Report on the investigation of

the fatality of a shore worker in No 2 cargo tank

on board the oil/chemical tanker

# *Bro Arthur*

at the Cargill Terminal, Hamburg, Germany

on 19 February 2010

Marine Accident Investigation Branch
Mountbatten House
Grosvenor Square
Southampton
United Kingdom
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**Report No 9/2010**
**August 2010**

Pursuant to Regulation 6 of Chapter XI -1 of the International Convention for the Safety of Life at Sea (SOLAS) and the Code of the International Standards and Practices for a Safety Investigation into a Marine Casualty (Casualty Investigation Code) (Resolution MSC.255 (84)), the MAIB has investigated this accident with the co-operation and assistance of the Federal Bureau of Maritime Casualty Investigation (BSU). The Coastal State's contribution to this investigation is acknowledged and gratefully appreciated.

**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."*

**NOTE**

This report is not written with litigation in mind and, pursuant to Regulation 13(9) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purposes is to attribute or apportion liability or blame.

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**Figures and Annexes**

## GLOSSARY OF ABBREVIATIONS, ACRONYMS AND TERMS

| | | |
|---|---|---|
| AB | - | Able Bodied seaman |
| BSU | - | Bundesstelle für Seeunfalluntersuchung |
| BTFR | - | Broström Tankers France |
| CCR | - | Cargo Control Room |
| CO | - | carbon monoxide |
| COSWP | - | Code of Safe Working Practices for Merchant Seamen |
| CPO | - | crude palm oil |
| DOC | - | Document of Compliance |
| EEBD | - | Emergency Escape Breathing Device |
| EN | - | European Norm |
| FRS | - | Fire and Rescue Service |
| ft | - | foot |
| $H_2S$ | - | hydrogen sulphide |
| HSEQ | - | Health, Safety, Environment and Quality |
| ICS | - | International Chamber of Shipping |
| IMO | - | International Maritime Organization |
| ISGOTT | - | International Safety Guide for Oil Tankers and Terminals |
| ISM Code | - | International Safety Management Code |
| kW | - | kilowatt |
| LNG | - | liquid natural gas |
| m | - | metre |
| 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 |
| MGN | - | Marine Guidance Note |

| | | |
|---|---|---|
| MSC | - | Maritime Safety Committee |
| MSDS | - | Material Safety Data Sheet |
| $O_2$ | - | oxygen |
| P&I | - | Protection and Indemnity |
| PGM | - | Personal Gas Monitor |
| PPE | - | Personal Protective Equipment |
| SI | - | Statutory Instrument |
| SMS | - | Safety Management System |
| SOLAS | - | International Convention for the Safety of Life at Sea |
| TSGC | - | Tanker Safety Guide Chemicals |
| UHF | - | Ultra High Frequency |
| UTC | - | Universal Co-ordinated Time |
| VHF | - | Very High Frequency |
| Fractionation | - | The process of crystallising and separating fatty acid compositions. In the case of crude palm oil, this results in the separation of 50% saturated and 50% unsaturated fatty acids, i.e. partially into a high melting fraction or stearin and a low melting fraction or olein. |
| Toolbox talk | - | Is a safety briefing convened to ensure that workers involved in a specific task are aware of the scope of the work, safety-related issues and their individual roles and responsibilities. |

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

## SYNOPSIS

At 2258 on 19 February 2010, a German shore worker was fatally injured on board the oil/chemical tanker *Bro Arthur*.

*Bro Arthur* had part-discharged at Rotterdam before arriving in Hamburg to offload her remaining crude palm oil cargo. A team of three cargo "sweepers" had been arranged under the operational direction of a supercargo. While exiting No 2 cargo tank on completion of the "sweeping" operation, one of the "sweepers" fell to the bottom of the tank.

The postmortem toxicology report identified that the casualty was under the influence of a variety of prescription and illegal drugs which would have caused severe impairment. All the evidence suggests that he fell from the vertical ladder as he lost his hand grip on the slippery surface. He had not been provided with a safety harness or fall arrestor.

The casualty had been sub-contracted by a German cargo tank cleaning company. This investigation does not seek to explore German contractual arrangements or legislative issues; these are being addressed, as appropriate, by the German authorities.

The MAIB investigation found that *Bro Arthur*'s safety management lacked direction in a number of organisational and equipment areas. There were issues relating to superficial risk assessments, inaccurate atmosphere testing routines, weak control of contractors, an unwillingness to confront individuals when their condition compromised safety, non-compliance with mandatory safety drills and unsuitable casualty recovery equipment.

Recommendations have been made to the Maritime and Coastguard Agency and the International Chamber of Shipping (ICS) which are designed to:

- Improve the control and safety of shore contractors who are employed on board vessels in port.
- Highlight the need for the provision of suitable portable rescue equipment that can be used for the recovery of personnel from deep cargo tanks.
- Ensure ships' staff are trained in the use of such equipment.

Recommendations have also been made to *Bro Arthur*'s management company and the manufacturer of atmosphere monitoring equipment supplied to the vessel.

The MAIB has produced a safety flyer, which contains details of the accident and appropriate safety lessons for promulgation to the industry via the ICS and the International Group of P&I Clubs.

Image courtesy of Broström

*Bro Arthur*

# SECTION 1 - FACTUAL INFORMATION

## 1.1 PARTICULARS OF *BRO ARTHUR* AND ACCIDENT

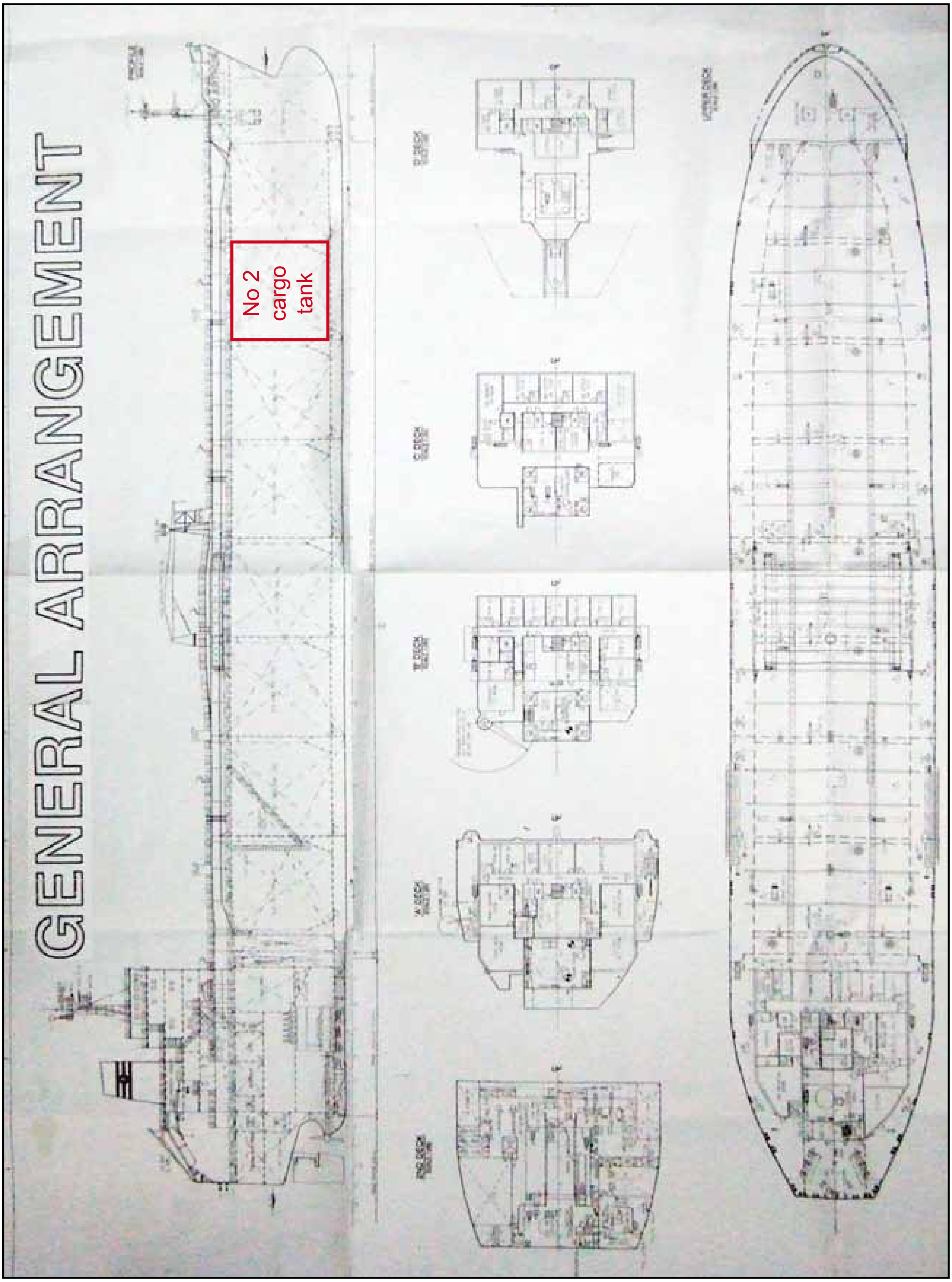
### Vessel details

| | | |
|---|---|---|
| Registered owner | : | Broström Tankers France S.A.S. |
| Manager | : | Broström Tankers France S.A.S. |
| Port of registry | : | Dover |
| Flag | : | United Kingdom |
| Type | : | Oil/chemical tanker IMO Type III |
| Built | : | 1995 by Halla Engineering and Heavy Industries Company, Republic of Korea |
| IMO Number | : | 9079171 |
| Classification society | : | Bureau Veritas |
| Construction | : | Steel, double hull |
| Length overall/breadth | : | 175.78m, 32.2m |
| Gross tonnage | : | 28226 |
| Engine power and/or type | : | 1 x MAN B&W, 6S50MC 2 stroke engine producing 7460kW |
| Service speed | : | 14 knots |
| Other relevant info | : | Single fixed pitch propeller |

### Accident details

| | | |
|---|---|---|
| Time and date | : | 2258 on 19 February 2010 |
| Location of incident | : | Cargill Terminal, Hamburg, Germany |
| Persons on board | : | 24 crew, 3 supernumeraries (master's wife, supercargo and relief master) and 3 shore workers |
| Injuries/fatalities | : | One shore worker fatality |
| Damage | : | No damage |

Figure 1




*Bro Arthur* - general arrangement drawing

## 1.2 SCOPE OF THE REPORT

This accident investigation relates to the death of a German shore worker who was sub-contracted by a German cargo tank cleaning company. It does not seek to explore German contractual arrangements or legislative issues; these are being addressed, as appropriate, by the German authorities.

## 1.3 BACKGROUND

### 1.3.1 Ship overview

*Bro Arthur* was built as a double hulled oil products tanker in 1995. She was converted to a chemical tanker in 2008, and in April and November 2009 was issued with two Attestations to her International Certificate of Fitness for the Carriage of Dangerous Goods in Bulk. These extended the range of cargoes the vessel was permitted to carry, including crude palm oil (CPO) and stearin, which were the cargoes on board at the time of the accident.

*Bro Arthur* was constructed with eight centre cargo tanks of corrugated steel design with a total capacity of 51737$m^3$ at 98% full. Each tank was fitted with an 850$m^3$/hour submerged cargo pump taking its suction from a 0.21$m^3$ well located centrally, adjacent to the after bulkhead. Cargo heating equipment was located on the main deck.

A general arrangement drawing of *Bro Arthur* is at **Figure 1**.

The ship had a crew complement of 22. All were Filipino nationals, with the exception of the Swedish master, who was on his final trip before retirement. Although most of the crew had wide chemical tanker experience, none had previously sailed on ships carrying CPO or stearin cargoes.

### 1.3.2 Ownership and management

The vessel was owned by Broström Tankers France S.A.S. (BTFR). Broström Tankers was acquired by A.P. Møller-Maersk A/S on 23 January 2009. However, BTFR held the vessel’s International Safety Management (ISM) Code Document of Compliance (DOC) and was responsible for the ship’s technical, overall commercial and Health, Safety, Environment and Quality (HSEQ) management. To ensure a common approach to strategic HSEQ issues, BTFR was accountable to A.P. Møller-Maersk’s HSEQ Manager.

*Bro Arthur* was allocated to the Handytankers pool which was responsible for the ship’s day-to-day commercial operation.

In accordance with a long-term management plan, the owners renamed *Bro Arthur* to *Maersk Cameron* on 10 March 2010. However, the vessel has remained on the UK ship register.

## 1.4 CARGO ISSUES

### 1.4.1 Cargo "sweeping", contracts and identification of Hamburg "sweepers"

To maximise the cargo discharge a team of cargo "sweepers" was commonly employed to "sweep" the residue cargo, using rubber squeegees, towards the tank's submerged cargo pump when the cargo depth had dropped to about 25cm.

Handytankers requested the ship's agent in Rotterdam and Hamburg to arrange for "sweeping" support. The Dutch agents instructed Dunk Tankcleaning Services Ltd, a company well known to both the agent and the supercargo, to attend the vessel in Rotterdam.

The Hamburg agent approached Höhse Tanker-Service and Consulting for a team of "sweepers". Due to other commitments, the company was unable to provide them, so asked M.Teske, a company it had used before, to assist. The owner of M.Teske accepted the job and arranged for an acquaintance to help. A third "sweeper" was sub-contracted from Hamburg-based Vision Port & Logistics GmbH. This sweeper had not previously worked with the M.Teske team.

For the purposes of this report the owner of M.Teske is identified as "Sweeper" 1. His acquaintance, who was the casualty, is identified as "Sweeper" 2 and the Vision employee as "Sweeper" 3.

### 1.4.2 Supercargo

The supercargo is a person who has wide experience in cargo operations, and normally acts on behalf of the charterer. His role is to advise the ship's staff on keeping the cargo in its optimum condition, to ensure that cargo discharge is maximised, to advise on tank cleaning and to liaise with terminal cargo surveyors.

In this case the supercargo was contracted by Handytankers to act on behalf of the time charterer, Cargill Trading Singapore Pte Ltd.

## 1.5 NARRATIVE

### 1.5.1 Events leading up to the ship's arrival at Rotterdam

On 6 January 2010 *Bro Arthur* was alongside Panjang in Indonesia preparing to load 34775$m^3$ of CPO into Nos 3, 4, 5, 6, 7 and 8 cargo tanks, which had previously contained soya bean oil. The cargo supplier passed the CPO and stearin Material Safety Data Sheets (MSDS) **(Annexes A and B)** to the chief officer, although the stearin cargo was to be loaded later. Although the chief officer did not have any experience with either of the Marpol 73/78 category Y[1]

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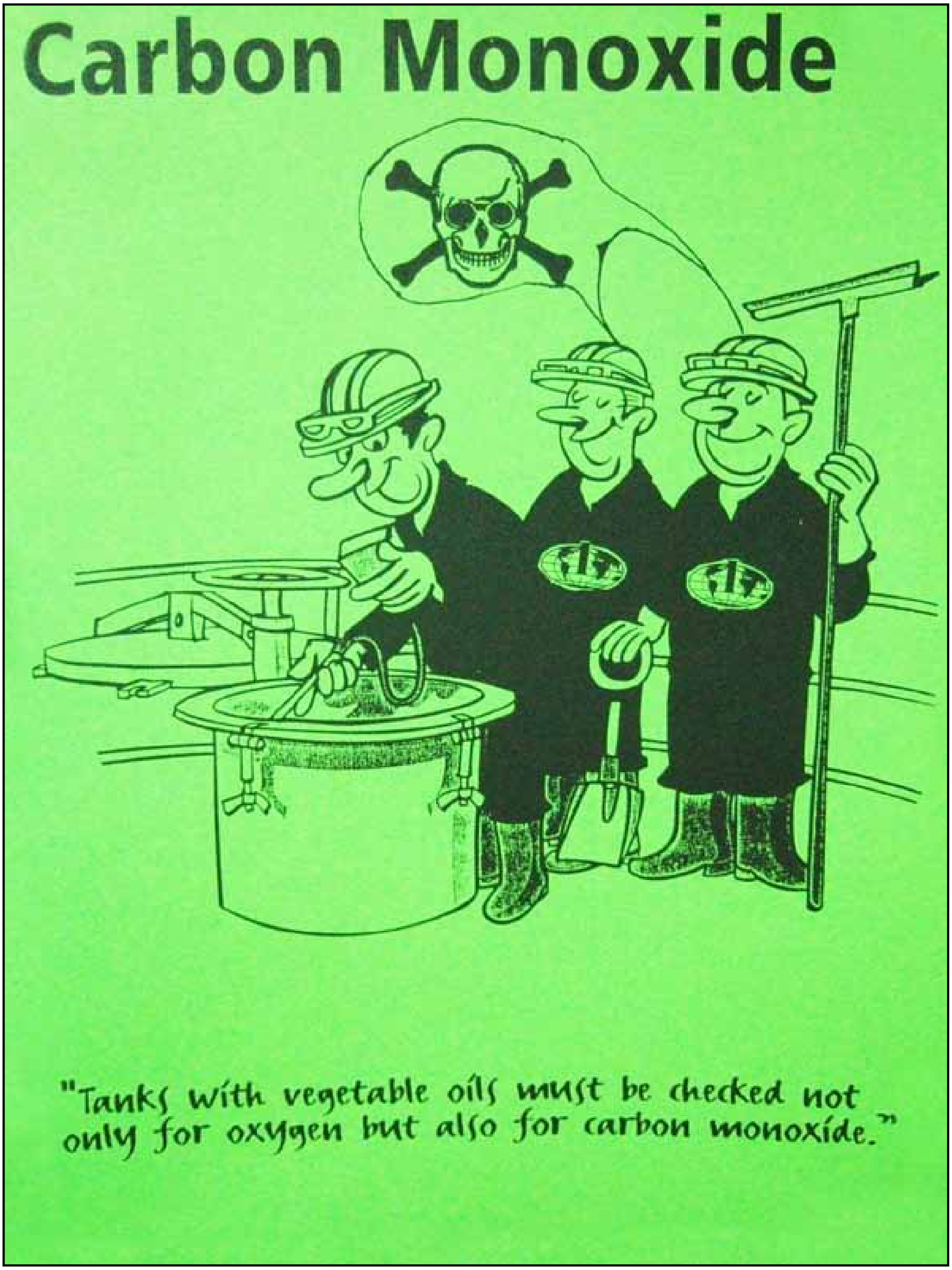
[1] Marpol 73/78 Annex II defines Category Y cargoes as: *"Noxious liquid substances which, if discharged into the sea from tank cleaning or deballasting operations, are deemed to present a hazard to either marine resources or human health or cause harm to amenities or other legitimate uses of the sea and therefore justify a limitation on the quality and quantity of the discharge into the marine environment".*

cargoes, there was nothing in the MSDSs which raised his concern or which required any special precautions to be taken. However, the supplier also passed a warning poster **(Figure 2)** to the chief officer. It advised that tanks containing vegetable oils should not only be checked for oxygen levels before entry but also for the presence of carbon monoxide (CO).

Figure 2




Vegetable oil warning poster supplied by P.T. Sari Dumai Sejati

The chief officer held his pre-loading conference to discuss the loading plan and brought the contents of the warning poster to the attention of the loading party. He then placed the poster in the Cargo Control Room (CCR).

The open hatch cargo loading was completed successfully and the ship sailed for Singapore, where bunkers were taken on 8 January.

On 10 January *Bro Arthur* arrived at Lubuk Gaung in Indonesia to load a further 3991$m^3$ of CPO into Nos 1, 5 and 7 cargo tanks and 4015$m^3$ of stearin into No 2 cargo tank, bringing it to 71% full. These tanks had also previously contained soya bean oil.

During the passage to Rotterdam the CPO was maintained at 50 - 60°C and the stearin at 60 - 70°C by circulating it through the steam heater on the main deck. The temperatures were regularly logged in the CCR.

### 1.5.2 Cargo operations in Rotterdam

*Bro Arthur* arrived at the Vopak Terminal Rotterdam at 0930 on 13 February, and the supercargo arrived mid-morning to supervise the cargo operations. On 15 February the ship shifted to the Cargill Terminal to complete the discharge of a total of 30732$m^3$ of CPO from Nos 3, 4, 6, 7 and 8 cargo tanks.

At 0917 on 16 February a 5-man “sweeping” team from Dunk Tankcleaning Services Ltd arrived on board under the direction of a supervisor. The team was met by the supercargo and was given an overview of the “sweeping” requirement together with rough timings for entry into the cargo tanks. None of the officers or crew gave a dedicated safety briefing to the contractors, and had no other conversation with them regarding instructions.

The chief officer carried out a risk assessment for the sweeping operation. He did not identify the need to wear a safety harness or fall arrestor. At 0930 he issued Enclosed Space Entry Permits for entry into Nos 3 and 6 cargo tanks.

The “sweeping” supervisor requested the chief officer to complete the Dunk Tankcleaning Services’ “Checklist Before Entering The Tank” **(Annex C)**. Based on the chief officer’s Permit to Enter and completion of his own checklist, the supervisor deemed that it was safe to enter No 3 cargo tank. He was equipped with a VHF radio, a Personal Gas Monitor (PGM), and full personal protective equipment (PPE) including thigh length industrial rubber boots but no gloves[2]. Once he had satisfied himself that the tank was safe, one of the sweepers remained with the chief officer on the main deck, adjacent to the cargo tank hatch, to act as the communications link with the “sweeping” supervisor as the remainder of the “sweepers” entered the tank at 1225.

[2] The supervisor was experienced in dealing with CPO. Owing to the very slippery nature of the cargo he felt safer climbing ladders without gloves because he believed he might otherwise lose his grip.

The supercargo confirmed that he was satisfied with the condition of the tank, and the team exited at 1325.

Further Permits to Enter were issued for Nos 4, 7 and 8 cargo tanks, and procedures followed those for "sweeping" No 3 cargo tank.

At 2044 on 17 February the "sweeping" team exited No 7 cargo tank. The supercargo and terminal cargo surveyor completed their surveys, and at 2325 *Bro Arthur* slipped from her berth for the passage to Hamburg.

### 1.5.3 Initial cargo operations in Hamburg

*Bro Arthur* arrived at Hamburg's Cargill Terminal at 0600 on 19 February 2010 for full discharge of her remaining cargo before proceeding to Portugal for a planned dry docking.

The chief officer completed the Ship/Shore Safety Checklist with the terminal staff who issued him a radio for emergency communication purposes with the terminal. At 1005 cargo operations started with the discharge of stearin from No 2 cargo tank followed, at 1045, by the CPO in No 1 cargo tank. At the time that discharge started, the cargo temperatures were recorded as 68.7ºC and 55.8ºC respectively.

At 1300 the chief officer carried out a cargo tank "sweeping" risk assessment **(Annex D)**, which identified the same three risks as those in Rotterdam. After the risk reduction measures were applied the risks were considered acceptable. No consideration was given to the use of a safety harness or fall arrestor during the entry or egress from the tank. The master and chief officer made regular visits to the CCR to check on the cargo discharge operations. At 1400 the master's replacement arrived on board and, from that point on, the master concentrated on his handover procedures.

At 1540 "Sweepers" 1 and 2 arrived on board. The chief officer directed them to a spare cabin until they were required; other than that the "sweepers" were provided with no other instructions by the crew. A short time later the supercargo met with the "sweepers" and gave a toolbox talk covering the "sweeping" requirement. He advised that, due to interruptions in the cargo discharge, they would not be required for some time. The "sweepers'" level of English was poor but the supercargo was confident they understood what was required of them. Notably, the supercargo noticed a strong smell of alcohol coming from the "sweepers", although he was unsure whether it was from one or both of them. The chief officer also noticed the odd demeanour of the "sweepers" and suspected this might have been due to alcohol. Although concerned, the supercargo decided to wait and reassess their condition at the time they were required for "sweeping" operations.

During the afternoon the "sweepers" regularly visited the mess room. They declined food but drank copious amounts of coffee. Both the chief cook and messman commented that the "sweepers" smelt strongly of alcohol and their behaviour was strange, because they were loud, running around the mess room and engaged in "play fighting" However, neither the chief cook nor messman brought this to the attention of the chief officer.

### 1.5.4 No 1 tank entry preparations and "sweeping"

At 1600 the water-driven forced ventilation fan was started to purge No 1 cargo tank **(Figure 3)**. At the same time the chief officer instructed the duty AB to rig the tank lighting, which consisted of a single pneumatically powered light, and to position a range of tank emergency safety equipment adjacent to the No 1 cargo tank hatch[3] **(Figure 4)**.

Figure 3

Water-driven forced ventilation fan

[3] The equipment included a rope, safety harness, Neil Robertson stretcher, resuscitation equipment and breathing apparatus set.

Figure 4


Tank emergency safety equipment

At about 1740 the ventilation fan was stopped and at 1750 the chief officer tested the 17.35m deep tank's atmosphere using an oxygen ($O_2$) meter with a 20m extension hose. He also tested the atmosphere for CO, hydrocarbons and hydrogen sulphide using a PGM connected to a 10m extension hose. The reading for $O_2$ was 21% and for CO and hydrocarbons it was 0%. The readings were entered on the SMS Form – FM041 - Multiple Enclosed Space Entry Permit for Nos 1 and 2 cargo tanks **(Annex E)** which was annotated to be valid from 1750 on 19 February until 0150 on 20 February 2010.

"Sweepers" 1 and 2 were called at 1800 to "sweep" No 1 cargo tank. As they entered the tank the supercargo noted that "Sweeper" 2 needed assistance from "Sweeper" 1 to descend the ladders. However, once at the bottom of the tank "sweeping" was completed efficiently and the supercargo declared himself satisfied at 1835. The "sweepers" then left the tank and returned to their spare cabin to await the instruction to "sweep" No 2 cargo tank.

### 1.5.5 No 2 tank entry preparations and "sweeping"

At 2058 "Sweeper" 3 arrived on board and was directed to the mess room to meet up with the other "sweepers". He noted the strange behaviour of "Sweeper" 2 and in particular his eye reactions. He believed that he might have been under the influence of drugs, although he did not mention this to anyone else.

No 2 cargo tank's forced ventilation was started at 2115. At the same time, the tank emergency safety equipment was moved adjacent to No 2 cargo tank hatch, and the tank lighting was rigged. At about 2150 the ventilation fan was stopped, and at 2205 the chief officer checked the tank atmosphere using the same equipment as for No 1 cargo tank, and obtained the same results. These were added to page 3 of the Permit to Enter **(Annex E)**.

At about 2220 the ventilation fan was restarted and the three "sweepers" met with the chief officer and supercargo adjacent to No 2 cargo tank hatch. Both noticed that the alcohol they had previously smelt had disappeared. As an AB lowered the "sweeping" squeegees to the bottom of the 17.34m deep tank, it was noted that surfaces of the hatch coaming and ladders were covered with a slippery coating of hard, white, waxy, solidified stearin **(Figure 5)**.

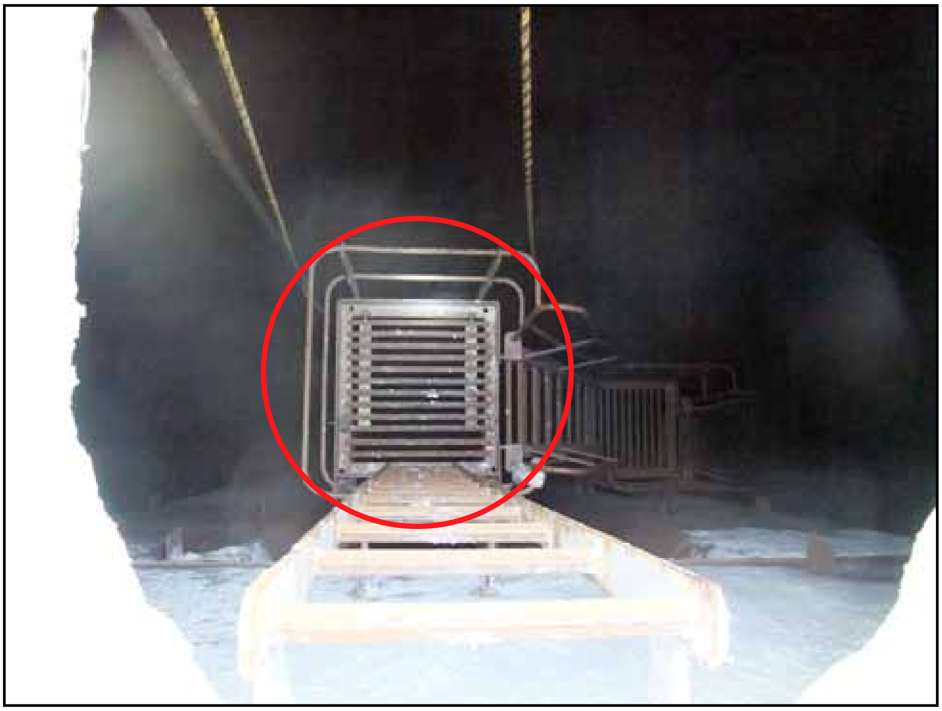
Figure 5

No 2 cargo tank hatch coaming showing solidified stearin coating

The chief officer told the group that the tank was safe to enter. They did not have their own safety checklist, and readily accepted the chief officer's opinion. To give added reassurance the chief officer gave "Sweeper" 1 a ship's PGM to provide warning of any change in the tank's atmosphere.

As the three "sweepers" descended the first vertical ladder, the supercargo followed and remained on the top resting platform **(Figure 6)** to act as communications link with the chief officer who was at the hatch coaming on the main deck. As the "sweepers" descended the three angled ladders to the bottom of the tank **(Figure 7)** the supercargo once again noted that "Sweeper" 1 was assisting "Sweeper" 2, but this did not cause him sufficient concern to abort the operation.

Figure 6



No 2 cargo tank - top resting platform

Figure 7

No 2 cargo tank - angled ladders

From his prominent position, and because of the lighting levels, the supercargo was able to easily monitor the cargo being "swept" into the pump suction well **(Figure 8)**. At 2255 the supercargo called to the "sweepers" that he was satisfied, and indicated they should leave the tank. The supercargo saw the "sweepers" heading towards the first angled ladder as he exited the tank.

Figure 8

No 2 cargo tank - cargo pump section well

### 1.5.6 Accident and post-accident actions

The "sweepers" carried their own squeegees up the ladders, and as "Sweeper" 3 reached the top resting platform he left his squeegee on the platform. Before going up the final vertical ladder **(Figure 9)** he turned and noted that "Sweeper" 2 was just starting up the final angled ladder towards the top resting platform, followed by "Sweeper" 1.

As "Sweeper" 3 arrived on the main deck he moved forward of the cargo hatch. A few seconds later, he and the supercargo heard at least one heavy thump. This was immediately followed by "Sweeper" 1 emerging from the hatch coaming shouting that "Sweeper" 2 *"had fallen and is dead".* The chief officer immediately contacted the CCR instructing the duty officer to alert the terminal staff on the emergency radio.

Figure 9

No 2 cargo tank - vertical ladder

The supercargo descended onto the tank's top resting platform and could see "Sweeper" 2 lying motionless on the tank top. He then decided to leave the tank to allow the ship's emergency party to deal with the situation.

By 2305 the master was informed of the accident and he went directly to the CCR to assume a command and control role. At the same time, the chief officer went to the bottom of No 2 cargo tank to see if he could render assistance to "Sweeper" 2. He found the casualty lying on his back, and it was clear from the amount of blood surrounding the casualty's head that he had suffered severe trauma. The chief officer was unable to locate a pulse, but decided to stay with the casualty as the second officer entered the tank to provide additional support.

Some time between about 2305 and 2315 "Sweepers" 1 and 3 left the ship unobserved by any of the crew, without recovering their belongings from their cabin.

At 2315 the local Fire and Rescue Service (FRS), police, ambulance and paramedic teams arrived on board. They entered the tank and informed the chief officer that the casualty was deceased. The chief officer offered the use of the ship's casualty recovery equipment, but the FRS declined, preferring instead to use their own light, easily portable, equipment. By 0020 on 20 February the master had informed BTFR, the charterer and A.P. Møller-Maersk A/S of the accident.

At 0030 the casualty was landed ashore using the ship's crane.

Cargo operations resumed at 0100 with the discharge of No 5 cargo tank.

In accordance with the company's Drug and Alcohol Policy, the master, chief, second and third officers and duty AB were alcohol breath tested between 0213 and 0236. All results were negative.

At 0215 "Sweeper" 3 made a statement to the Hamburg Waterway Police. At the time of writing this report "Sweeper" 1 had not been located by the German authorities.

Two inspectors from the Marine Accident Investigation Branch (MAIB) attended the vessel on 20 February.

Cargo operations were completed on 22 February and *Bro Arthur* departed Hamburg on 23 February for her planned dry docking in Portugal.

## 1.6 ENVIRONMENTAL CONDITIONS

At the time of the accident the ship was in sheltered waters. It was cloudy, and throughout the day there had been intermittent snow. The wind was south-westerly force 4 and the air temperature was 3ºC.

## 1.7 CARGO CHARACTERISTICS

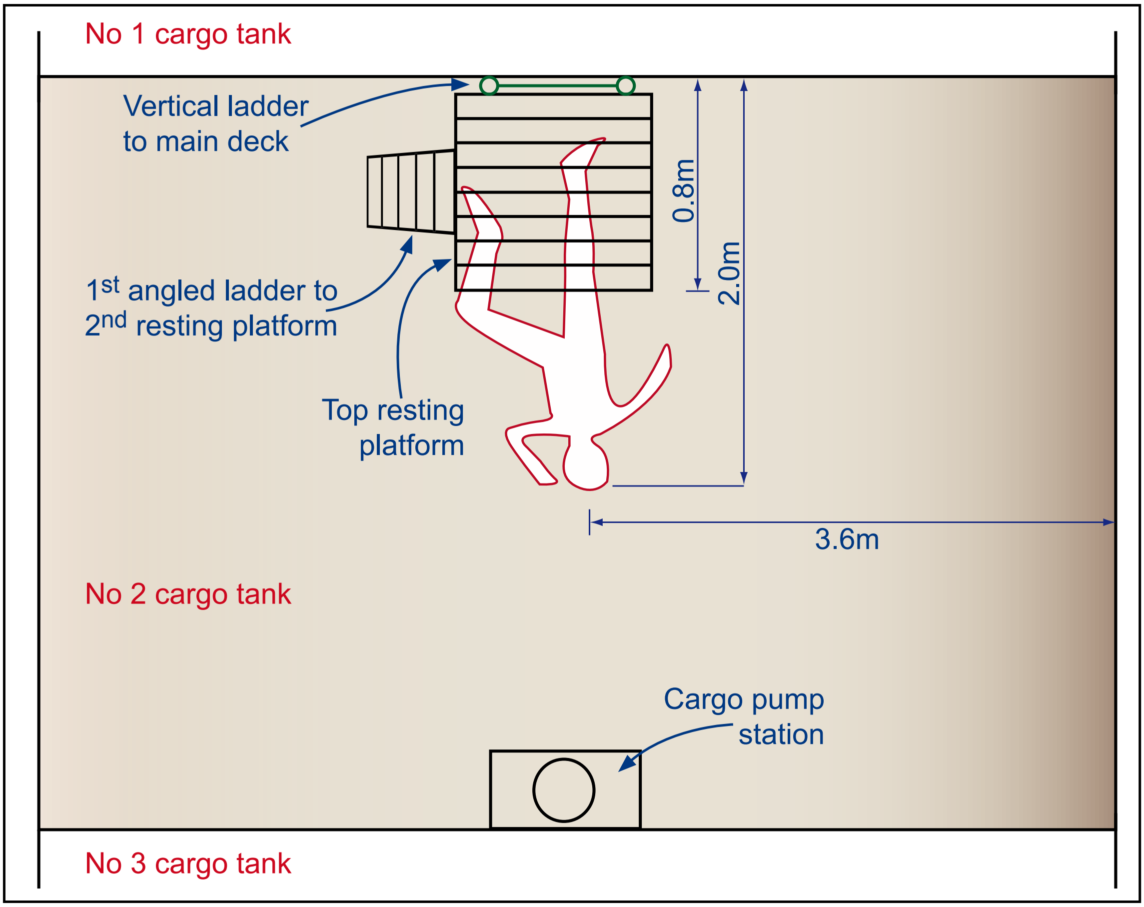
CPO and stearin are used extensively in the cooking, baking, pharmaceutical and cosmetic industries. Stearin is a fractionation of CPO with a melting point of about 44ºC, while CPO has a melting point of between 33-39ºC. Both products are wax like in their solid state, making exposed surfaces extremely slippery. During passage the cargoes are heated to maintain them in their liquid form. To ease the discharge of the cargo the viscosity for both CPO and stearin is increased by raising their temperatures to 55-70ºC.

## 1.8 LOCATION OF THE CASUALTY AND POSTMORTEM INFORMATION

The casualty, who was a 56 year old German national, was found lying on his back with his head pointing towards the after bulkhead of No 2 cargo tank. He was positioned aft of, but directly in line with, the centre of the top resting platform which was also in line with the vertical ladder giving access to and from the main deck. His position is shown in the schematic at **Figure 10**. He was wearing overalls, both his boots and at least his right-hand glove **(Figure 11)**. Witnesses were unsure if the casualty was wearing his left-hand glove.

The postmortem report confirmed that the cause of death was heavy multiple trauma consistent with a fall from height. The toxicology report confirmed that the casualty was not under the influence of alcohol. However, the blood sample confirmed the presence of antidepressants, hypnotic and sedative drugs as well as methadone and opiates.

Figure 10




Schematic showing position of the casualty (not to scale)

Figure 11

"Sweeper" 2's right hand, palm plasticised faced glove

## 1.9 HAMBURG "SWEEPERS'" – PERSONAL PROTECTIVE EQUIPMENT

The "sweepers" were dressed in plasticised paper overalls, calf length industrial rubber boots with a deep tread **(Figure 12)**, and they wore cotton palm plasticised faced gloves. They did not have hard hats, protective glasses, PGMs, radios or EEBDs.

Figure 12

Hamburg "sweepers'" industrial rubber boots

## 1.10 TANK ACCESS ARRANGEMENTS

### 1.10.1 Regulations

The latest regulation for the specification of the means of access to *Bro Arthur'*s cargo tanks is covered in Chapter II-1, Part A-1, Structure of Ships, Regulation 3-6 of the International Convention for the Safety of Life at Sea (SOLAS).

Paragraph 2.1 of the reference highlights that the means of access specifications are to comply with the International Maritime Organization's (IMO) Maritime Safety Committee resolution MSC.133(76), which was in force when *Bro Arthur* was built. Paragraphs 5 and 6 of MSC.133(76) deal with the ladder maximum angles, lengths, widths, rung spacing and guardrails' specifications as well as the requirements for resting platforms **(Annex F)**.

Further regulation regarding the access through hatches, i.e. vertical ladders applicable to tanker cargo spaces, is laid out in Regulation 3-6, Paragraph 5.1. The reference includes:

> "*For access through horizontal openings, hatches or manholes, the dimensions shall be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space…"*

### 1.10.2 Means of access - No 2 cargo tank

No 2 cargo tank was accessed directly from the main deck through a 1.1m diameter round hatch and 1m deep hatch coaming fitted with two internal and two external rungs. The 3.45m vertical ladder **(Figure 9)**, which was not fitted with any back restraining hoops, led to the 0.8m$^2$ top resting platform **(Figure 6)**. The platform was fitted with a central hinged access for casualty evacuation purposes. The access was secured with two drop nosed pins.

Two consecutive 60º ladders were fitted at right angles to the top platform, and each had its own 0.8m$^2$ resting platforms. A final ladder, fitted at right angles to the lower resting platform, gave access to the bottom of the tank.

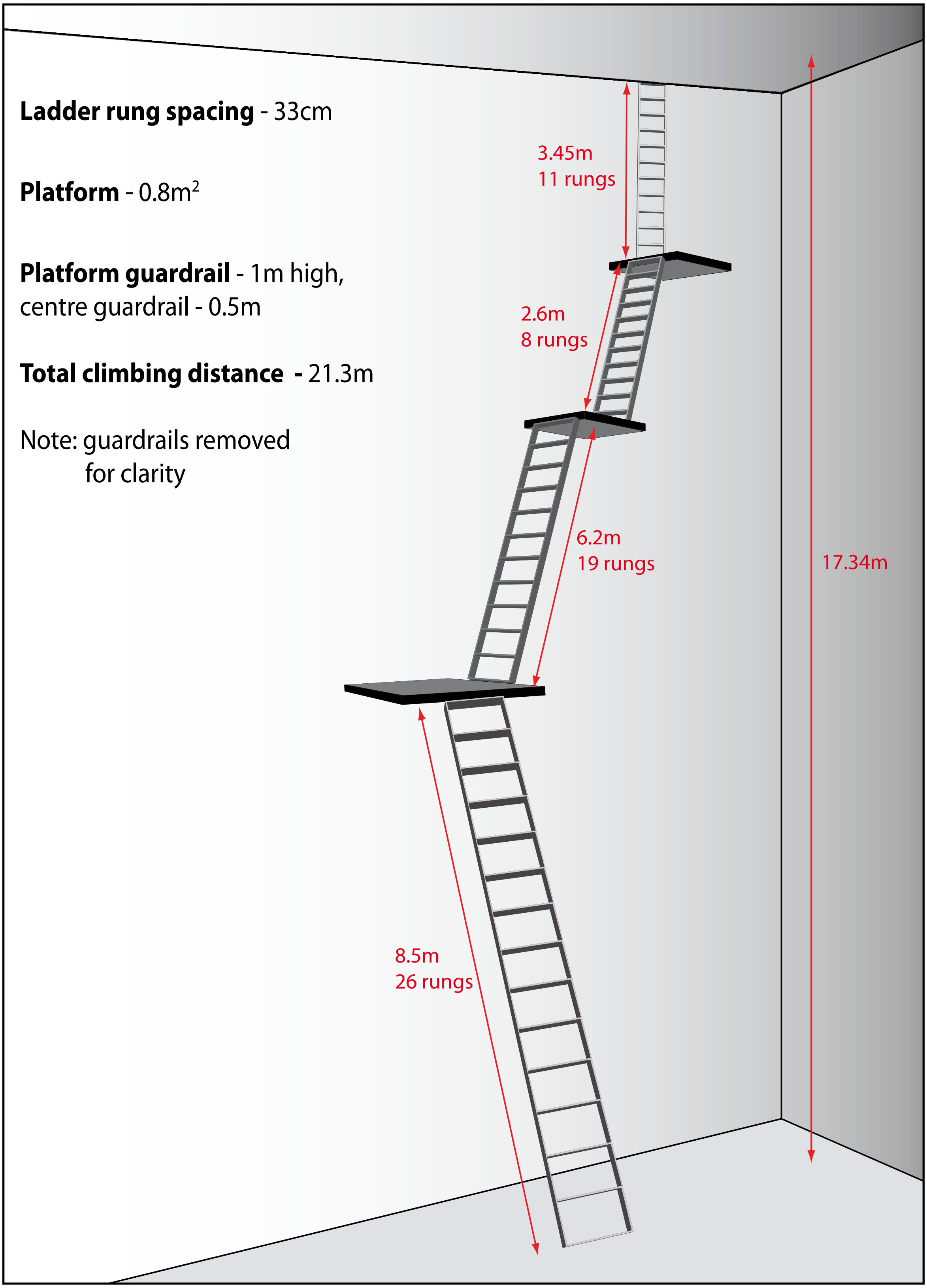
The whole system was of steel construction. Each resting platform was fitted with a 1m high top guardrail with an intermediate rail equidistant from the top guardrail and platform base. The ladder guardrails were continuous and were welded to the platform guardrails.

A general arrangement of the access system is at **Figure 13**. A schematic showing the vertical and angled ladder arrangement dimensions is at **Figure 14**.

Figure 13


General arrangement of No 2 cargo tank access system

Figure 14




No 2 cargo tank vertical and angled ladder dimensions

## 1.11 ENCLOSED SPACE ENTRY PROCEDURES

### 1.11.1 Regulation

Statutory Instrument (SI) 1988 No. 1638 – The Merchant Shipping (Entry into Dangerous Spaces) Regulations 1988, laid down the principles for entry into dangerous spaces, i.e. cargo tanks, for UK registered ships. The regulation also highlighted the need for the employer, master and other person to take full account of the principles and guidance contained in the Maritime and Coastguard Agency's (MCA) publication – Code of Safe Working Practices for Merchant Seamen (COSWP).

### 1.11.2 Company instructions

The company's instructions for entering an enclosed space were detailed in the ship's SMS document - PR053 – Enclosed Space Entry dated 15 September 2008 **(Annex G)**. The instruction put the responsibility for the correct implementation of the procedure on the chief officer for spaces other than those associated with the engine room.

To ensure a safe entry into an enclosed space, the instruction identified three distinct phases:

- A risk assessment
- Atmosphere testing
- Entry Permit

### 1.11.3 Risk assessment

The Risk Assessment Procedure was detailed in the ship's SMS Form PR277 **(Annex H)** and laid out how to complete the Risk Assessment Form FM171.

The procedure emphasised the need to define and identify the dangers and risks involved, and to specify the control and mitigating measures to be taken. The "sweeping" risk assessments for Rotterdam and for the early operations in Hamburg **(Annex D)** identified only three risks, two of which, risk of asphyxiation and falling/slipping scored 12 and 9 respectively, which was in the "high" risk red zone. After control measures, involving the use of gloves, and non-slip boots, lighting, ventilation and atmosphere testing, the residual risk factor score fell to 4 and 3 respectively, which placed both into the "medium" risk amber zone.

Following the accident a revised risk assessment was carried out on 21 February in conjunction with Maersk's HSEQ Manager **(Annex I)**. The assessment identified seven risks: four of these were in the "high" risk red zone and two in the "medium" risk amber zone. After the control measures, which included further PPE and the use of a safety harness or fall arrestor, were applied, all the residual risks fell into the "low" risk green zone.

### 1.11.4 Atmosphere testing

The SMS document PR053 emphasised the need to ensure that tank atmospheres were safe before an Entry Permit was issued.

Section 3.4 of the International Chamber of Shipping's (ICS) Tanker Safety Guide Chemicals (TSGC), which was carried on board *Bro Arthur,* provided detailed guidance on atmosphere testing, and in particular the need to test the atmosphere at the top, middle and bottom of the tank. It also highlighted that:

> "*Sampling and measurement should be done by personnel trained in the use of the equipment and sufficiently knowledgeable to understand the results obtained. It is vital that the correct instruments are used".*

### 1.11.5 Entry Permit

The comprehensive instructions and prerequisites for issuing the Entry Permit, SMS form FM041, were laid out in the company's SMS document PR053. These covered the need to regularly check the tank's atmosphere and also to identify the safety equipment and PPE requirements.

While there was no mention of the need for a device to assist the recovery of a casualty from an enclosed space to be readily available, PR053 required that a lifeline, safety harness, resuscitation equipment and breathing apparatus be immediately available at the entry point. It also stated that:

> "*the lines of communications for dealing with emergencies should be clearly established and understood by all concerned".*

The instruction also required that the following PPE was to be worn:

- Protective suits, safety boots
- Helmet, gloves and glasses
- UHF radio, safety torches
- PGM, to include measurement of $O_2$
- EEBD (subject to risk assessment)

## 1.12 SAFETY HARNESSES/FALL ARRESTORS

### 1.12.1 Equipment on board

At the time of the accident, *Bro Arthur* carried three safety harnesses conforming to European Norm (EN) 361, but no fall arrestors. The harnesses were manufactured in 2006. There was evidence of wear on the web strapping, the spring clip screwed securing sleeves were found to be partly corroded, and the attached lifelines were abraded.

After the accident the harnesses were replaced with double clip versions conforming to EN 355. A fall arrestor was also provided which could be connected to the safety harness and secured at the hatch coaming or to an overhead support **(Figure 15)**.

Figure 15

Fall arrestor

**1.12.2 Guidance and regulation on the use of safety harnesses and fall arrestors**

The ship's SMS document PR053 and Section 10.5 – Safeguards for Enclosed Space Entry of the International Safety Guide for Oil Tankers and Terminals (ISGOTT) highlighted that:

*"For large spaces, or where climbing access will be undertaken, the wearing of safety harnesses may also be appropriate".*

COSWP, Section 4.10 - Protection from Falls also identified that:

*"All personnel who are working aloft, outboard or below decks or in any other area where there is a risk of falling more than two metres, should wear a safety harness …".*

The reference also highlighted that inertial clamp devices (fall arrestors) allow more freedom in movement than a safety harness.

SI 2010 No. 332 – The Merchant Shipping and Fishing Vessels (Health and Safety at Work) (Work at Height) Regulations 2010 came into force on 6 April 2010, about 7 weeks after the accident. The regulation applies irrespective of whether the work is carried out at a height of more than 2m[4].

4 COSWP is to be amended to reflect the removal of the 2 metre rule in the Regulation.

Marine Guidance Note (MGN) 410 (M+F) The Merchant Shipping and Fishing Vessels (Health and Safety at Work) (Work at Height) Regulations 2010, issued in March 2010, provides comprehensive guidance on the Regulations.

The SI defines "work at height" as including:

> *"obtaining access to or egress from any place on a ship while at work …"*

Further clarification is provided at Section 2.2 of the MGN which states that "work at height" may also include:

> "*working in or entering or exiting deep tanks, such as ballast tanks".*

Importantly, Section 4 of the MGN states that:

> "*…the Work at Height Regulations 2010 apply to all activities of workers on UK registered vessels and government ships (other than Royal Navy vessels) wherever they are in the world".*

When applying the regulations and guidance for working at height, employers are required to take appropriate measures to minimise any risks they have identified through the risk assessment process. These may include installing guards or the use of safety harnesses or fall arrestors.

## 1.13 CONTROL/MANAGEMENT OF CONTRACTORS

### 1.13.1 ISGOTT guidance

Section 9.7 of ISGOTT provides broad guidance on the management of contractors. It places emphasis on the need to ensure that contractors understand the need to comply with all relevant safe working practices. It also states that contractors should be supervised and controlled by a Responsible Officer and that, where applicable, they should sign the formal approval for work being undertaken.

### 1.13.2 SMS guidance

The ship's SMS document PR201 **(Annex J)** – Contracting and Using Riding Personnel was supported by checklist CL107 – Familiarisation of Riding Personnel **(Annex K)**. Both documents were directed towards the use of seariding contractors, and not the use of contractors such as cargo "sweepers" while in port. The purpose of the instruction was intended to ensure that contractors were well qualified for the intended work and that they had received sufficient training in safety matters. However, the supercargo had not been subjected to any familiarisation training despite taking passage, at sea, from Rotterdam to Hamburg.

### 1.13.3 Contractors - Health and Safety responsibility

The employers', company's and workers' health and safety responsibilities relating to UK registered vessels were laid out in SI 1997 No. 2962 - The Merchant Shipping and Fishing Vessels (Health and Safety at Work) Regulations 1997.

Guidance on the Regulations was provided in MGN 20 (M+F) – Merchant Shipping and Fishing Vessels (Health and Safety at Work) Regulations 1997. Guidance was also provided in COSWP, paragraph 13 of the Introductory and Regulatory Framework which highlighted the complexity of employment relationships on board a ship in respect of contractors and sub-contractors among others. The regulations therefore recognised two levels of “employment” responsibility: the “employer” and the “Company”.

In relation to this accident, the casualty’s employer was Hamburg-based Höhse Tanker-Service and Consulting. However, Regulation 13 (b) and (c) of SI 1997 No. 2962 required that the company[5], in this case BTFR (even though it was not the worker’s employer), should:

> *“ co-ordinate arrangements for the protection of all workers and the prevention of risks to their health and safety”*

and

> *“ensure that all workers are informed of the significant and relevant findings of the risk assessment ...”*

MGN 20 (M+F) and SI 1997 No. 2962, Regulation 21 also placed a duty on the worker:

> “*to take reasonable care for the heath and safety of himself and of any other person aboard ship who may be affected by his acts or omissions ...”*

Had the ship been in a UK port, the activities of the “sweepers” would have been subject to the shore-based Management of Health and Safety at Work Regulations 1999, as well as the regulations governing those working on a ship.

## 1.14 TANK ATMOSPHERE TESTING EQUIPMENT

### 1.14.1 General

At the time of the accident, *Bro Arthur* held the following four types of tank atmosphere testing equipment on board:

- Two Riken Keiki PGMs (Explosimeters) HC Detector Model NP – 237H for measurement of combustible gas concentrations in inerted cargo tanks.
- Two Riken Keiki, RX 415 (Type HC) monitors fitted with a standard 20m extension hose for determining $O_2$ levels.

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5 The Regulations define the Company as “*…the owner of the ship or any other organisation or person such as the manager, or bareboat charterer, who has responsibility for the operation of the ship from the owner”.*

- Two Riken Keiki, GX-2009 (Ex Type A) PGMs with a 10m sampling extension hose **(Figure 16)**, for measuring combustible gas, $O_2$, $H_2S$ and CO levels.
- Two Gastec GV-100S **(Figure 17)** gas sampling hand pumps with a selection of detector tubes for measuring toxic gases including CO, $H_2S$, benzene and total mercaptan. No sampling extension hoses were delivered with the units. However, since the accident, two 20m hoses have been supplied to the ship.

Figure 16


Riken Keiki GX-2009 (Ex Type A) Personal Gas Monitor

Figure 17

Gastec GV-100S gas sampling hand pump

### 1.14.2 Riken Keiki, GX-2009 Personal Gas Monitor

The GX-2009 PGM is manufactured by Tokyo based Riken Keiki Co. Ltd for worldwide distribution. The programmable unit, which has a data logging capability, is designed to be worn by a person entering an enclosed space, such as a cargo tank. When a dangerous gas condition is detected, the PGM emits audible and vibrating alarms to alert the wearer to exit the space/don breathing apparatus.

The PGM can be fitted with an aspirator adapter connected to a 3m (10 feet) extension hose when it is necessary to draw a sample from an area, such as a cargo tank, before entry. The unit used by the chief officer to test the atmosphere in No 2 cargo tank was fitted with a 10m extension hose **(Figure 18)**.

Figure 18

Riken Keiki GX-2009 (Ex Type A) Personal Gas Monitor,
with aspirator and 10m sampling hose extension arrangement

### 1.14.3 Gastec GV-100S gas sampling hand pump

The Gastec GV-100S atmosphere sampling system employs gas detector tube technology. A precise volume of the atmosphere to be sampled is drawn up using a small hand-operated pump through a glass tube filled with a detecting reagent for the particular gas being sampled. The tube is graduated and, after certain correction values are factored in, the presence of the particular gas can be read off the tube in parts per million.

The system's ambient prevailing temperature limits are between 0ºC and 40ºC. The hand pump can also be fitted with multi-spectrum detector tubes known as Polytec Tubes. These enable a number of gases to be detected during a single sampling of the atmosphere.

Gastec's accessory list identifies 5m and 10m extension hoses that can be fitted to the tip of the sampling pump for measurement of atmospheres in tanks.

## 1.15 CASUALTY RECOVERY EQUIPMENT

The davit arrangement used for cargo slops removal and light stores work was also utilised to recover a casualty from a dangerous space. It was stowed in a main deck starboard midships store. The heavy steel unit, with a safe working load of 0.1 ton, comprised a removable base which was fitted with wheels to improve portability. A davit type arm was fitted into a socket located in the base. The single hoisting/lowering wire was simply passed over a central wheel, without any captive arrangement, and then through a block located at the end of the davit arm. The wire drum was pneumatically driven by connecting a portable hose to a low pressure air supply on the main deck. The casualty recovery equipment is shown in **Figure 19**.

Figure 19

*Bro Arthur*'s casualty rescue equipment

Following the accident, a demonstration was carried out to confirm the practicality of using the recovery equipment. The findings are discussed at Section 2.

Section 10.6.2 (Emergency Procedures, Assisting a Casualty) - of the COSWP briefly discussed removal of injured persons from holds. However, it merely stated that:

> *"... where available a manually operated davit, suitably secured over the access opening should be used to assist in removing a casualty".*

Section 17.8.3 (Entering Enclosed or Confined Spaces) of the COSWP touched on the need to consider the removal of an incapacitated person. It stated that:

> *"A means of hoisting an incapacitated person from the confined space may be required".*

## 1.16 EMERGENCY DRILLS

The statutory requirement to carry out rescue drills from a dangerous space, which includes an enclosed or confined space, was laid down in SI 1988 No. 1638 – The Merchant Shipping (Entry into Dangerous Spaces) Regulations 1988.

Regulation 6 (b) required the master to:

> "*… ensure that drills simulating the rescue of a crew member from a dangerous space are held at intervals not exceeding two months, and that a record of such drills is entered in the official log book".*

Both Section 3.8 of the TSGC and Section 10.6.2 of ISGOTT emphasised the importance of conducting enclosed space casualty rescue drills to ensure each member of the rescue team was aware of his/her role and to familiarise team members with the rescue equipment.

*Bro Arthur*'s emergency drill schedule was programmed by BTFR's shore offices and distributed to its fleet. The drill schedule was available electronically in the ship's SMS. A copy of the schedule, known as the Emergency Situations Drill Plan (BTFR) from January 2009 until December 2012, is at **Annex L**.

The casualty rescue drill from an enclosed space was not specified as a separate drill in the schedule, but BTFR advised that Situation No 302 – Illness-Injury covered the requirement.

## 1.17 RECENT INSPECTIONS

The last tanker industry external vetting inspection of *Bro Arthur* was carried out in Aratu, Brazil, on 4 October 2009 on behalf of Shell. BTFR carried out a 3-day visit in Tianjin, China commencing on 11 December 2009 and the last State Port Control Inspection took place in Vlaardingen, Netherlands on 13 February 2010.

## 1.18 SIMILAR ACCIDENTS

### 1.18.1 MAIB statistics – falls from height

The MAIB's accident database records numerous instances of falls from relatively low heights which have resulted in minor injuries. Since 2005 there have been 16 serious injuries occurring on board UK registered ships of 500 gross tonnage and over as a result of falls from fixed ladders, including those fitted in tanks, when the casualty was not wearing a safety harness or fall arrestor.

### 1.18.2 Fatal accident *Ville de Mars*

On 28 January 2009 the chief officer of the UK registered *Ville de Mars* entered a water ballast tank for inspection purposes. The vertical access ladder and the stringer, from which he fell 8m and died, were very slippery and unguarded. There were many shortcomings in the ship's procedures including inadequate risk assessments which failed to identify the need for the use of a safety harness or fall arrestor.

### 1.18.3 MAIB statistics – control of contractors

Poor briefings, incomplete risk assessments and weak oversight of contractors were factors in the death of a shore worker on 10 October 2003 on board the liquid natural gas (LNG) tanker *Hilli* and, more recently, in the events leading up to a fire on board *Maersk Newport* on 15 November 2008.

### 1.18.4 Fatal accident - *Hilli*

A specialist UK contractor was involved in chemical cleaning of the main boilers on board the LNG *Hilli*. A boiler specialist was contracted to maintain the interests of the owner, so the ship's crew did not become involved in any oversight or preparation of risk assessments. The boiler was not correctly vented during the cleaning process, and hydrogen gas built up in the steam drum. The gas was ignited as an inspection lamp was passed into the steam drum by the UK contractor; the subsequent gas explosion resulted in his death.

### 1.18.5 Fire – *Maersk Newport*

*Maersk Newport* was undergoing repairs in Algeciras, Spain following heavy weather damage. A technical superintendent dealt with the repair contractors, without involving the ship's staff. As a result, the crew had not briefed the contractors on safety issues and a risk assessment for the required burning and weld repair had not been carried out. A fire subsequently started and acetylene and oxygen bottles exploded. The crew were caught unawares because they were not advised of the hot work programme and appropriate risk control measures were not established.

## 1.19 INTERNATIONAL GROUP OF PROTECTION AND INDEMNITY (P&I) CLUBS

The Group provides a forum for sharing information on matters of concern to clubs and their members of the insurance industry. These include general issues such as oil pollution and personal injury as well as current issues such as maritime security.

# 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 ANALYSIS OF POSSIBLE CONTRIBUTING FACTORS TO THE FALL

### 2.2.1 Eyewitness account

At the time of writing this report, unfortunately "Sweeper" 1 had not been located by the German authorities, therefore the only eyewitness account to the accident itself has not been available. However, a good deal of evidence was gathered on which to base a high probability as to the cause of the accident.

### 2.2.2 Condition of the ladders

The ladders, fastenings, resting platforms and guardrails were inspected and found to be in excellent condition throughout.

It could be argued that had the vertical ladder been fitted with back restraining hoops, a person falling backwards would make contact with the hoops and be directed onto the top platform. However, the SOLAS requirements emphasise that the arrangements must not interfere with the access of a person wearing breathing apparatus, or impair the recovery of a casualty. Back restraining hoops would severely compromise these requirements. If comprehensive risk assessments are carried out and suitable alternative restraints - e.g. safety harnesses/fall arrestors identified as a control measure, then by default, back restraining hoops become unnecessary.

All aspects of the means of access complied with the current regulations and are not considered to have contributed to the accident.

### 2.2.3 Lighting levels

The single pneumatically powered light provided a satisfactory level of illumination within the tank. At the time of the accident it was dark and the deck lights were switched on, which also provided light into the cargo hatch and vertical ladder areas. During the inspection of the tank it was found that there were a few shadows, but the top resting platform and vertical ladder were well lit. Lighting levels are not considered to be a contributory factor.

### 2.2.4 Temperature

The stearin cargo was heated at 66ºC during the sweeping procedures. The tank atmosphere temperatures were not measured, but would have been substantially lower than this as the tank was being force ventilated with ambient air at 3ºC. Both the supercargo and "Sweeper" 3 indicated that the tank atmosphere was warm. It is possible that the warm atmosphere coupled with the fairly arduous "sweeping" task could have had a detrimental effect on performance, particularly on a person in poor health.

## 2.3 CAUSE OF THE ACCIDENT

### 2.3.1 Casualty's physical condition

The chief officer, supercargo, messman and chief cook all considered the behaviour of "Sweepers" 1 and 2, especially that of "Sweeper" 2, to be unusual. Indeed, "Sweeper" 3 considered that "Sweeper" 2 might have been under the influence of drugs. While he had nothing to properly support this hypothesis, the postmortem toxicology report confirmed that "Sweeper" 2 was under the influence of a variety of prescription and illegal drugs which, in the opinion of the German medical authorities, would have caused severe impairment.

### 2.3.2 Mechanics of falling from the vertical ladder

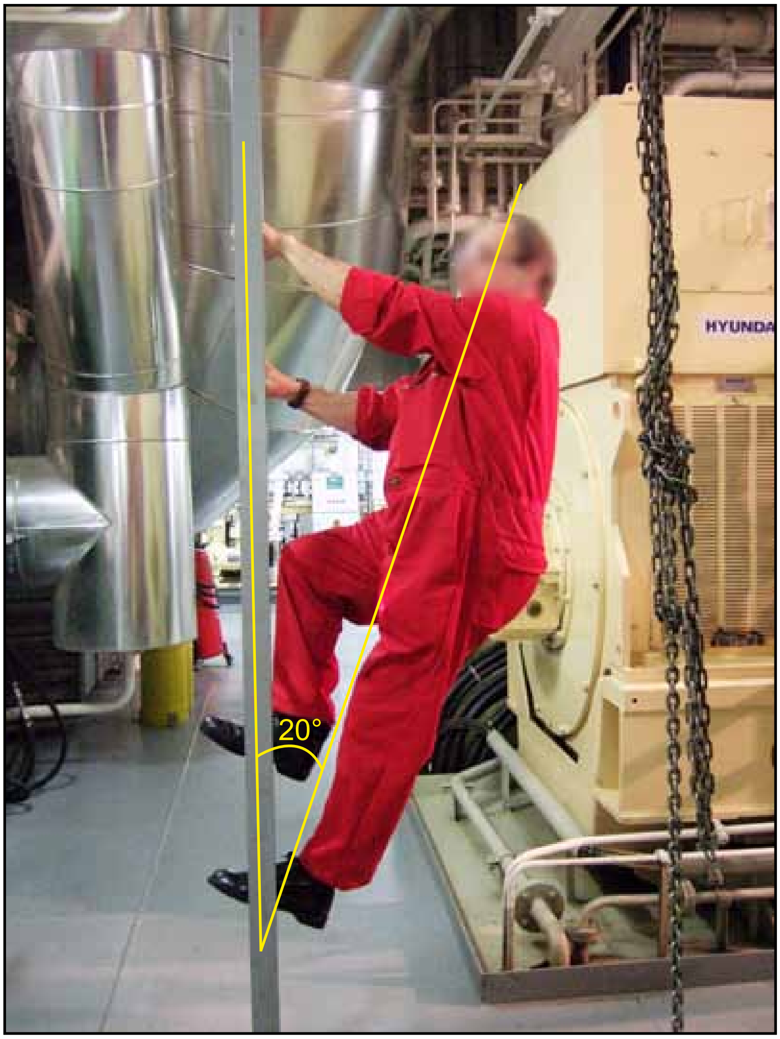
It is known that the approximately 1.6m tall casualty was found directly in line with the centre of the top resting platform, which is itself directly in line with the centre of the vertical ladder accessing the main deck. The three squeegees were found on the top resting platform, which indicates that the casualty had reached this level.

Before he left the tank, "Sweeper" 3 saw "Sweeper" 2 preceding "Sweeper" 1 up the final angled ladder, and it is reasonable to expect this order to have continued up the vertical ladder, especially as there was little room on the top resting platform for two persons.

The casualty's industrial rubber boots were in very good condition with a deep tread which would have given good grip. Had his feet slipped while maintaining a hand-hold, he would have fallen vertically onto the platform.

It is likely that the casualty was at least on the fourth rung up of the vertical ladder (about 1.2m from the top resting platform), and as he adopted the naturally backward leaning posture of about 20º to the vertical **(Figure 20)** he lost his handgrip and fell backwards, initially pivoting about his feet on the ladder rung. As he rotated backwards he is then likely to have passed over the top guardrail of the top resting platform and fallen about 18m onto the tank top. If he was lower than 1.2m on the vertical ladder it is doubtful that his body pivot point would have been low enough for him to pass over the top guardrail, in which case he would have landed on the platform itself.

Figure 20



Position of person ascending a vertical ladder

### 2.3.3 Reason for fall

The reason why “Sweeper” 2 fell backwards was probably a combination of his physical impairment due to the influence of drugs, and the slippery nature of the residual solidified stearin cargo on the ladder rungs. He might also have been adversely affected by the tank temperature and fairly arduous work. When the right plasticised faced glove was recovered it was found to be heavily contaminated with solidified stearin, which would have made it extremely slippery and would have made his hand grip on the vertical ladder more difficult, especially in his impaired state.

## 2.4 CONTRACTOR ISSUES

While the “sweeping” task itself was uncomplicated, the safety of the workforce nevertheless required careful consideration by both the ship’s staff and contractor. Their safety depended largely upon careful assessment of the risks of all phases of the sweeping operation, the employment of competent, responsible and fit personnel, the provision of suitable equipment and having a ship’s team practised to deal efficiently with emergencies.

### 2.4.1 Comparisons between the Rotterdam and Hamburg "sweeping" operations

The "sweeping" contractor in Rotterdam was very focused on the safety of its workforce. The team were effectively led, had a competent level of English and were well equipped with a comprehensive outfit of safety and communications equipment. Their pre-"sweeping" safety checklist, coupled with the ship's entry permit ensured they were well prepared for the task.

On the other hand, the Hamburg "sweeping" organisation was at best haphazard, uncoordinated and ill prepared for the task. It was brought together at short notice by the initial contractor, who was unable to fulfil the "sweeping" requirement. The team had only the most basic PPE, did not have their own PGMs, communications equipment, or a safety checklist, and there was no one clearly in charge. It was also obvious to a number of the officers and crew that the behaviour of the two M.Teske company "sweepers" was strange and of concern, and which should have prompted doubts about their suitability to fulfil the "sweeping" task safely.

All these factors conspired against a safe "sweeping" operation in Hamburg, but were not acted upon. This was partly because there was no shipboard instruction for the control and management of contractors while alongside.

### 2.4.2 Ship's staff and supercargo relationship with Hamburg "sweepers"

As "Sweepers" 1 and 2 arrived on board, the chief officer noticed their strange behaviour, which he believed might have been due to alcohol. Their appearance was dishevelled, they were very loud, their behaviour strange and their level of English poor. These points militated against the mild mannered chief officer confronting them or questioning their suitability for the task ahead. Despite both the messman and chief cook also having concerns about the "sweepers'" behaviour, this was not reported.

The supercargo noticed a strong smell of alcohol coming from one or both of the "sweepers". He also noted their odd demeanour, and that "Sweeper" 2 needed assistance to descend the cargo tank ladders. However, he did not raise any formal concerns with the ship's officers. He was aware that, in Hamburg, very few companies carry out cargo "sweeping". In the supercargo's view, obtaining a replacement team would have been very difficult, and there was a commercial responsibility on him to discharge the remainder of cargo as soon as possible.

While the supercargo had concerns, he nevertheless felt it was safe to proceed and, because of the good "sweeping" results obtained in No 1 tank, he felt that it was safe to use the "sweeping" team again in No 2 cargo tank.

### 2.4.3 Management of contractors

The issue of the management of contractors was broadly discussed in ISGOTT, Section 9.7 – Management of Contractors, although its sister publication, the TSGC did not cover the subject. The ISGOTT reference placed the responsibility on the master for ensuring that contractors were aware of the relevant safety practices, and that contractors should be effectively supervised and controlled by a "*Responsible Officer"*. In this case it was likely to have been the chief officer, but this was not clearly defined. The lines were also slightly blurred in that the supercargo was also involved in managing the "sweepers" on behalf of the charterers but had not received any familiarisation training himself despite this being required by the ship's SMS **(Annex J and K)**.

Although COSWP covers the various organisational health and safety responsibilities in its "Introduction and Regulatory Framework" section, it does not provide an easy interpretation on the master's, other officers' and crew's, health and safety responsibility with regard to contractors and sub-contractors.

The *Maersk Newport* case outlined at Section 1.18.3, highlighted that unclear demarcation of responsibility can lead to confusion and the omission of safety procedures. In this case, although it was not formally stated, the chief officer was content for the supercargo to make the decision as to the suitability of the "sweepers" to carry out their tasks. However, there was a responsibility on the crew to raise concerns regarding safety. Despite worries about the condition of the Hamburg "sweepers", they were not properly raised and so not addressed. The crew should be encouraged to report their concerns.

"Sweeper" 2 was clearly responsible for his own physical condition and for the impact it had on his own safety and the safety of others. The range of drugs identified in the postmortem toxicology report showed that he had scant regard for this. Nevertheless, it was important that contractors received the appropriate safety briefings and the control measures imposed to ensure safe working practices.

While the SMS provided guidance on the direction of seariding contractors, it did not do so for the management of contractors and sub-contractors while alongside to ensure that safe working practices were followed. The SMS merits review in this respect to ensure that the master, other officers and crew have sufficient information to ensure compliance with their health and safety obligations regarding contractors and sub-contractors, as laid out in The Merchant Shipping and Fishing Vessels (Health and Safety at Work) Regulations 1997.

An important element of promoting safe practices for entry into dangerous spaces was the adherence to established, proven procedures including carrying out effective risk assessments.

## 2.5 ENCLOSED SPACE ENTRY PROCEDURES

While the three stages of the enclosed space entry procedures, risk assessment, atmosphere testing and issue of the entry permit laid out in the SMS were followed each element was, in itself, incomplete.

### 2.5.1 Risk assessments and use of safety harnesses

The "sweeping" risk assessments for both Rotterdam and Hamburg were superficial in that they only identified three risks. In Rotterdam the "sweeping" team were very safety conscious and it could be argued that the paucity of identified risks and control measures was mitigated by the safety attitude of the "sweepers".

However, this was not the case in Hamburg, where the "sweepers'" attitude to safety was far less conscientious. This could have prompted a review of the risk assessment, taking particular account of the very slippery nature of the solidified stearin. Had this been done then the assessment might have identified the need to wear a safety harness during entry and egress from the cargo tanks as recommended in ISGOTT, COSWP and SMS document PR053 and since addressed in The Merchant Shipping and Fishing Vessels (Health and Safety at Work) (Work at Height) Regulations 2010. MGN 410 (M+F) identifies entering and exiting a tank as an example where the regulations apply. It is therefore important that this hazard is formally recognised through the risk assessment process. Although the Regulations did not come into force until 6 April 2010, the ship's SMS covering Enclosed Space Procedure, did highlight that wearing a safety harness may be appropriate when accessing large spaces, but this seems to have been disregarded in the pre-accident risk assessments.

Post-accident tank entry risk assessments identified seven risks and control measures reflecting the requirements of SMS document PR053. They also identified the use of a safety harness or fall arrestor as an additional control measure.

### 2.5.2 Atmosphere testing

The chief officer was aware from the cargo MSDSs that there were no identified hazards associated with the cargoes. However, the warning poster he received during cargo loading advised of the need to test the atmosphere for CO. CO has a density very similar to air and is easily moved by air currents throughout a tank during tank ventilation.

The $O_2$ content of the atmospheres in No 1 and No 2 cargo tanks was measured using the correct meter connected to a 20m extension hose which reached to the bottom of the tanks.

This was not the case when the atmosphere was tested for the presence of other gases including CO. The tests were carried out from the main deck using the Riken Keiki, GX-2009 Personal Gas Monitor connected to a 10m extension hose. The readings obtained for combustible gas, $H_2S$ and CO levels were 0%. It was on the basis of these readings, and the 20.9 - 21% $O_2$ obtained using the $O_2$ meter, that it was decided that the tanks were safe to enter and the Entry Permit signed. This was an unsafe act because the hose was only 10m long and so the atmosphere was only tested to less than halfway down the tank, and not at the bottom, where the work was to take place. Therefore, the Entry Permit was invalid.

The chief officer did mitigate this by fixing one of the ship's PGMs to "Sweeper" 1. However, he did not give any instruction as to its use assuming that he was probably already familiar with the equipment.

## 2.6 TEST EQUIPMENT SELECTION

### 2.6.1 General

The GX-2009 PGM was used for atmosphere testing because the Gastec GV-100S units delivered to the ship in December 2009 were not supplied with any extension hoses. However, similar shortcomings have been identified with the instructions for both types when used with extension hoses.

### 2.6.2 Riken Keiki, GX-2009 Personal Gas Monitor

The GX-2009 Operator's Manual only identified a manufacturer's option of fitting a 3m (10ft) sampling extension hose to the PGM. The manual stated that when the 3m hose was fitted, the aspirator bulb required 15 compressions (i.e. 5 compressions/m) to draw a representative sample up to the PGM for assessment.

Although some distributors provided extension hoses up to 30m in length, there were no instructions in the Operator's Manual to indicate the number of aspiration bulb compressions required for hoses in excess of 3m. It is not possible to simply extrapolate from the 5 compressions/m needed for the 3m hose as the friction losses may well be different for longer hoses. This will affect the accuracy of the readings on which a decision is made for safe entry into a dangerous space.

As a result of this investigation Riken Keiki Co. Ltd has conducted a series of trials to determine the number of compressions required to ensure a representative sample is drawn into the unit for assessment when using extension hoses. This is discussed further at Section 4.

### 2.6.3 Gastec GV-100S

The Gastec GV-100S could be fitted with a standard 5m or 10m extension hose as part of the manufacturer's options package. The readings obtained using extension hoses of up to 10m in length have proven to be accurate when the unit is operated in accordance with the existing instructions.

In common with the Riken Keiki GX-2009 PGM, some distributors do offer a range of hoses up to 30m in length[6].

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[6] *Bro Arthur* was supplied with 2 x 20m extension hoses post accident.

The manufacturer has advised that hoses longer than 10m indicate a lower and inaccurate result, due to the resistance that interferes with the air flow through the detector tube. In addition, the ambient temperature operating limits of the Gastec GV-100S are between 0ºC and 40ºC and might have been exceeded. It is not possible to be categoric about this because the tank temperature was not taken after it had been force-ventilated with fresh air at 3ºC. Had the chief officer used this equipment, the results could well have been incorrect and so invalidating the Entry Permit.

Gastec Corporation's Research and Development department is currently evaluating the use of extension hoses up to 30m in length.

### 2.6.4 Summary

There is a clear need for accurate instructions regarding the use of the Riken Keiki, GX-2009 Personal Gas Monitor and Gastec GV-100S sampling equipment when connected to greater than 3m and 10m extension hoses respectively. Without this guidance those responsible for approving the safe entry into dangerous spaces may well be making their decisions based on inaccurate information, which they believe to be correct but which could easily compromise workers' safety.

## 2.7 SUITABILITY OF THE CASUALTY RECOVERY EQUIPMENT AND DRILLS

The rapid deployment of, and familiarity with, casualty recovery equipment is fundamental in improving the chances of survival of a seriously injured person in a dangerous space such as a cargo tank.

### 2.7.1 Recovery equipment

With the exception of general comments in the ship's SMS and COSWP, that rescue equipment should be available during entry into a dangerous space, there was very little guidance on the requirements for casualty recovery equipment.

During a demonstration of *Bro Arthur*'s casualty recovery equipment it was noted that, because of its weight and awkward design, it was very difficult to man-handle across the deep, main deck longitudinals. Once adjacent to No 2 cargo tank hatch it was found that the davit arm was unable to directly plumb the hatch when fitted to the unit's base. The davit arm was removed from the base and attempts made to secure it to the hatch coaming's external rungs using rope because there were no brackets or sockets fitted to the hatch coaming **(Figure 21)**. This proved very difficult, and the arm was extremely unstable, and again a straight plumb through the hatch could not be achieved. In addition, when the wire was eventually lowered, it repeatedly came off the central guide wheel.

Figure 21

Casualty rescue equipment securing arrangements to
No 2 cargo tank hatch coaming

The team was clearly unpractised in rigging the equipment for recovery. The demonstration took 18 minutes from the initial movement of the unit from outside the deck store to the wire passing through the hatch. Even then it was poorly secured, and it is quite possible that its use could have caused additional injuries to a casualty.

The excessive time taken to deploy the unit, its weight, instability, inability to directly plumb the cargo tank hatches or be passed easily through a hatch to recover casualties from double bottom tanks, makes it unsuitable for rescue purposes.

Research shows there are a number of commercially available lightweight tripods and quad pods which merit consideration as an alternative to the existing arrangement.

### 2.7.2 Drills

Ships' teams well drilled in the recovery procedures from a dangerous space can be significant in the survivability of casualties. Realistic drills will help ensure that the emergency team's reactions are instinctive and safe, as well as proving the functionality of the rescue equipment.

Frequently, organisers of drills opt to use a space, such as a steering gear compartment, rather than a cargo tank to carry out the drill because it is less disruptive. While this still has value, it is far different from carrying out a rescue from a cargo tank. Where practicable, drills should include tank recovery.

The mandatory requirement to carry out a 2-monthly rescue drill from a dangerous space received scant attention. The drill was not individually specified in the ship's drill schedule but was understood to be included in "Situation No 302 – Illness-Injury drill". Importantly, **Annex L** does not show the drill being programmed for either 2009 or 2010, and no-one on board could recall the drill being conducted. The last "Illness-Injury" report produced was for drills carried out on 26 January 2008 and on 2 August 2008.

The drill schedule merits prompt review to ensure that it is compliant with the regulations for casualty recovery drills.

## 2.8 SAFETY MANAGEMENT

The circumstances of this accident identified that the safety management of *Bro Arthur* was lacking direction in a number of organisational and material areas. These include superficial risk assessments, inaccurate dangerous space atmosphere testing routines, weak control of contractors, an unwillingness to confront individuals when their condition compromised safety, non-compliance with mandatory safety drills, and unsuitable casualty recovery equipment.

The last internal company inspection did not identify any of the issues in this report. All its recommendations were related to the material condition of the vessel although the SMS and safety gear is indicated as being checked. A review of the company's auditing/inspection procedures is merited to ensure that safety issues are covered, together with strong consideration being given to providing senior seariding staff to improve the onboard safety management.

## 2.9 FATIGUE

The bridge and cargo operations watchkeeping pattern enabled crew involved to have at least 8 hours sleep during the 24 hours preceding the accident. Fatigue is not considered to be a factor in relation to the actions or decisions made by the crew.

During the 8 hours that the casualty was on board, he was working for only about 1 hour. It is unknown what rest or sleep he had taken before arriving on board *Bro Arthur*, so it is not possible to determine whether, in his case, fatigue was a contributory factor in the accident.

# SECTION 3 - CONCLUSIONS

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

1. The management of contractors was not included in the ship's SMS or in either the TSGC or COSWP, two major safety publications referred to by tanker crews. [2.4.1, 2.4.3]

2. The safety management of *Bro Arthur* lacked direction in a number of organisational and equipment areas. There were issues relating to superficial risk assessments, weak control of contractors and an unwillingness to confront individuals when their condition compromised safety. [2.8]

3. A number of persons on board were concerned about the unusual behaviour and the smell of alcohol from "Sweepers" 1 and 2. They were not confronted regarding their suitability for the "sweeping" task and no consideration was given to the risk of impairment. [2.4.1, 2.4.2, 2.4.3]

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

1. The casualty recovery equipment was unfit for purpose and there was no specific guidance in two of the major publications – ISGOTT, TSGC and lack of emphasis in COSWP. [2.7.1]

2. The company's emergency drill schedule did not comply with the mandatory requirements for casualty evacuation from a dangerous space. There were no drills programmed for 2009 or for 2010. [2.7.2]

3. The manufacturer of the Gastec GV-100S atmosphere test equipment did not provide information on the operation of its units when connected to sampling extension hoses exceeding 10m. [2.6.3, 2.6.4]

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

1. "Sweeper" 2 had little regard for his own personal safety. The postmortem toxicology report identified that he was under the influence of a variety of prescription and illegal drugs, which caused him severe impairment and is highly likely to have contributed to him falling from the vertical ladder. [2.3.1, 2.3.3, 2.4.3]

2. The Hamburg "sweepers'" organisation was at best haphazard, uncoordinated and ill prepared for the task. They lacked sufficient PPE and communications equipment. However, they were allowed to continue with their task because of commercial pressures. [2.4.1, 2.4.2]

3. The warm temperature in No 2 cargo tank, coupled with the physical effort of the “sweeping” task might have had a detrimental effect on the casualty’s performance, contributing to his slipping from the vertical ladder. [2.2.4, 2.3.3]

4. The risk assessments for cargo “sweeping” were superficial. Insufficient consideration was given to the extreme slipperiness of the stearin cargo and the risk it imposed on access and egress to the cargo tank, so the option of using a safety harness or fall arrestor was overlooked. [2.5.1]

5. The ship’s SMS did not specify when the use of a safety harness/fall arrestor was required. [2.5.1]

6. The Entry Permit was issued based on inaccurate atmosphere test results because the tests were taken only mid-way down the tank and not from the bottom of the tank due to the limitations of the test equipment carried on board. [2.5.2]

7. The use of palm plasticised faced gloves in very slippery environments is unsuitable and is likely to have caused the casualty to lose his handgrip on the vertical ladder. [2.3.3]

8. The manufacturer of the Riken Keiki, GX-2009 PGM atmosphere test equipment did not provide information on the operation of its units when connected to sampling extension hoses exceeding 3m. [2.6.2, 2.6.4]

# SECTION 4 - ACTION TAKEN

## 4.1 THE MARINE ACCIDENT INVESTIGATION BRANCH

The MAIB has produced a Safety Flyer highlighting the circumstances and lessons learned from this accident **(Annex M)**.

## 4.2 A.P. MØLLER-MAERSK A/S

A.P. Møller-Maersk A/S has:

- Introduced senior seariding auditing staff to improve the safety culture on board its vessels.
- Conducted a fleet audit of safety harness and fall arrestor equipment and is equipping each of its vessels with eight safety harnesses complying with EN 355 standards, four inertial fall arrestors and four "Y" type fall arrest lanyards.
- Contracted Maersk Maritime Technology to design a portable overhead arrangement for attachment of the fall arrestor equipment which is suitable to access all areas where an arrestor is required.
- Issued Controlled Fleet Information Notice 008/10 **(Annex N)** instructing that:
  - crews are not to enter a tank unless a full risk assessment is carried out and an Entry Permit issued
  - fall arrest systems are to be used when transiting all vertical (or near vertical) ladders exceeding 5 metres in height.

## 4.3 RIKEN KEIKI CO. LTD

Riken Keiki Co. Ltd has amended the content of the GX-2009 Personal Gas Monitor Operator's Manual to include guidance on the use of the equipment when connected to sensor extension hoses up to 30m in length **(Annex O)**.

The amendment is to be brought to the attention of the company's worldwide distributors.

## 4.4 GASTEC CORPORATION

The Gastec Corporation is conducting investigations into the effects on the operation of the Gastec GV-100S atmosphere sampling equipment when connected to extension sampling hoses of up to 30m in length. The work is expected to conclude in the summer of 2010, with the issue of additional guidance provided in the Operator's Manual.

## 4.5 THE INTERNATIONAL CHAMBER OF SHIPPING AND INTERNATIONAL GROUP OF PROTECTION AND INDEMNITY CLUBS

The International Chamber of Shipping and International Group of Protection and Indemnity Clubs have undertaken to promulgate, via their membership, the MAIB's Safety Flyer which highlights the circumstances and lessons learned from this investigation.

## SECTION 5 - RECOMMENDATIONS

The **Maritime and Coastguard Agency** is recommended to:

**2010/119** Provide additional guidance on the following:

- Management of contractors and sub-contractors with emphasis on the master's and other officers' and crew members' related health and safety responsibilities.
- The need for the provision of lightweight, portable casualty recovery equipment suitable for recovery from deep cargo tanks, and for the crew to be fully trained in its use.

The **International Chamber of Shipping** is recommended to:

**2010/120** Include guidance on the following in the respective International Chamber of Shipping publications during their next periodic review:

- TSGC - Management of contractors and sub-contractors with emphasis on the master's and other officers' and crew members' related health and safety responsibilities.
- TSGC and ISGOTT - The need for the provision of lightweight, portable casualty recovery equipment suitable for recovery from deep cargo tanks and for the crew to be fully trained in its use.

**A.P. Møller-Maersk A/S** is recommended to:

**2010/121** Review its Safety Management System and internal auditing procedures to ensure:

- Guidance is provided on the management of contractors in port.
- Effective risk assessments are carried out and that identified control measures are adhered to.
- Instructions are issued to its fleet which require mandatory bi-monthly tank rescue drills.
- Guidance is issued on the use of the Riken Keiki GX-2009 and Gastec 100S atmosphere testing equipment following amendments to the operator manual in respect to their use with extension hoses.

**Gastec Corporation** is recommended to:

**2010/122** Complete its investigations to determine the effects on the operation of the Gastec GV-100S equipment when connected to sampling extension hoses, and:

- Amend its Operator's Manual as appropriate.
- Advise its distributors of the changes made.

**Marine Accident Investigation Branch**
**August 2010**

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