussed at Section 2.

1.9.5 Fixed washing equipment repairs

On 9 March 2009 the chief officer submitted his first request to the vessel's manager for spares to repair the defective fixed washing systems. The request was approved on 16 March 2009. A further request was made for spares, also on 16 March, which was agreed the same day.

None of the spares had been received on board by the time of the accident. It was also noted that neither of the stores requests were annotated as "urgent", and there was no record of the ship's staff requesting assistance from the shore management team to improve the fixed washing system reliability.

1.9.6 Inspection/audit observations

On 7 January 2009 Jo Tankers conducted an internal International Safety Management (ISM) Code audit while the ship was at Rotterdam. There were no non-conformities, observations or improvement notes related to the cargo tank fixed washing systems.

During 8 and 9 January 2009 British Petroleum (BP) carried out an inspection of *Jo Eik* on behalf of the Oil Companies International Marine Forum (OCIMF), also while she was berthed in Rotterdam. The report stated:

> *"The ship complaining about tank washing machines onboard that the quality of them is not good. They are using a lot of spares to keep them working good. Same has been reported before."* [sic]

The company's response to this repeat observation is discussed at Section 2.

CDI inspectors conducted an inspection during 17-19 April while *Jo Eik* was in Savannah. Because of the ongoing cargo operations the inspection centred on documentation, crew qualification and propulsion and auxiliary machinery checks. With the exception of checking the tank high level alarms, no physical checks were made on the cargo handling or tank washing equipment.

1.9.7 Weather precautions during tank washing

Section 6.16 of the vessel's Quality Management System (QMS) highlighted the need to suspend tank washing operations when using portable washers if there was lightning in the immediate area or during heavy weather. This was to reduce the risk to personnel and equipment in the event of sparks being generated.

Section 2.25 of the Cargo Handling Procedures (QCH) identified the risk of vapours accumulating in deck areas during cargo loading, tank washing or gas freeing in periods of calm weather.

1.9.8 Risk assessment

An undated risk assessment covering tank washing operations was completed. The assessment confirmed that suitable controls were in place to deal with the identified risks. The measures included the use of PPE, meeting and briefing the crew and officers, and use of checklists. A copy of the risk assessment is at **Annex K**.

1.10 *JO EIK* CARGO HANDLING PROCEDURES

1.10.1 Responsibilities

The chief officer was in overall charge of cargo operations. The Standard Deck Orders stated that the Duty Deck Officer was in charge of the cargo team during his (her) period of duty, and for all cargo and ballast operations unless the master or chief officer relieved him(her) of the duty.

1.10.2 Pre-arrival conference

Cargo handling procedures were contained in Chapter 2 of the ship's QCH.

Section 2.16 of QCH – Cargo Plan/Pre-Arrival Conference **(Annex B)**, required the chief officer to conduct a pre-arrival conference prior to arrival in a load or discharge port. The purpose of the conference was to advise all those involved in cargo operations of the intended procedures, cargoes to be transferred, dangers associated with the cargo and specific precautions required, duties of those involved, and tank washing arrangements. The conference should be attended by all deck officers and crew members involved in the cargo operation. Of particular note is that Item 1 of Section 6 – Reminders - of the notes stated:

"Wear proper PPE at all times when handling this cargo" [sic]

The instruction also required that the chief officer identified cargo equipment defects. Where there were defects the chief officer was to ensure that unsafe cargo operations could not occur because of these. In particular the chief officer was responsible for:

- *"Identifying all hazards associated with each cargo to be handled, and Personal Protective Equipment (PPE) required for these cargoes"*
- *"Making sure that all relevant information is reviewed, recorded and distributed"*

1.10.3 Cargo programme

The purpose of the cargo programme was to support the pre-arrival conference. It covered general precautions to be observed and, in particular, the unloading sequence, discharge pressures, pumping rates and tank washing requirements.

The chief officer produced a cargo programme, which was approved by the master, for both the transfer of Sylfat and for the StS transfer for the CST **(Annex F)** while at Teesport, as required by Section 2.16 of the QMS.

Bullets 5 and 22 of the general precautions section of the reference stated respectively:

> *"Closed discharging through out the operations, make sure all tank lids and butterwash holes*[3] *are closed"* [sic]

> *"Lastly read the material safety data sheets for cargo classifications and fire fighting agents to be used during fire and health hazard and medical first aid guide."* [sic]

1.10.4 Cargo checklists

To help ensure that cargo operations were conducted as safely as possible, Jo Tankers produced a comprehensive set of 11 cargo checklists **(Annex L)**. These were contained in the ship's QCH documentation. The lists covered the various stages of loading, discharge, tank washing as well as operational safety procedures and stowage plan preparation.

Prior to the StS transfer the staff of *Jo Eik* completed and ticked off cargo checklist 1 – "Safety for All Operational Procedures" and the items on cargo checklist 9 – "Before Washing".

Items 3 and 16 of Checklist 1 respectively required that:

- All dangers associated with the product have been discussed at the pre-load/discharge meeting
- Everybody involved in the operation has been properly instructed, and;

Items 4 and 6 of Checklist 9 respectively required that:

- All personnel have been instructed to use PPE
- Confirmation that washing machines were in good working order.

1.10.5 Closed cargo operations

The ship's QMS and "Standard Deck Orders" stated:

> "*Unless otherwise instructed loading and discharging will be completely closed"*

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[3] This is meant to read Butterworth hatches.

This means that all tank lids, including Butterworth hatches, were to be closed and that cargo levels were to be monitored using the hermetically sealed system. The closed operation did not preclude the use of normal tank venting systems which vented displaced gases to atmosphere. However, some hazardous cargoes and certain port regulations required a vapour line to be connected which directed the displaced gases back to a terminal facility or, in the case of an StS cargo transfer, to the off-loading ship.

1.10.6 StS cargo transfers

General guidance on StS cargo transfers was provided at Section 2.18 of the ship's QMS and at Section 5.14 of the TSGC. The guidance in both documents was based on StS operations conducted in open water, without the support of shore authorities or terminal facilities. There was no specific guidance available to the crew of *Jo Eik* which related to StS operations conducted alongside a terminal berth where the terminal was merely facilitating the cargo transfer.

1.10.7 Miscellaneous ship instructions and orders relating to PPE

A lot of guidance was provided to the crew of *Jo Eik*, via the vessel's formal safety procedures and other documentation, about when BA should be donned during cargo and tank washing operations. Paragraph C of QSA 5.4 - Vapour Inhalation Precautions stated:

> "*BA is to be worn by all personnel who are likely to come into contact with toxic vapours"*

Section 1.1.1 of the QCH 1.1.1 also required that full protection should be used when taking samples from tanks and more specifically during tank washing operations.

In addition to the Jo Tanker sponsored cargo handling instructions, the officers of *Jo Eik* had produced a number of orders/instructions to complement the company's orders. These included Cargo Operation Reminders, Cargo Standing Orders, Standing Orders for Duty Officers and Standard Deck Orders.

The instructions and orders reiterated and reinforced those contained in the QMS Manual. However, of note are item numbers 3 and 12 of the Standard Deck Orders. Number 3 stated:

> *"The Duty Deck Officer will familiarise him(her)self with the stowage plan, the properties and dangers of the cargoes to be loaded or discharged, before arrival on loading or discharging at the terminal /anchorage".*

Number 12 stated that:

> *"Unless otherwise instructed, the use of chemical gloves and filter mask is compulsory during:*
>
> - *connecting and disconnecting*
> - *taking manifold samples*
> - *during stripping and blowing"*

1.11 VOPAK TERMINAL CARGO HANDLING PROCEDURES

1.11.1 General procedures

Cargo handling procedures at the Vopak Terminal were based on the guidance and safety checklists provided in the ISGOTT and TSGC manuals. The procedures included comprehensive safety checks both on the jetty and on board the ship. The safety checks, cargo transfer details and safety information were all contained in the Terminal Cargo Information Book.

Ships were designated as “Known” or “Unknown”. An “Unknown” ship was met by a terminal representative who fully explained Vopak’s procedures on jetty manning, hourly checks, emergency procedures **(Annex M)** and security. *Jo Eik* was “Unknown” and the full briefing was given to the chief officer after receiving the cargo stowage plan. Following the briefing, all items in the safety checklists in the Cargo Information Book had to be completed.

Check Item 1 of Part C – Bulk Liquid Chemicals – Verbal Verification, was ticked to verify that the chief officer of *Jo Eik* had confirmed the correct MSDS giving the necessary data for safe cargo handling was held.

On completion of the checks a Vopak ship/shore radio was passed to the ship enabling direct communications between the ship and terminal staff.

Vopak personnel were required to be immediately available on the jetty for the first 10 minutes following the start of cargo transfer ashore and for the 10 minutes before pumping ceased. In the meantime, hourly safety checks were required to be carried out and recorded in the Cargo Information Book.

A copy of the hourly check record sheets for *Jo Eik* and *Puccini* are at **(Annex N)**.

1.11.2 Vopak StS transfer procedures

Vopak’s StS transfer procedures were covered in VTT-OPS-SHIP-0020 – Issue 1 **(Annex O)**. The document laid out the general StS procedures and responsibilities for the agent in obtaining permission for the transfer, the responsibilities of the masters of both ships and that of the Vopak Terminal staff.

The safety checks conducted by the terminal staff were identical to those conducted for the ship to shore transfer discussed at Section 1.11.1. In this case two Cargo Information Books were completed, one for *Jo Eik* as the discharging ship and one for *Puccini* as the receiving ship.

1.11.3 StS risk assessments

The StS transfer was subjected to a risk assessment. The control measures relating to hazardous substances were identified as functional cargo tank gauges, effective on board procedures and use of PPE. All nine areas that were assessed in respect of the StS transfer fell into the “Low Risk” band, and the existing control measures were considered adequate.

1.11.4 Emergency routines

To help deal with the management of emergencies the Vopak Terminal had a comprehensive "On Site Emergency Plan" which was last updated in January 2009. The Plan included instructions and a checklist **(Annex P)** for dealing with a toxic release from the company's own facilities, from adjacent premises or from a berthed ship.

1.12 HANDLING CARGOES WITH A HYDROGEN SULPHIDE CONTENT

1.12.1 Ship procedures

At the time of the accident there were no specific onboard procedures or guidance for the safe carriage of cargoes containing H_2S. However, Engine Room Procedure (QER) 6.2 did identify the risk of H_2S in fuel bunkers, and its reaction with iron oxide to create iron sulphide and heat as well as generating corrosive sulphate reducing bacteria.

A number of general precautions were also covered. These included the need to properly ventilate and test tanks prior to entry and for the need to wear personal H_2S monitors while crew were inside bunker tanks.

1.12.2 Vopak terminal procedures

There were no Vopak Terminal guidelines for dealing with cargoes containing H_2S. It was normal practice for the Terminal to carry out a risk assessment, based on the cargo advice from the master, and that gained from the cargo MSDS, to evaluate and implement any special handling procedures.

1.13 RISKS ASSOCIATED WITH H_2S, DIMETHYL SULPHIDE, DIMETHYL DISULPHIDE AND METHYL MERCAPTAN

1.13.1 General

The individual MSDSs for all four chemicals emphasise the strong, foul odour associated with them. They all have vapour densities which are heavier than air. With air valued at "1.0" their densities range from 1.66 for methyl mercaptan to 4.8 for H_2S.

Each chemical can cause severe irritation, particularly if absorbed through the respiratory system in sufficient concentrations.

1.13.2 Methyl Mercaptan

British Oxygen Gases MSDS G-239, revised 22 October 1996 - Section 11 – Toxicological Information, Inhalation Effects – advises:

> *"Methyl mercaptan has effect similar to hydrogen sulfide on the respiratory system. Exposure to concentrations above 400 ppm may paralyze the respiratory system".*

The emergency overview of the MSDS stated:

> *"…….. Inhalation may result in pulmonary paralysis, sudden collapse and death. ……..."*

It is significant that Section 2.3.7 of ISGOTT manual identifies that the initial effects of exposure to mercaptans is similar to those caused by H_2S.

1.13.3 H_2S

H_2S is a very toxic, corrosive, flammable gas which is soluble in water.

The ISGOTT manual emphasises the importance of distinguishing between concentrations of H_2S in atmosphere, expressed in ppm by volume, and concentrations in liquid, expressed in ppm by weight. It has been shown that a liquid containing 70 ppm (by weight) H_2S can produce a concentration of 7000 ppm (by volume) in the gas stream leaving a tank vent.

The Threshold Limit Value – Time Weighted Average (TLV – TWA) exposure to H_2S is 5 ppm over a period of 8 hours. Exposure below this level should pose no ill effects. Over-exposure to H_2S is extremely dangerous. The sense of smell can break down at relatively low levels (50 – 100 ppm), and if exposure continues because the H_2S cannot be smelt, then the results can be fatal, as shown in Table 1 which is re-produced from the ISGOTT Manual.

H_2S Concentration (ppm by volume in air)	**Physiological Effects**
0.1 – 0.5 ppm	First detectable by smell.
10 ppm	May cause some nausea, minimal eye irritation.
25 ppm	Eye and respiratory tract irritation. Strong odour.
50 – 100 ppm	Sense of smell starts to break down. Prolonged exposure to levels above 100 ppm induces gradual increase in severity of the symptoms and death may occur after 4-48 hours exposure.
150 ppm	Loss of smell in 2-5 minutes.
350 ppm	Could be fatal after 30 minutes' inhalation
700 ppm	Rapidly induces unconsciousness (few minutes) and death. Causes seizures, loss of control of bowel and bladder. Breathing will stop and death result if not rescued promptly.
700 + ppm	Immediately fatal
Note: Persons over-exposed to H_2S vapour should be removed to clean air as soon as possible. The adverse effects of H_2S can be reversed and the probability of saving the person's life improved if prompt action is taken.	

Table 1 – Typical effects of exposure to hydrogen sulphide

1.14 VAPOUR MEASUREMENT

1.14.1 Vapour monitoring equipment on board *Jo Eik*

Jo Eik was equipped with various monitors and Draeger test tubes for measuring combustible gases, carbon monoxide and oxygen levels. The ship also held three Riken Keiki GX2001 personal gas monitors capable of detecting H_2S. All the equipment was in good condition and in date for maintenance and calibration.

1.14.2 Vopak Terminal readings of contaminated area

The following readings were obtained by Vopak terminal staff in the vicinity of the walkway where the crew had assembled during the recovery of the casualties.

Vapour Identified	At Walkway Level	Below Walkway Level (0.5m)
Volatile Organic Compounds (VOCs)	10 -15 ppm	411 ppm
Oxygen (O_2)	20.9%	20.9%
Hydrogen Sulphide (H_2S)	4-5 ppm	25 ppm

Table 2 – “Entry Rae” PGM-3000 Multi Gas Monitor readings

The H_2S sensor of the Entry Rae PGM-3000 Multi Gas Monitor is subject to cross-sensitivity by a number of other vapours. Of particular note is that the vapour concentrations of the following components of the CST cargo will be shown on the monitor’s H_2S display:

- turpentine
- methyl mercaptan
- dimethyl sulphide
- methyl sulphide
- hydrogen sulphide

1.15 RESPIRATORY PROTECTION

1.15.1 General

Section 2.3.6.5 of the ISGOTT manual states that self-contained breathing apparatus should always be worn if it is considered necessary to breach the integrity of the cargo system, and a vapour free atmosphere cannot be guaranteed. This would include:

- Open gauging and sampling
- Washing filters and mopping up spills
- Removing blanks from systems
- Draining lines to an open containment

The reference also advises against using respirator protection against H_2S vapour as concentration levels may exceed the operational capability of the respirator cartridge. The TSGC manual also emphasises the use of self-contained breathing apparatus in preference to a respirator.

1.15.2 *Jo Eik*

Jo Tankers' ships used to be equipped with full and partial face respirators with a range of filters. However, there was over reliance on the protection they afforded. Because of this and potential confusion over fitting the correct filter for the specific circumstances, they were removed from the fleet. In their place, *Jo Eik* was equipped with a breathing apparatus trolley (Draeger PAS Air Pack 2) **(Figure 13)** incorporating twin, large capacity air bottles with extension hoses and face masks for use on the upper deck areas.

Section 6.1 of the ship's Safety, Health and Environmental Protection Procedures (QSA) specifically prohibited the use of gas/vapour filter masks. The instruction stated:

> *"The use of any Gas/Vapour Filter Masks during Cargo Handling, Tank Washing or any other Cargo Related Work is strictly prohibited on board all Jo Tanker ships. The same restrictions are also applicable when entering any enclosed spaces, including but not limited to bunker compartments".*

1.15.3 Vopak Terminal

Vopak terminal staff were equipped with Scott Sari full face respirators fitted with a Pro 2000 combined filter to EN 14387; 2004, EN 12941 and EN 12942 standards **(Figure 14)**. The filter protected against organic and inorganic gases including H_2S to a concentration of 1.0% / volume.

1.15.4 Intertek OCA

Intertek OCA provided its surveyors with full face respirators and a wide range of filters. In this case the surveyor's respirator was fitted with an EN 141 A2 filter **(Figure 15)** which provided protection against organic compounds but at concentrations up to 0.5% / volume. Importantly, it did not protect against inorganic compounds such as H_2S or mercaptans.

1.16 STRUCTURAL LAYOUT IN THE VICINITY OF P10 CARGO TANK

The positions of P10 cargo tank and of the outboard and inboard Butterworth hatches are shown at the general arrangement drawing section at **Figure 16**.

1.16.1 Outboard Butterworth hatch area

The outboard Butterworth hatch area was reasonably well exposed to airflows across deck, with the exception that it was partially shielded by the port bulwark flare adjacent to the ladder giving access to the upper deck from the main deck **(Figure 17)**.

Figure 13

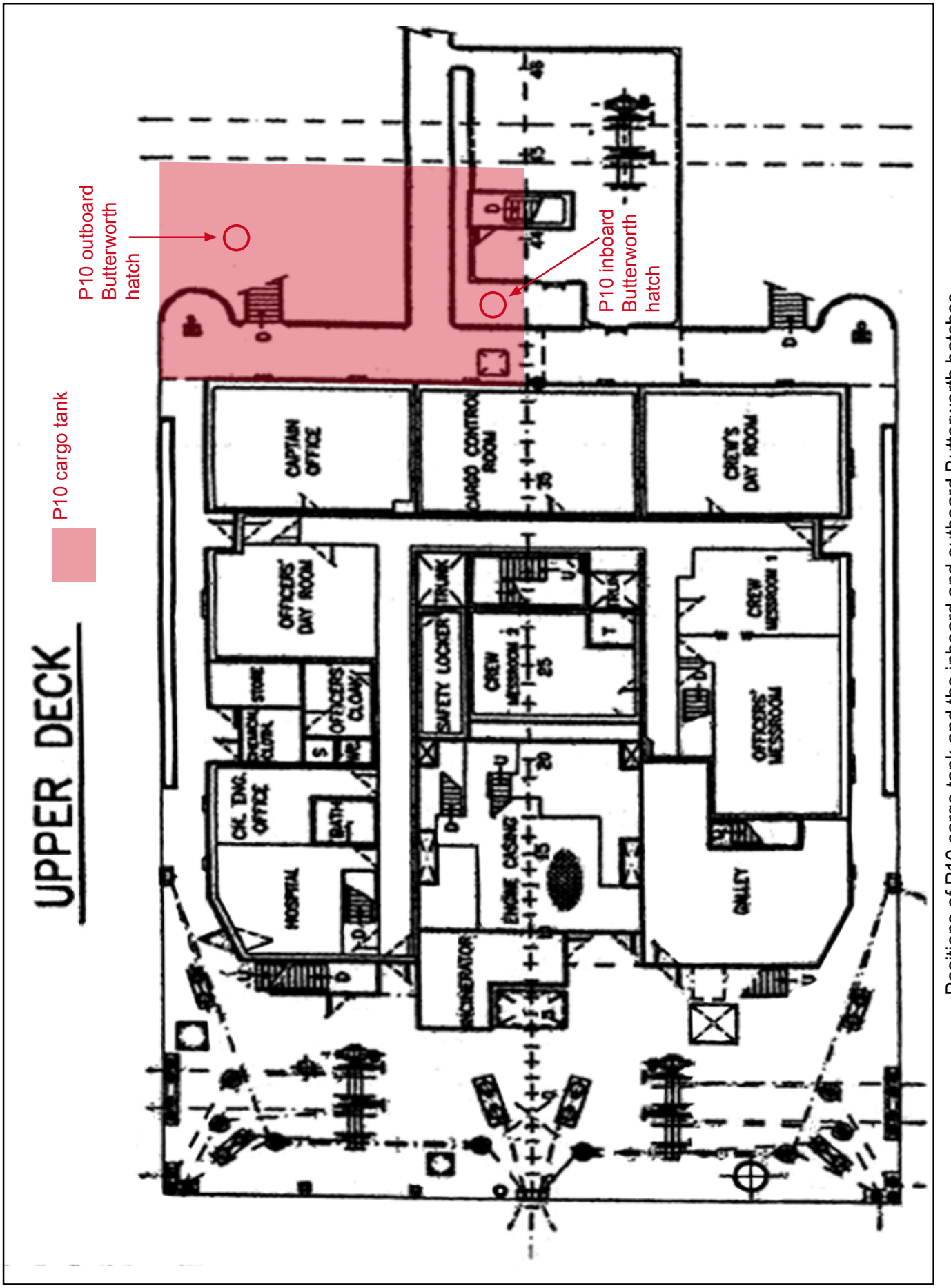
Draeger PAS Air Pack 2
breathing apparatus trolley

Figure 14

Vopak Terminal Scott Sari full face
respirator fitted with a
Pro 2000 combined filter

Figure 15

Intertek OCA surveyor's respirator fitted with an EN 141 A2 filter



Positions of P10 cargo tank and the inboard and outboard Butterworth hatches

Figure 17

P10 outboard Butterworth hatch and port bulwark flare

1.16.2 Inboard Butterworth hatch area

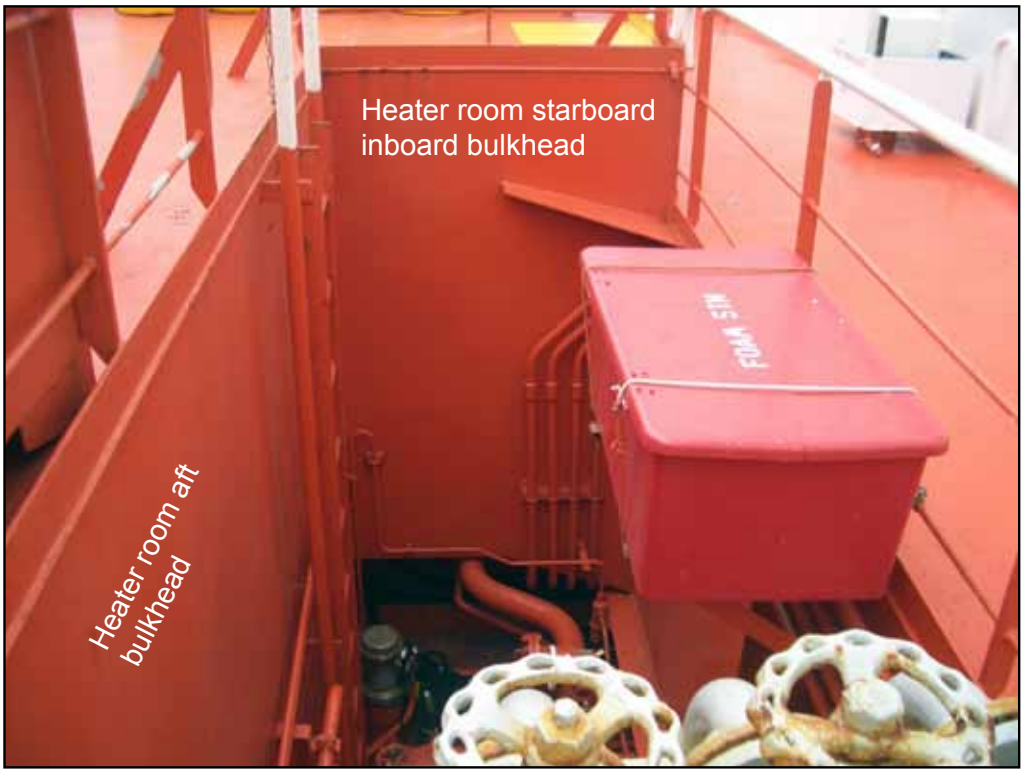
The inboard Butterworth hatch was far more enclosed, and the airflows were considerably restricted by the nature of the construction around the hatch. The heater room bulkheads were forward and to starboard of the hatch **(Figure 18)**. At deck level the area was confined by the deck deep longitudinals **(Figure 19)**. Aft of the space was the forward bulkhead of the superstructure and the area above was partially covered by the transverse walkway – **Figure 20**. The port side was largely obscured by pipework, and at the extreme port side the bulwark flare further enclosed the area **(Figure 21)**.

1.17 ENCLOSED SPACES

1.17.1 International Maritime Organization (IMO) definition and advice

During the 1990s the IMO became increasingly concerned over the number of fatalities resulting from crew members entering spaces that had depleted oxygen, toxic or flammable atmospheres. As a result it adopted Assembly Resolution A.864(20) - "Recommendations for Entering Enclosed Spaces Aboard Ships" on 27 November 1997.

Figure 18



Heater room bulkheads

Figure 19

Deck deep longitudinals

Figure 20

Transverse walkway (shown in condition post casualty recovery)

Figure 21

Port side bulwark flare

The Resolution included advice on general precautions, authorisation for entry, risks and emergency drills. It also defined an "enclosed space" as a space which had any of the following characteristics:

- *"limited openings for entry and exit*
- *unfavourable natural ventilation*
- *is not designed for continuous worker occupancy"*

1.17.2 Ship's routines and identification

The ship had comprehensive enclosed space routines supported by strict permit to enter procedures, which were covered under QMS QSA 8.7.

The crew who were interviewed were fully aware of the procedures as most of them had been involved in tank maintenance and washing. They were not all aware of the definition of an enclosed space, or that areas other than tanks could constitute an enclosed space.

1.18 EMERGENCY DRILLS AND CHIEF OFFICER'S EMERGENCY PARTY ROLE

1.18.1 Drills

The ship's drill matrix specified that "enclosed space rescue" drills were to be carried out every 3 months in accordance with the Norwegian Administration's requirements. In 2008 the first drill was conducted on 17 May followed by drills in June, July and October **(Annex Q)**. At the time of the investigation there was no record of the drill being conducted in 2009 **(Annex R)**. The Exercise Log held on the bridge recorded that a toxic gas release exercise was carried out in April 2009, although the exact date is unclear.

The rescue drills, using the portable tripod hoisting equipment, were carried out to practise the recovery of crew overcome or injured in tanks. However, there was no record of drills being carried out to deal with casualties who had been overcome in areas other than tanks.

1.18.2 Chief officer's emergency party role

The ship's QMS, Quality Emergency Manual (QEM) 5.8.2 specified that the chief officer's emergency situation role in a tank rescue was:

> *"Wear a BA resuscepac*[4]*. Administer artificial resuscitation with either spare face mask or resuscepac".* [sic]

1.19 CLEVELAND EMERGENCY ALARM SCHEME (CEAS)

The CEAS system was established in recognition of the need for close co-operation between companies involved in chemical production, processing and manufacturing in the heavily industrialised area of Seal Sands in Teesport.

[4] The "resuscepac" is a propriety resuscitation oxygen pack which is fitted to a casualty prior to recovery.

The internet based information system linked 19 of the high risk industries as well as the harbourmaster and emergency services. The mutual aid system was an integral part of the CEAS members' accident management organisations and allowed for accidents, warnings, or enquiry initiation reports to be made. The purpose was to provide incident support and to identify and report safety related issues quickly so that the appropriate action could be taken as early as possible.

Vopak's CEAS system was located in the Terminal's operations room and was operated by the operations manager and his assistant as well as by shift supervisors.

1.20 INDEPENDENT ANALYSIS OF THE CST CARGO BY CERAM RESEARCH LIMITED

1.20.1 General

The gas monitor readings taken by Vopak staff indicated that cargo vapours, including H_2S, were present in the immediate area where the chief officer and AB were overcome.

The MSDS held on board *Jo Eik* stated that H_2S was a component of the CST cargo along with other sulphur compounds and methyl mercaptan. What was not known was whether those, or other compounds in the cargo, might have initiated the increased H_2S readings on the gas monitor. It was also not known to what extent H_2S and the other compounds might have contributed to the chief officer and AB becoming casualties, and whether the other compounds might have acted as an H_2S suppressant.

CERAM Research Limited, based in Stoke-on-Trent, is a chemical materials testing specialist and was contracted by the MAIB to conduct an analysis of the CST cargo.

1.20.2 Scope of the analysis

CERAM was commissioned to analyse 450 millilitre CST samples taken from 06CS, 07CS and P10 cargo tanks to determine:

- The concentration of compounds present.
- The concentration of gases dissolved in the liquid by volatising a portion of the liquid.
- Whether the CST cargo would have degraded during storage / transportation to generate additional H_2S concentrations.
- Based on the analysis, MSDS data, and exposure limits, an opinion on the effects of exposure.
- Whether any of the compounds present acted as an H_2S suppressant.

1.20.3 Analysis report

The report concluded that there were high levels of organosulphur compounds in the samples and that H_2S levels were below 300 ppm, which was the lower limit of the testing instrumentation. The report also concluded that the organosulphur compounds would have triggered the H_2S concentrations detected on Vopak's gas detection monitor.

It was also concluded that the highest levels detected were those of methyl mercaptan (methanethiol) at 1710 ppm. The report highlighted that methanethiol causes similar effects on the central nervous and respiratory system as H_2S.

A copy of the report is at **Annex S**.

1.21 TRADE ASSOCIATIONS

1.21.1 International Federation of Inspection Agencies (IFIA)

Intertek OCA was a member of IFIA, which is the trade association that represents inspection agencies and organisations that provide testing and certifications services internationally.

IFIA's objectives are to review and, where possible, to improve methods, standards, safety procedures and rules observed by its membership for the benefit of members and their clients.

1.21.2 Tank Storage Association (TSA)

Vopak Terminal Teesside Limited was a member of the TSA. TSA's role is to represent its membership on safety, health, environmental and technical matters.

The TSA sits on a number of key UK industry groups including the Health and Safety Executive's Chemical and Downstream Oil Industries Forum. The association is also a member of the Brussels based Federation of European Tank Storage Associations.

1.22 SIMILAR ACCIDENTS

1.22.1 MAIB statistics

The MAIB's accident database shows that, from 1997, there have been 37[5] reported accidents as a result of ships' personnel entering untested, enclosed spaces containing oxygen depleted or contaminated atmospheres. There were 16 deaths and 48 injuries as a result of these accidents.

1.22.2 Recent enclosed space investigations

Since September 2007 this is the fourth MAIB investigation related to oxygen depleted or contaminated atmospheres. The previous three accidents resulted in the deaths of six seafarers.

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[5] Of the 37 accidents 22 occurred on board UK registered ships and 15 on foreign registered ships.

Concerned that the safety measures already in place had failed to prevent these fatal accidents, and because of the continued risks associated with entry into enclosed spaces, the MAIB's Chief Inspector of Marine Accidents published MAIB Safety Bulletin 2/2008 in July 2008 **(Annex T)**.

The Bulletin included an overview of the three accidents, which concluded that they were largely due to:

- Complacency leading to lapses in procedure;
- Lack of knowledge;
- Potentially dangerous spaces not being identified; and,
- Would-be rescuers acting on instinct and emotion rather than knowledge and training.

1.22.3 Marine Accident Investigators' International Forum (MAIIF)

Co-incident with these investigations MAIIF identified a large number of fatalities in the shipping industry worldwide which were related to work in confined or enclosed spaces, and considered that the occurrence of such accidents was increasing.

Accordingly, in October 2007, MAIIF tasked its representative from Vanuatu to research the incidence of this type of accident with a view to the submission of a paper to the IMO. By mid June 2009 there had been responses from 18 administrations which identified that there had been 101 reported accidents resulting in 93 fatalities and 96 injuries since 1997.

A paper has subsequently been presented to the IMO.

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 CAUSE OF THE ACCIDENTS

The pre-wash of P10 cargo tank was carried out in accordance with the procedure for a MARPOL Category X cargo. The AB who was overcome by cargo fumes had been on board *Jo Eik* since February 2009, and was fully familiar with the tank washing process using the portable washing equipment. Because of the unreliability of the fixed washing system it had become common practice to use the portable systems.

Throughout the washing procedure the inboard Butterworth hatch was left open with the portable washing equipment water supply hose passing through it. As the washer agitated the atmosphere in the tank, sufficient heavier than air cargo vapours were driven out of the open Butterworth hatch with the water mist to create a hazardous environment in the vicinity of the hatch.

Before the AB went down the ladder to shut off the valves supplying hydraulic power to P10 deepwell pump, he noticed a very strong pungent smell. He did not consider the need for respiratory protection because he did not recognise the risks and had not been warned of the cargo hazards. As he descended the ladder, climbed over the deep deck longitudinals and was adjacent to P10 inboard Butterworth hatch, he could no longer smell the vapours. Immediately afterwards he slipped into unconsciousness.

Each of the components of the CST cargo had hazards associated with them, the most dangerous of which were H_2S and methyl mercaptan (which has very similar physiological effects to that of H_2S). Although it is known from the cargo analysis that the H_2S concentration was less than 300 ppm, the methyl mercaptan concentration was 1710 ppm. The physiological effects on both the AB and chief officer strongly support the hypothesis that inhalation of the accumulated cargo vapours, coupled with possible oxygen deficiency in the vicinity of P10 inboard Butterworth hatch, was the cause of their disablement.

It is known that the Vopak gas monitor displayed an H_2S concentration just below the walkway of 25 ppm. Because of the cross-sensitivity of the gas monitor sensor to other gases evolved from CST cargo, it is most likely that H_2S was not the only gas detected. Significantly, methyl mercaptan was in high concentrations. The AB reported that he lost his sense of smell, fell unconscious very soon afterwards and suffered violent spasms following his rescue. This suggests, from the data at Table 1 - Section 1.13.3, that the effect of the cargo vapour concentration in the area of the Butterworth hatch might have been equivalent to that of an H_2S concentration as high as 700 ppm.

The chief officer was less affected during his attempted rescue of the AB because he was more distant from the immediate risk area. However, he lost control of his muscles, was unable to move or speak, and slipped in and out of consciousness before he was rescued. Referring again to Table 1, it appears that the effect of the vapour concentrations in the vicinity of the chief officer might have been equivalent to that of an H_2S concentration as high as 350-700 ppm.

2.3 THE MATERIAL SAFETY DATA SHEETS

A cargo specific MSDS is an essential component in the effective and safe management of cargo handling procedures. The information contained in the MSDS determines whether there is a need for special procedures to ensure the safety of the crew, terminal staff and the ship, and protection of the environment.

It follows that all parties should hold the same cargo specific MSDS, so all those involved in cargo operations are apprised of the need to adopt appropriate risk control measures. In this case there were two different MSDSs in circulation for the CST cargo. The one obtained by Jo Tankers was passed, in good faith, to the ship's agents and then on to the Vopak Terminal staff and to *Puccini*. Apart from the need for a MARPOL pre-wash, there was nothing to indicate the need for special precautions to be adopted, so none were considered.

The cargo specific MSDS which was passed to the chief officer of *Jo Eik* in Savannah identified H_2S as a constituent part of the CST cargo, and warned of the potentially fatal effects of inhaling the cargo vapours. This important information was not passed on, so no-one involved in dealing with the StS transfer was aware of the true dangers of the cargo; therefore the risk assessments and safety control measures were not based on accurate information. In addition, there were no specific instructions on board *Jo Eik* for handling H_2S cargoes.

Although levels of H_2S above 300 ppm were not detected in the gas phase sample of the CST cargo later analysed by CERAM, the potential for H_2S was clearly indicated in the cargo specific MSDS. This should have prompted the need for BA respiratory protection, as recommended in the ISGOTT and TSGC, which no-one on board *Jo Eik* considered.

2.3.1 Intertek OCA surveyor's respiratory protection

The Intertek OCA cargo surveyor accessed an MSDS from the internet. His research identified a need for respiratory protection against organic vapours and so he fitted an A2 filter to his respirator which was appropriate for the risks he identified. However, he did not realise that the CST cargo included H_2S, which released inorganic vapours for which a B2 filter was required. Although at the time, vapour concentrations would have been low in the areas where he took the samples and undertook his tank checks, he was nevertheless not properly protected against the hazards posed by the cargo.

It is emphasised that BA is the preferred respiratory protection against cargo vapours. Where respirators and filter canisters are considered to provide suitable protection, the rationale for doing so should be supported by appropriate risk assessments.

The surveyor would have been better protected had he consulted the cargo specific MSDS and fitted the correct filter or, alternatively, fitted a multi-spectrum filter to his facemask so as to protect against both organic and inorganic vapours.

2.4 EFFECTIVENESS OF *JO EIK* BRIEFINGS AND CHECKLISTS

2.4.1 Arrangements at Savannah

The chief officer was unable to refer to the CST MSDS in preparation for the pre-arrival conference at Savannah because it was not passed to him until just before cargo loading. The MSDS was later posted outside the CCR as confirmed by the checklist of the CDI inspector who attended the ship at Savannah.

When the MSDS for the CST cargo was received on board *Jo Eik*, there was no attempt made to carefully review the document and brief the crew about the likely risks and necessary precautions that would be required due to the nature of the product. Instead, the MSDS was merely posted in a position where it was assumed the crew would see it, read it and be guided accordingly.

2.4.2 Pre-arrival conference at Bayonne and Teesport and cargo discharging programme

During the Bayonne pre-arrival conference on 29 April the key point of advising the crew to wear respiratory equipment was not covered because proper reference was not made to the MSDS. In addition, the Cargo Discharging Programme covering the StS transfer did not specify the need for respiratory protection.

The StS transfer planned at Bayonne was cancelled and it was another 6 days before *Jo Eik* arrived at Teesport. However, a further pre-arrival conference was not carried out. This was justified on the basis that one had already been conducted on 29 April. There was anecdotal evidence that this was not uncommon and that pre-arrival conferences were not always conducted as required by the QMS instructions. This poor practice and complacent attitude can easily lead to crews forgetting the relevant safety issues during the prolonged intervening period. The pre-arrival conference should always be held as close to the loading / unloading operation as is reasonably practicable.

2.4.3 *Jo Eik* checklists

The SMS on *Jo Eik* incorporated a comprehensive set of checklists covering all phases of cargo loading, unloading and washing. The use of checklists is long established and helps to ensure that operations can be conducted safely. However, to be effective, each check should be diligently undertaken, and this was not the case prior to, during or post the StS operations.

It is clear that the discipline of correctly completing the checklists was given scant attention. Despite all checks being confirmed to be correct the dangers posed by the presence of H_2S were not identified, no one was advised to wear respiratory protection and only 7 out of 65 fixed washing machines were functional.

2.4.4 Summary

The various elements of the ship's QMS documentation, including checklists, specified many control measures that should have provided protection against the cargo vapour hazards. These were not complied with. This complacent attitude led to lapses in well documented procedures, which put the crew at risk.

2.5 CLOSED OPERATIONS, PPE USE AND TANK WASHING

2.5.1 Closed operations

To avoid risks to crew, terminal workers, and to the environment it was normal practice for cargo operations to be classed as "closed operations" (see section 1.10.5) to prevent spills and release of vapours.

Bullet point No 5 of *Jo Eik*'s Cargo Discharge Programme covering the StS transfer to *Puccini* specifically stated that the tank lids and Butterworth hatches were to be kept closed, and so prevent the release of harmful vapours.

Had the Vopak Terminal staff been aware of the hazardous content of the CST, their normal procedure would have been to carry out a risk assessment and require that a vapour return line be fitted to return the displaced gases from *Puccini*'s tanks to *Jo Eik*, and so extending the principle of closed operations. This would have prevented the discharge of the pungent gases to the atmosphere.

When the portable washing equipment was used it was not possible to adopt the "closed operations" principle because the Butterworth hatches had to be open as the washer water supply hose passed through the hatch. This clearly carried with it the risk of cargo vapour discharge, which compromised crew safety.

2.5.2 PPE use

QCH 1.1.1 required that full protection should be used when taking samples and during tank washing operations.

While the crew were unaware of the specific cargo vapour risks, an AB accompanied the Intertek OCA surveyor, and opened the hatches for cargo sampling. The surveyor was wearing a respirator and filter, but this did not prompt the AB to question the safety of the cargo, such was the extent of the complacent attitude on board in respect to the use of respiratory equipment.

However, even if the MSDS had been properly consulted, the difference it would have made on board is questionable since instructions on the use of BA during cargo and tank cleaning operations were well published in the ship's QMS documentation but were not always complied with.

While the PPE guidance had been developed to improve safety, and it was explicit, it had not been properly followed by the crew and did not seem to have been properly enforced by the vessel's senior officers. The prevailing attitude of some of *Jo Eik*'s crew was that vapour releases were common on board a chemical tanker, and that they posed insufficient risk to require respiratory protection. This dangerous and casual attitude compromised the safety of the crew.

2.5.3 Tank washing

The Vopak Terminal did not provide any standard guidance or set any limitations on open tank washing. However, there was a requirement for the terminal to be advised of any tank washing operations that were intended to be conducted alongside the facility, and each notification was considered on a case by case basis.

When tanks containing hazardous cargoes, such as H_2S, were to be washed, it was Vopak's practice to carry out a risk assessment to determine if any washing restrictions were required. Because the Terminal had the incorrect MSDS for the CST cargo carried by *Jo Eik*, no risks were identified and no restrictions were imposed on the prewash operation.

2.6 FIXED WASHING SYSTEMS

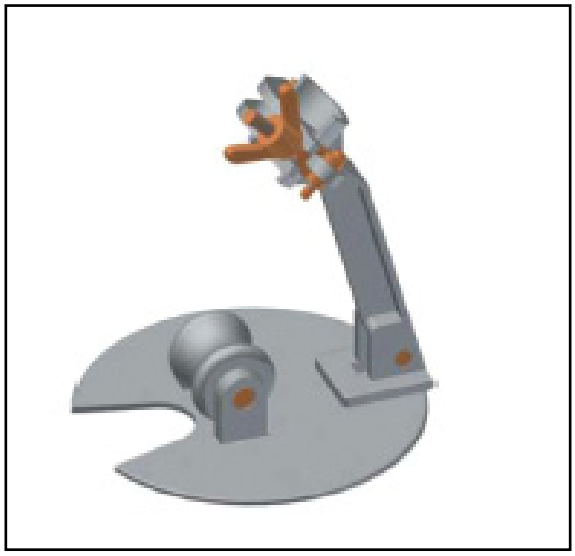
2.6.1 Impact of defective fixed washing systems

There were no regulations that required the explicit use of fixed washing systems. Indeed, chemical tankers are currently being built without any fixed systems. However, the instructions in the ship's P&A Manual stated that the fixed washing equipment was to be the normal system for tank washing.

Had the fixed machines been reliable, and had they been used, the Butterworth hatches would have remained closed and the cargo vapour would not have escaped. As the cargo vapours were miscible with water they would have been absorbed by the pre-wash water and safely discharged to the shore-receiving facility for processing and disposal.

The inboard Butterworth hatch was left open, and as there was no hose guide or blank fitted to reduce the release of the cargo vapours, these eventually accumulated in the vicinity of P10 inboard Butterworth hatch. Portable hose saddle and guide systems are readily available to give the hose a good tank entry line and to reduce any vapour release **(Figure 22)**.

Figure 22



Typical portable hose saddle and
Butterworth hatch closing plate

It is reported that the outboard P10 Butterworth hatch cover had been dropped onto the washer hose, but the hatch cover could not possibly have formed a seal with the washer hose passing through the opening. However, unlike the inboard hatch, the area around the outboard hatch was more exposed to the environmental airflows and, therefore, the vapour would have dissipated more readily.

2.6.2 Fixed washing equipment defects

At the time of the accident, it was reported that only 7 out of 65 fixed washing machines were fully functional. During OCIMF's January 2009 inspection in Rotterdam the crew advised the inspector of the unreliability of the equipment. The inspector noted that the comment had been made during previous inspections. Jo Tankers responded to the effect that the defects were due to the extreme cold weather and excess grease on the rotational washer head gearing. After servicing the equipment, Jo Tankers reported to the OCIMF inspector that the machines were fully functional.

Despite this reassurance the fixed washing machines continued to fail, which raises doubt about the effectiveness of the shipboard maintenance and inspection regime.

During the investigation MAIB inspectors carried out a trial on a randomly selected fixed washer (P10 tank, outboard washer). On opening up the sea water supply the washer initially rotated at a steady rate. After 35 seconds the rotation slowed and at 52 seconds the unit stopped rotating. The crew advised that this was typical of the problems experienced with the fixed systems in which they had lost confidence. It was reported that in many cases the units did not rotate at all.

Because of the equipment's history of unreliability it would have been reasonable for the shore management to have made regular checks or requested feedback from the ship regarding the status of the equipment. Equally, there was a responsibility on the ship's staff to report the defects, but this did not happen. Scrutiny of the ship's Safety Committee Meeting minutes for the previous 12 months did not reveal any mention of the defective fixed washing machines or that these defects could compromise the safe washing of cargo tanks.

The continued failure of the fixed washing machines merited closer attention both by the ship's crew and shore management to ensure that the requirements of the vessel's QMS and Standing Orders on "closed operations" during tank washing could be complied with.

2.6.3 Inspection

The OCIMF and CDI inspection checklists did not specifically target the operational status of tank washing equipment, although general checks were made on cargo and tank equipment.

While it would be helpful if the checklists required dedicated washing equipment checks to be carried out, in most cases it simply would not be practical to conduct the full range of functional checks because of cargo operations undertaken at the time of the inspections. However checks could be made against defect list data and through targeted questions to the crew.

2.7 EMERGENCY REACTIONS

2.7.1 Attempted rescue

Unfortunately many "would be" rescuers of casualties often become casualties themselves because of an emotive urge to help without considering the consequences. This is especially so where casualties are trapped in what are regarded as typical enclosed spaces, such as tanks, cable lockers and deep bilge areas.

In this case the chief officer, the person who should have stood back and taken charge of the rescue, decided to approach the casualty from the port side, through an array of pipes, which made access very difficult. He did not consider using a monitor to test the atmosphere and he did not equip himself with a BA despite the presence of a very strong smell and BA sets being readily available.

As the chief officer made his way towards the unconscious AB, another AB took large gulps of air before descending the ladder to attempt to rescue his colleague. His attempts were unsuccessful. He was captured by the jetty CCTV footage staggering around the walkway, suffering from the effects of vapour inhalation while being assisted by other crew members. While his actions are understandable they could easily have resulted in him also becoming a casualty.

2.7.2 Final rescue

The rescue by the crew wearing BA was swift once the situation had been clarified. The use of the sling fixed to the gantry on the forward bulkhead of the superstructure was well considered and proved faster than trying to set up the emergency rescue tripod to hoist the casualties to the walkway.

However, many of the crew, without any form of respiratory protection, assembled on the walkway immediately above the accident site to receive the casualties. While the urgency to help their colleagues was well intentioned, they nevertheless put themselves in danger because they did not know the cause of the accident. Despite the very strong smells in the immediate area, no-one considered testing the atmosphere even though suitable test equipment was readily available.

It was not until the Vopak Terminal staff arrived on board that the crew and casualties were instructed to move from the walkway into fresh air to avoid putting anyone else in danger.

2.7.3 Raising the alarm

The purpose of the Vopak Terminal emergency procedures, including raising the alarm, was to ensure that a standard process was followed so that the terminal could expedite assistance by the emergency services and establish its own on site emergency plan procedures to make the area safe.

In this case the alarm was quickly raised by the OS of the afternoon watch, and the ship's emergency teams mustered promptly. However, Vopak Terminal's emergency routine – "In The Event of an Emergency On Board the Ship: Action to be Taken by Ship Personnel", which is listed in the Cargo Information Book, was not followed **(Annex M)**.

The chief officer, who had the ship/shore radio, signed the "Emergency Procedures" page in the Cargo Information Book and placed it in the CCR. The master did not have a copy of the emergency procedure and one was not placed on the bridge, so the master was unaware of the routine to be followed. The one person who was aware of the procedure was the chief officer, and at the crucial time he had become a casualty. The master's first action was to contact the ship's agent, who then in turn contacted the harbourmaster's office. It was then that the harbourmaster's office initiated a call to the emergency services.

The convoluted way that the emergency situation on board *Jo Eik* was transmitted to the authorities ashore was far from ideal. At best it could have resulted in misinformation and delays in securing help from the emergency services. At worst, it could have compromised the casualties' chances of survival.

2.7.4 Vopak Terminal reactions

Despite no-one being aware of the true hazards posed by the CST cargo, there was nevertheless a warning that was not properly followed through by the Vopak Terminal staff.

At 0245, just after connecting the cargo transfer hose to *Puccini*, the crew and Vopak jetty staff noticed a very strong pungent smell. As the gasses in *Puccini*'s tanks were being displaced to atmosphere, the smell worsened, which resulted in the Mutual Aid Message being posted on the CEAS system at 0703, and again at 0757, requesting information regarding the source of the smell. This was not properly investigated by the Vopak Terminal. It was assumed that the smell originated from another site. No-one visited *Jo Eik* or *Puccini,* where it was known that cargo was being transferred, to find out if the smell originated from the cargo. As it was, Vopak's jetty operator had already noticed the strong smell but did not at this point report it.

Had the source of the smell been properly investigated there was a chance that cargo operations would have been suspended, the cargo risks identified, and safety measures, such as the need for respiratory protection, recognised.

After the accident was identified, Vopak Terminal's On-Site Emergency Plan was swiftly initiated.

The first on-site accident feedback to the Vopak's operations room was provided by the Shift Day Supervisor who was also the on site co-ordinator. He had equipped himself with a gas monitor, but despite the indications of a vapour release he did not have any respiratory protection, although respirators with multi-spectrum filters were readily available. Despite the crew on the walkway appearing to be unaffected by vapour it would have been prudent for the supervisor to have had respiratory protection immediately available.

2.8 ROLE OF THE CHIEF OFFICER DURING EMERGENCY RECOVERY OF PERSONNEL

Jo Eik's emergency response procedures (QEM 5.8.2) require that the chief officer dons a BA and carries a rescue pack to fit to a casualty while he personally attempts a rescue. This requirement will, in effect, remove the chief officer's ability to maintain an overview of the emergency response effort.

Jo Eik carries eight officers including the master. There is sufficient flexibility in the manning levels to allow another officer to lead any rescue attempt. This would allow the chief officer to adopt an "on scene commander's" role and so effectively manage his manpower and equipment resources to best effect.

2.9 EFFECTIVENESS OF EMERGENCY DRILLS

Realistic, properly monitored and assessed drills for the recovery of casualties from an enclosed space are fundamental in preparing crews to deal instinctively with this type of emergency.

One of the essential points of the drill is to drive home the need to ensure that those involved in rescue operations wear the appropriate PPE to avoid becoming casualties themselves. This very important lesson seems to have been forgotten as the chief officer and the forenoon watch AB attempted to rescue the AB without using BAs resulting in both being variously affected by the cargo vapour on deck.

When planning drills, proper consideration should be given to identifying locations where similar accidents might occur. This means areas of the deck as well as tanks and other conventionally accepted enclosed spaces.

2.10 ENCLOSED SPACES

The area surrounding P10 inboard Butterworth hatch was an enclosed space as defined by the IMO (Section 1.17.1). However, it was not recognised as such by anyone on board *Jo Eik*, and was not identified as such in the vessel's QMS documentation. This was because it was on the main deck and did not fall into the usually accepted interpretation of an enclosed space, such as a tank, boiler drum or crankcase.

Vapours can accumulate if open cargo operations are inadvertently allowed, and during tank gauging. They can also build up during open tank washing when the atmosphere is agitated and vapours are driven from open hatches by the action of the tank washers.

It is normally expected that the vapours will be dissipated by environmental airflows across the deck. However, airflows around the superstructure areas are especially prone to eddies which prevent the safe dissipation of vapours and allow them to accumulate. As this accident shows, an apparent open area can in fact be an enclosed space in accordance with the IMO definition. To make matters worse, the air flow at the time of the accident was directly from the stern, so there would have been very little exchange of air in the area of the accident.

At the time of the accident there were no signs posted or other methods used to warn of areas on the deck which should be considered as enclosed spaces. The appropriate level of protection to be used in such areas should be determined by risk assessments, and promulgated in the QMS procedures.

2.11 FATIGUE

The officers and crew worked 4 hour watches. None of those interviewed expressed any concern about excessive workload or of arduous conditions on board. The day before the accident, the ship was at anchor and all crew were well rested.

Fatigue is therefore not considered to be a contributory factor to this accident.

SECTION 3 - CONCLUSIONS

3.1 SAFETY ISSUES DIRECTLY CONTRIBUTING TO THE ACCIDENT WHICH HAVE RESULTED IN RECOMMENDATIONS

1. There were two different MSDSs in circulation for the CST cargo. The MSDS which was passed to the Vopak Terminal staff, agents and to *Puccini* did not identify that the H_2S could pose a hazard, so control measures were based on inaccurate information. [2.3, 2.5.3]

2. The cargo vapours were allowed to escape from P10 Butterworth hatches because there were no arrangements for closing off the opening around the portable washer water supply hose where it entered the tank. [2.5.1, 2.6.1]

3. There was a complacent attitude on board *Jo Eik* regarding the use of BA. Although the instructions for wearing BA were explicit in the vessel's QMS, this was not enforced and personnel were therefore put at risk. [2.5.2]

4. A pre-arrival conference was not carried out before arrival at Teesport. There was anecdotal evidence this was not an isolated case. The crew were not aware of the cargo hazards and safety precautions to be taken. [2.4.2]

5. Cargo checklists were not completed diligently, so the effectiveness of the checklists was compromised. [2.4.3, 2.4.4]

3.2 OTHER SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION ALSO LEADING TO RECOMMENDATIONS

1. The Intertek OCA cargo surveyor did not have access to the cargo specific MSDS and he equipped himself with a respirator filter that was inappropriate. [2.3.1]

2. The master did not follow the Vopak Terminal's emergency procedures as stipulated in the Cargo Information Book. [2.7.3]

3.3 SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION WHICH HAVE NOT RESULTED IN RECOMMENDATIONS BUT HAVE BEEN ADDRESSED

1. None of the crew recognised the risk of cargo vapours accumulating in the enclosed area around P10 inboard Butterworth hatch as the tank atmosphere was agitated during the washing procedure. [2.2, 2.10]

2. The crew did not properly refer to the CST cargo MSDS, so the H_2S hazards associated with the cargo were not identified at the pre-arrival conference and therefore the need for respiratory protection was not enforced. In addition, there were no specific instructions for handling cargoes containing H_2S. [2.3, 2.4.1, 2.4.2]

3. The fixed washing machines had a long history of unreliability and the crew had lost confidence in their use. This led to the portable washing machines being routinely used, which was contrary to the vessel's P&A manual instructions and negated the principle of "closed operations". [2.6.1]

4. The chief officer and AB compromised their safety by attempting to rescue the casualty AB without testing the atmosphere and without wearing BA. As a result, the chief officer became a casualty himself and the AB suffered from the effects of cargo vapour inhalation. [2.7.1]

5. The majority of the crew of *Jo Eik* compromised their safety by remaining in the immediate vicinity of the accident during the rescue and post rescue phase. [2.7.2]

6. Vopak Terminal's investigation of the CEAS Mutual Aid Messages was not thoroughly conducted. [2.7.4]

7. QEM 5.8.2 required that the chief officer wore a BA and personally carried the rescue equipment to recover a casualty from an enclosed space instead of acting in a more appropriate supervisory role as the on-scene commander. [2.8]

8. The rescue actions by the chief officer and AB were poorly conceived and dangerous. The management and assessment of emergency drills involving hazardous products merits review. [2.9]

9. The area around P10 inboard Butterworth hatch was an enclosed space in accordance with the IMO definition. This, and other similar areas on the deck were not recognised as enclosed spaces, so the appropriate precautions were not taken. [2.10]

SECTION 4 - ACTIONS TAKEN

4.1 THE MARINE ACCIDENT INVESTIGATION BRANCH

The Chief Inspector of Marine Accidents has produced a Safety Flyer highlighting the circumstances and lessons to learn from this accident **(Annex U)**.

4.2 VOPAK TERMINAL TEESSIDE LIMITED

The terminal operator has:

- Held a post accident meeting with the emergency services that attended the accident to discuss procedural issues. This highlighted the need to improve access for the emergency services, improve communications with the security staff and emphasise the correct terminal emergency procedures to ships' masters.
- Issued instructions **(Annex V)** to strengthen the CEAS alert response procedures to determine if causes of alerts originate from Vopak Terminal operations.

4.3 CHEMICAL DISTRIBUTION INSTITUTE

The Chemical Distribution Institute:

- Has issued a memorandum, on 17 August 2009, instructing all its inspectors to verify that MSDSs held on board are the specific documents, as issued by the shipper, for the cargo being handled.
- Will place before its Technical Committee, by the end of 2009, an amendment to the Question and Guidance Notes for its Chemical Tanker Ship Inspection Report. The amendment will implement questions to:
    - Identify that the MSDS is correct for the cargo carried as issued by the shipper.
    - Seek evidence that the cargo specific MSDS is promulgated to receivers (terminal or transhipment ships/barges) either directly from the ship or via the ship operator or agent, and that there is a formal procedure in the ship's Safety Management System to support this.

4.4 JO TANKERS AS

The ship's manager has:

- Provided new instructions at QCH 1.6 – "New Cargoes for the Company, Ship, Master or Chief Officer" **(Annex W)** requiring that all relevant information is held for the cargo and that related hazards and safety procedures are covered at the pre-arrival conference.

- Issued “Lessons to Learn” Number: 7/2009 – Unconscious Crew Members due to Inhalation of Cargo Vapours **(Annex X)** to its fleet advising of the circumstances of the accident and the precautions that need to be taken to prevent a re-occurrence.
- Issued procedures for handling cargoes containing H_2S at QSA 7.3.2 **(Annex Y)**.
- Programmed a presentation on the circumstances of the accidents at its fleet conference to be held in Manila from 16 to 18 November 2009.
- Commenced a review of QEM 5.8.2 - rescuing personnel from an enclosed space. The chief officer’s role will change from personally leading the rescue to that of an on-scene commander’s function.
- Instructed its fleet to:
    - Carry out risk assessments in accordance with the new instruction at QSA 5.41 **(Annex Z)** to identify and clearly mark areas on deck which constitute an enclosed space, and where cargo vapours may build up.
    - Ensure deck crew wear personal gas detectors when handling products containing H_2S and when involved in cargo/washing/gas freeing operations when they are likely to come in contact with cargo vapours from open hatches and cargo lines in accordance with QSA 7.3.1. **(Annex AA)**
- Arranged for crews to carry out additional training in rescue operations involving hazardous products.
- Instigated a repair plan to address the tank fixed washing system defects. With effect from 27 July 2009 all fixed washers were reported as fully operational.

SECTION 5 – RECOMMENDATIONS

Jo Tankers AS is recommended to:

2009/180 Provide Butterworth hatch closing arrangements to reduce cargo vapour discharge when using tank portable washing equipment.

2009/181 Implement management control measures to verify:

- Pre-arrival conferences are conducted as close to the arrival at the loading/discharge port as possible.
- Cargo checklists are completed diligently; tank washing defects are identified and corrective action taken to maintain the principle of "closed operations" as far as is practicable.
- Crews use the respiratory protection in accordance with its QMS instructions.
- Terminal emergency procedures are clearly promulgated and that key personnel, in addition to the chief officer, are familiar with them.

International Chamber of Shipping, Tank Storage Association and the **International Federation of Inspection Agencies** are recommended to:

2009/182 Promulgate via their membership the MAIB's Safety Flyer which highlights the circumstances and lessons to learn from this investigation.

International Chamber of Shipping is recommended to:

2009/183 Include the following safety issues identified in this report in the next periodic review and amendment of the Tanker Safety Guide Chemicals:

- Emphasise the need for the cargo specific MSDS to be held on board as supplied by the shipper.
- That the cargo specific MSDS is promulgated to receivers (terminal or transhipment ships/barges) either directly from the ship or via the ship operator or agent so that risk control measures are based on accurate information.
- That areas of the deck which fall into the IMO's definition of an Enclosed Space are identified, and that appropriate control measures are in place following risk assessment.

Intertek OCA is recommended to:

2009/184 Review its procedures for accessing cargo specific MSDSs to ensure that cargo surveyors are equipped with the appropriate PPE respiratory protection.

Marine Accident Investigation Branch
November 2009

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