The Viking Islay

Date: 29th September 2007

Details:
Three seamen died on board as a consequence of entering an enclosed space. Two seamen went into the chain locker with the intention of securing a rattling anchor chain. One seaman entered the chain locker and collapsed, the other seaman realized there was an emergency, raised the alarm and then entered the chain locker and subsequently also collapsed. The fist rescuer could not enter wearing breathing apparatus and therefore donned an Emergency Escape Breathing Device (EEBD). At some point, the hood of the EEBD was removed and the rescuer collapsed. All three seamen died due to an oxygen deficient atmosphere in the chain locker.

Key Issues:
There was no equipment on-board for the safe entry of confined spaces and no means of testing the atmosphere for oxygen levels so there was no way of telling if the areas could support human life. The shore-based personnel had banned work in dangerous spaces unless the vessel was in port or specialists were on-board. The policy did not take into account the need for crew to enter confined spaces while at sea. According to the MAIB, "the policy was unrealistic and provided the crew with insufficient practical guidance for the conduct of day-to-day operations". A toolbox-talk risk identification system was on-board but only regarded as an administrative function rather than a safety device. Audits failed to identify the shortcomings and the confined space rescue drills were not appropriate for spaces as small as the chain locker.

Result of Investigation:
A jury cleared the Captain of the Viking Islay, of failing to discharge his duties properly in such a manner to cause deaths. However, Vroon (the Company who own the Viking Islay) admitted three breaches of the merchant shipping safety regulations. The defence was that the safety system was at fault; it generated too much paperwork and was a victim of its own complexity. The judge said the most serious breach was the firm's failure to provide an oxygen meter despite a request from the Captain 6 months before the incident. The judge fined the firm £160 000 for sailing to provide an oxygen meter and £80 000 for failing to evaluate the efficiency of its SMS and £40 000 for failing to ensure the third engineer had the appropriate certificate of competency.

Report on the investigation of

work undertaken in a dangerous enclosed/confined space

and the consequent attempted rescue on board

ERRV *Viking Islay*

resulting in the loss of three lives

at the Amethyst gas field, 25 miles off the East Yorkshire coast, UK

23 September 2007

Marine Accident Investigation Branch
Carlton House
Carlton Place
Southampton
United Kingdom
SO15 2DZ

Report No 12/2008
July 2008

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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CONTENTS

GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AB	-	Able Bodied Seaman, an experienced and qualified member of the deck crew
AMA	-	Advanced Medical Aider, an advanced first-aid qualification particular to the offshore industry
BA	-	Breathing Apparatus
CO	-	Carbon Monoxide
CO_2	-	Carbon Dioxide
CoC	-	Certificate of Competency
COSWP	-	Code of Safe Working Practices for Merchant Seamen
CPP	-	Controllable Pitch Propeller
CPR	-	Cardiopulmonary resuscitation
DOC	-	ISM - Document of Compliance
DDPA	-	Deputy Designated Person Ashore
DPA	-	Designated Person Ashore
EDS	-	The Merchant Shipping (Entry to Dangerous Space) Regulations 1988
EEBD	-	Emergency Escape Breathing Device (Sabre ELSA on *Viking Islay*)
ELSA	-	Emergency Life Support Apparatus (a type of EEBD, a short duration BA, to be used for escape purposes only)
ENSCO 92	-	A jack-up type drilling rig, operated by the ENSCO Company
ERRV	-	Emergency Response Rescue Vessel (A “standby vessel”)
FCP	-	Forward Control Point
FRC	-	Fast Rescue Craft
GMT	-	Greenwich Mean Time
GRT	-	Gross Registered Tons
H_2S	-	Hydrogen Sulphide (an extremely hazardous, toxic gas)
HSE	-	Health and Safety Executive
IACS	-	International Association of Classification Societies
IMO	-	International Maritime Organization
ISM Code	-	International Management Code for the Safe Operation of Ships
Knots	-	Speed in nautical miles per hour

kW	-	Kilowatt
LR	-	Lloyd's Register of Shipping classification society
MAIIF	-	Marine Accident Investigators' International Forum
MCA	-	Maritime and Coastguard Agency (The UK Flag State administration)
MGN	-	Marine Guidance Note
MIN	-	Marine Information Note
O_2	-	Oxygen
OOW	-	Officer of the Watch
PFEER	-	Prevention of Fire and Explosion and Emergency Response
ppm	-	parts per million
PTW	-	Permit to Work
RA	-	Risk Assessment
SEC	-	Cargo ship Safety Equipment Certificate
SMC	-	ISM - Safety Management Certificate
SMS	-	Safety Management System
SOLAS	-	The International Convention for the Safety of Life at Sea 1974 (as amended)
STCW	-	The International Convention on the Standards of Training, Certification and Watchkeeping for Seafarers 1978 (as amended)
STW	-	IMO Committee on Standards of Training for Watchkeeping
T	-	Tonnes
TRIC	-	Toolbox-talk Risk Identification Card
UK	-	United Kingdom
UKOOA	-	UK Offshore Operators Association
VHF	-	Very High Frequency Radio
Vroon	-	Vroon Offshore Services Ltd

Times: All times used in this report are GMT unless otherwise stated

Viking Islay

SYNOPSIS

On 29 September 2007, three seamen on board the ERRV *Viking Islay* lost their lives as a consequence of entering an enclosed space. The ERRV *Viking Islay* was working in the North Sea conducting rig support operations when two of the vessel's seamen went forward with the intention of securing a rattling anchor chain within the chain locker. One of the seamen entered the chain locker and collapsed. It is probable that the other seaman, realising that help was urgently required, raised the alarm with the duty watchkeeping rating on the bridge before he, too, entered the chain locker in an attempt to help his companion. He also collapsed.

During the consequent rescue efforts, the first rescuer found he was unable to enter the chain locker wearing a BA, and he therefore donned an EEBD. He entered the space, but at some point the hood of the EEBD was removed, or became dislodged and this rating also collapsed.

All three seamen died as a result of an oxygen deficient atmosphere within the chain locker.

The MAIB's investigation has concluded:

- The oxygen deficient atmosphere within the chain locker was caused by natural on-going corrosion of the steel structure and anchor chain within the space.
- The crew of *Viking Islay* failed to recognise the chain locker was a potentially dangerous enclosed/confined space, or the likelihood that the atmosphere within the space could become oxygen deficient over time. Consequently, well established permit to work measures were not considered before the space was entered.
- Training and subsequent drills in the use of EEBDs had not been sufficient to ensure the limitations of the equipment were recognised in an emergency.
- The ship manager's company policy on entry into enclosed spaces was not clear and did not take into account scenarios that could require crews to enter confined spaces while at sea. A further consequence of this was that gas monitoring equipment supplied to the vessel was unsuitable for ensuring safe entry into enclosed spaces.
- The audit regime employed by the ship's managers to ensure compliance with its SMS failed to detect deficiencies in training, equipment and safety culture on board *Viking Islay*.

The ship manager has taken action to address many of the safety issues identified during the investigation. However, recommendations have been made to Vroon Offshore Ltd and the Maritime and Coastguard Agency on the promulgation of additional information to highlight limitations on the use of EEBDs and improvements in the training given to mariners in the use of this type of equipment.

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *VIKING ISLAY* AND ACCIDENT

Vessel details

Registered owner	:	Viking North Sea Ltd, Aberdeen, UK
Manager(s)	:	Vroon Offshore Services Ltd, Aberdeen
Port of registry	:	Aberdeen
Flag	:	UK
Type	:	Emergency Response Rescue Vessel, Class B (up to 300 survivors)
Built	:	1985, Spain
Classification society	:	Lloyd's Register of Shipping, +100A1 Offshore Supply/Standby Vessel
Construction	:	Steel
Length overall	:	53m
Gross tonnage	:	928
Engine type and power	:	Two MAK Diesel engines, 2921kW total
Other relevant info	:	Twin screw CPP, one tunnel thruster at bow

Accident details

Time and date	:	1100 GMT 23 September 2007
Environmental conditions		Swell 1.5m, sea 0.5m, 3/8th cloud cover, visibility good
Location of incident	:	53 42.22N 001 08.9E
		While standing-by rig *ENSCO 92*, at the Amethyst gas field, 25 miles off the East Yorkshire coast, Southern North Sea, UK
Persons on board	:	Twelve
Injuries/fatalities	:	Three fatalities. No other injuries
Damage	:	None

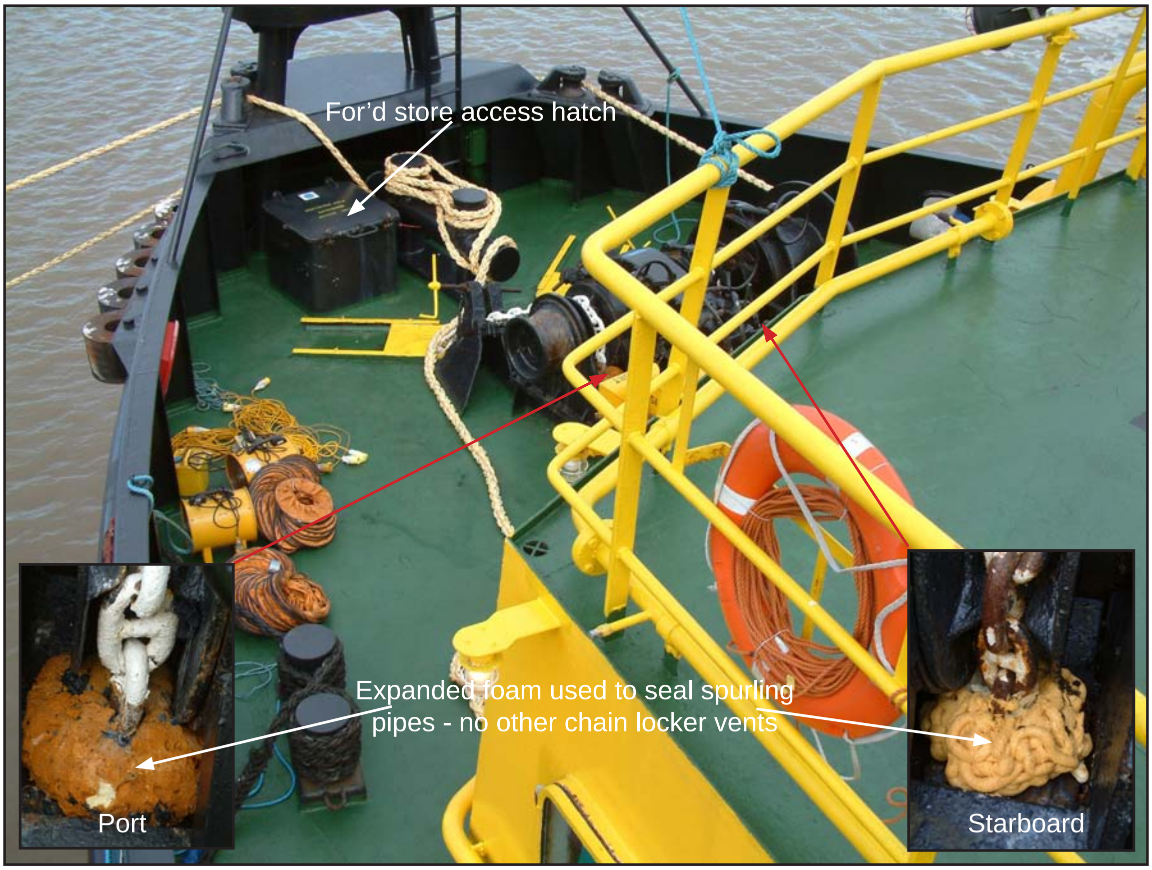
1.2 NARRATIVE

1.2.1 Events preceding the accident

On Friday 21 September 2007 the Emergency Response and Rescue Vessel (ERRV) *Viking Islay* arrived at Immingham pilot station, following a duty period of about 28 days offshore. The ship had not anchored during the trip as anchoring was forbidden at the offshore location.

As was normal in preparation for arrival, *Viking Islay*'s starboard anchor had been walked out a short distance; it was not dropped clear of the hawse pipe, but just moved enough to confirm that it was free and clear to be run out in case of any emergency. Possible impediments to the anchor chain running free included the expanded foam, that was routinely used to seal the top of the spurling pipe[1] on the foredeck, and light rope lashings used to secure the anchor chain within the chain locker **(Figure 1)**.

Figure 1



The foam was used to prevent water entering the chain locker via the spurling pipe. Light lashings were sometimes applied inside the chain locker by the crew, in order to prevent the hanging part of the anchor chain from moving in rough weather **(Figure 2)**. Such movement could cause the chain to bang noisily against the spurling pipe, or other steelwork.

[1] Spurling pipe: The tube running from below the anchor windlass on the foredeck, through the foc'sle store down to the chain locker, so enclosing the anchor chain

Figure 2

Chain locker - showing rope lashings used to stop anchor chain rattling

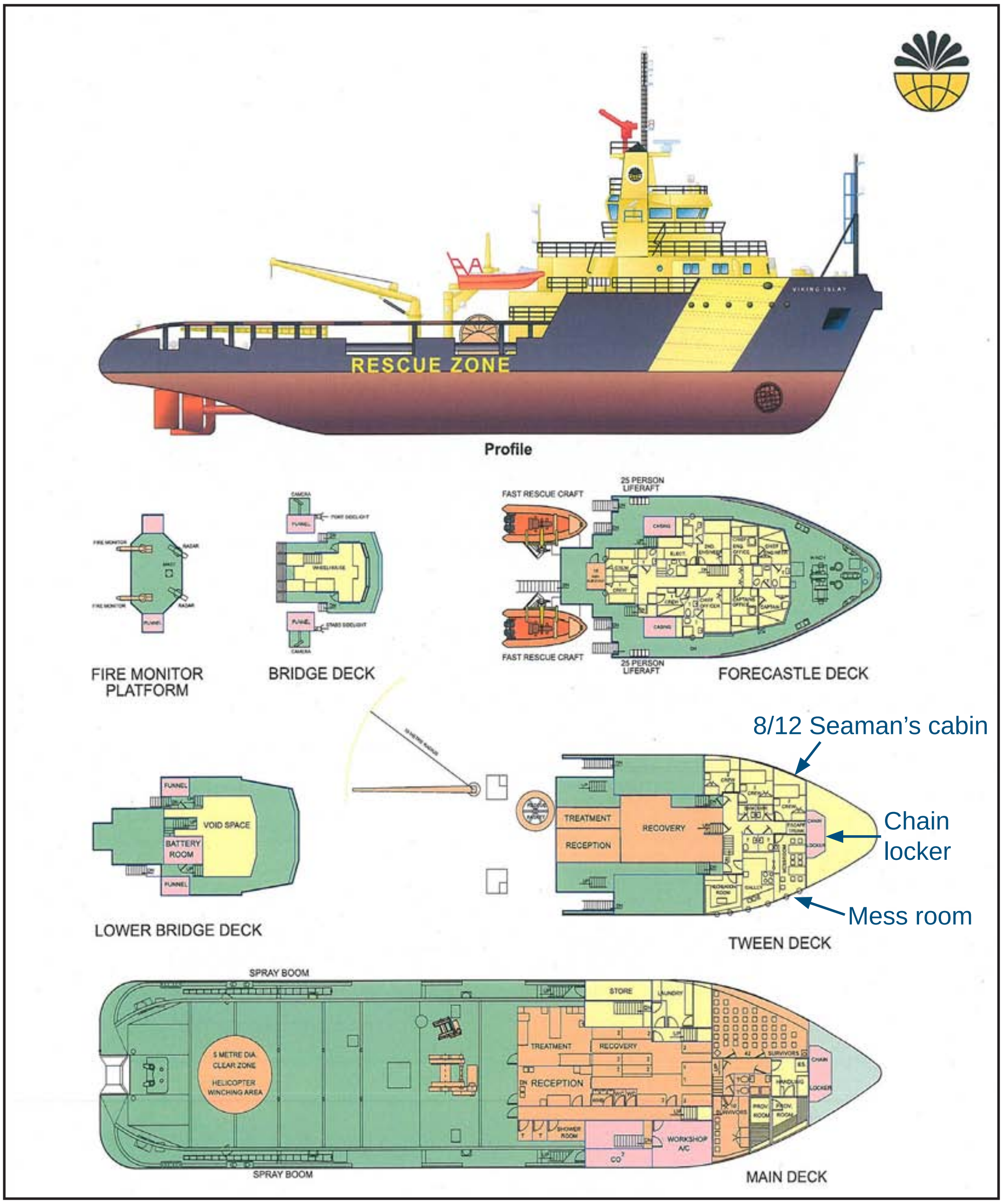
The port anchor was not walked out and the port spurling pipe remained sealed with expanded foam.

The ship was alongside at 0950. The purpose of the visit was to take on bunkers and stores, undertake some minor repairs and, as was normal routine, conduct a full crew change. Both the off-going and on-coming masters were regulars on *Viking Islay*, as were the majority of the crew. Many crew members had been on this ship for several years, and all were experienced in the ERRV business. Those crew members who were new to *Viking Islay* received their safety induction as per company instructions.

The chain locker was not entered during the port visit.

At 1150 on Saturday 22 September 2007, *Viking Islay* sailed for the rig *ENSCO 92*. The pilot was dropped at 1420; the starboard spurling pipe was resealed using an aerosol of expanding foam (of the type commonly used ashore in building works). At 1625, *Viking Islay* arrived on station, the relief vessel was released and *Viking Islay* began its 28-day standby routine. The weather conditions at that time were logged as swell 1.5m, sea 0.5m, 3/8th cloud cover, visibility good.

Figure 3

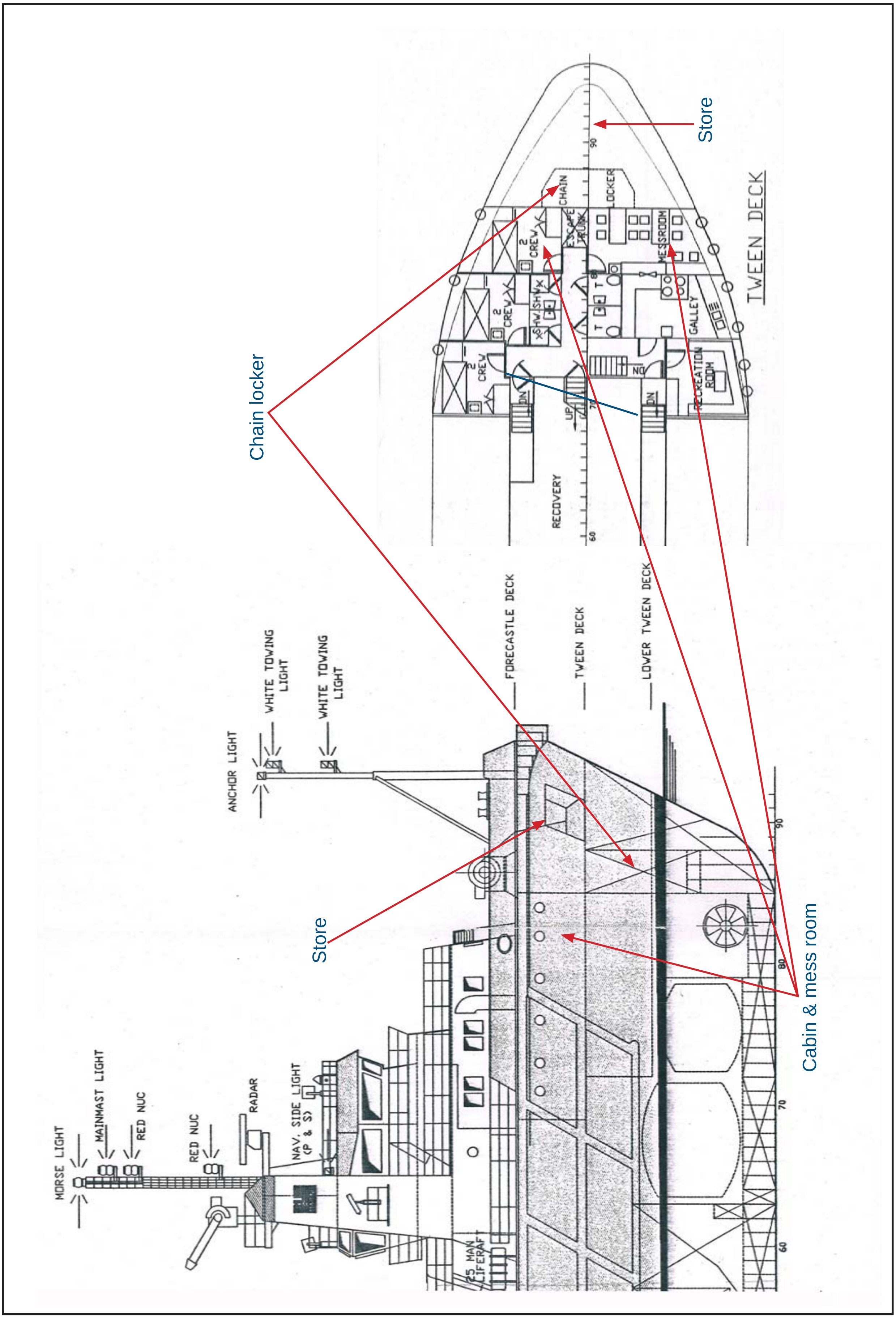


Side and plan views of *Viking Islay*

Due to the motion of the ship during the night, the starboard anchor chain began to bang against something within the chain locker, probably the spurling pipe. This disturbed the 8/12 seaman[2], Mr MacFadyen, whose cabin shared a common bulkhead with the chain locker. It is possible that others were aware of the noise, as the mess room also abutted the same bulkhead **(Figures 3 and 4)**.

No routine maintenance work was planned for Sunday 23 September. However, the crew expected operational and emergency drills to be conducted during the afternoon.

2 8/12 seaman: The crew member assigned the 8 to 12 watch (both am and pm) on a ship with a standard three watch system.



Viking Islay - bow profile and plan

1.2.2 The initial accident

It is likely that the noise made by the anchor chain during the night was discussed between Mr MacFadyen and the two day workers[3], Mr Ebertowski and Mr O'Brien, over breakfast, before they started work at 0800.

At 0800, the master and Mr MacFadyen took over the bridge watch. At about 0900, Mr MacFadyen told the master that the two day workers wanted to go into the chain locker to tie off the anchor chain and so stop it banging. The master agreed that this work could be done, but later in the morning as a helicopter movement to the rig was expected shortly.

Just before 1000, *Viking Islay* stood by for the helicopter movement. Sometime after the helicopter departed, the master went to his cabin to use the lavatory, leaving Mr MacFadyen in charge of the watch and alone in the wheelhouse. At about 1055, the two day workers, carrying a portable VHF radio, went forward to enter the chain locker. They took no other equipment with them, and no safety related documentation (such as a risk assessment or a permit to work) was completed.

The day workers went forward and opened the hatch down to the foc'sle store from the foredeck. This store area was used to store mooring ropes and other general deck gear. As a regularly used working area, the store was well lit and was naturally ventilated.

The two day workers went to the aft part of the foc'sle store and lifted the loose duckboards, beneath which were three access manholes. The forward hatch served the fore peak water ballast tank, and the after two gave access to the port and starboard sides of the anchor chain locker. Although there were two manholes, the internal dividing bulkhead which separated the two anchor chains only extended to about half the height of the chain locker, and the upper parts of the spaces were common. The manholes serving the chain locker were smaller than that serving the ballast tank, and were square in shape rather than the more conventional oval found at the ballast tank access. The heavy steel manhole covers were secured with eighteen 24mm nuts and bolted down onto a rubber gasket, so forming a watertight seal **(Figure 5)**.

The day workers removed only the starboard cover to access the compartment, and no portable lighting or ventilation fans were rigged. The atmosphere within the chain locker was not tested.

As all three people directly involved in the initial accident died, it has been necessary for MAIB to construct the most likely scenario from the evidence available. It was likely that:

> Mr Ebertowski entered the chain locker to tie off the chain; this was a one man job. Mr O'Brien, the leading hand[4], stood by at the entrance, keeping in radio contact with Mr MacFadyen in the wheelhouse. As Mr Ebertowski descended into the chain locker, he collapsed. Mr O'Brien saw this, and called the bridge by VHF to alert Mr MacFadyen to the problem.
>
> Mr O'Brien then entered the chain locker in an attempt to rescue Mr Ebertowski, but he too was overcome and collapsed at the bottom of the chain locker, partly on top of his colleague.

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3 Day workers: seamen who do not keep routine watches, but carry out routine work during the day.

4 Leading hand: The senior day work seaman, nominated by the master as "in charge" of the other day worker.

Figure 5

Foc'sle store - showing access hatches to chainlocker

1.2.3 The consequent fatal rescue attempt

On hearing the VHF call from the leading hand, Mr MacFadyen left the wheelhouse and ran down through the accommodation; he was clearly agitated and raised the alarm by shouting for help. His calls were heard by several others, including the mate and second mate, and these two ran forward with Mr MacFadyen and entered the foc'sle store. Looking down through the open chain locker access, they were able to see two bodies at the bottom of the dark space. They returned to the accommodation and, assisted by the cook, gathered together rescue equipment including breathing apparatus (BA) and a short duration emergency escape breathing device (EEBD). The intention was that the EEBD could be fitted to a casualty as a form of emergency first-aid.

The master returned to the wheelhouse and, at 1107, sounded the general alarm. This roused the remaining crew members, who gathered at the designated muster point aft of the accommodation, before making their way to the foredeck. The master informed *ENSCO 92* of the emergency by VHF radio, and the rig began its own preparations to assist *Viking Islay*.

At 1110, the rescue party returned to the foc'sle; Mr MacFadyen quickly donned BA and entered the store, assisted by the cook, carrying an EEBD. The 12/4[5] seaman donned the ship's second BA and stood by at the foc'sle hatch, together with the chief mate. The second mate was called to the wheelhouse to assist the master.

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5 12/4 seaman: The crew member assigned the 12 to 4 watch (both am and pm) on a ship with a standard three watch system

Inside the foc'sle store, Mr MacFadyen attempted to enter the chain locker. Being a large man, he was unable to descend through the hatch while wearing BA, so he removed it. He asked the cook to give him the EEBD; the cook opened the EEBD case and the air supply started automatically. Mr MacFadyen donned the EEBD by pulling the hood over his head, and immediately began to enter the chain locker. The chief mate ordered the 4/8[6] seaman to don the BA discarded by Mr MacFadyen and to stand by in the store, together with the 12/4 seaman.

The cook crossed the compartment to collect torches, and when he returned to the hatch a few seconds later he saw Mr MacFadyen in difficulties, at the bottom of the ladder. His EEBD hood was partly off, pushed high up on his head and, as the cook looked down, he saw Mr MacFadyen collapse.

1.2.4 Subsequent rescue efforts

The chief mate then directed the 12/4 seaman to enter the chain locker using BA. Before doing so, the 12/4 seaman looked in and saw the three men at the bottom of the space. Mr MacFadyen was collapsed on one side of the locker. The EEBD hood remained pushed high up on his head and the 12/4 seaman could hear the air still discharging. However, the EEBD bottle was not on Mr MacFadyen's body, but was lying on the other side of the locker with the air supply hose stretched tautly. With the help of the cook, the 12/4 seaman, an agile and slim man, was able to enter the chain locker without removing his BA. He took a line with him to recover Mr MacFadyen.

Mr MacFadyen's EEBD air supply was exhausted by the time the 12/4 seaman reached the fallen men. He checked Mr MacFadyen for a pulse and signs of breathing; none was found. He then tied a rope under Mr MacFadyen's arms and climbed out of the locker. Together with the 4/8 seaman, and with great difficulty, they hauled Mr MacFadyen out of the chain locker into the foc'sle store. The 4/8 seaman also checked the victim, but found no signs of life. It was now about 1122.

The 12/4 seaman's BA low air alarm sounded, so both men left the store. Once on deck they fitted fresh BA cylinders. The 12/4 seaman was by now exhausted, so the chief mate ordered the third engineer to don that BA set.

Realising the scale of the problem facing his crew, the master contacted HM Coastguard, seeking help and additional supplies of air. Other ships that were close-by immediately offered assistance.

Meanwhile, the rig had mobilised a team of four men ready to transfer to assist the crew of *Viking Islay*. This group consisted of a three man "extraction team" (specialists trained in the use of BA and techniques for rescue from dangerous enclosed/confined spaces) and a medic.

The 4/8 seaman, now accompanied by the third engineer, re-entered the foc'sle store, wearing BA, and together they recovered Mr MacFadyen to the upper deck where other crew members began Cardiopulmonary Resuscitation (CPR). It was now 1125. The rig medic gave medical advice to *Viking Islay* by VHF radio.

At 1133, the third engineer entered the chain locker, with the 4/8 seaman standing by at the entrance. Both were wearing BA.

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6 4/8 seaman: The crew member assigned the 4 to 8 watch (both am and pm) on a ship with a standard three watch system

At 1140, the master manoeuvred *Viking Islay* closer to the rig to allow the rig's rescue team to transfer to *Viking Islay* using a personnel basket attached to the rig's crane. This transfer was completed at 1151, and the rig team went immediately to the foredeck where the rig medic took charge of the resuscitation efforts.

Over the next 40 minutes the rig team, working together with *Viking Islay*'s crew, recovered Mr O'Brien and Mr Ebertowski from the chain locker. In order to access the chain locker, the extraction team had to remove their BA cylinders; however they managed to keep their face masks in place, and therefore breathed good air throughout. During this time a rescue helicopter arrived and landed another medic on board, and resuscitation efforts continued on Mr MacFadyen, but without success.

The reason for the dangerous atmosphere within the chain locker could not be determined, and it was decided that the space should be sealed. The third engineer started to replace the manhole cover. As he was doing this, his BA's low air supply alarm sounded so he left the task part completed and went up on deck. The used EEBD was abandoned in the foc'sle store.

At 1247, the rescue helicopter, with three victims on board, left the scene for the Hull Royal Infirmary.

By 1340, all the rig's personnel had been transferred back to *ENSCO 92*, and *Viking Islay* was then released from standby duty. The vessel berthed in Immingham at 2000 on Sunday 23 September 2007.

1.3 *VIKING ISLAY* AT IMMINGHAM

When *Viking Islay* arrived at Immingham, the foc'sle store hatch was dogged down, and since the accident had been opened only to retrieve the mooring ropes. The chain locker had remained closed since the accident.

Both compartments were treated as dangerous enclosed/confined spaces; safety cover for the attending analysts was provided by the Humberside Fire and Rescue Service.

On 24 September, samples of the atmospheres of both the foc'sle store and the chain locker were obtained, using an extension tube connected to a direct reading atmosphere testing meter. Care was taken to minimise any mixing of the atmospheres of the foc'sle and the chain locker.

Results of testing the atmosphere of the chain locker were as follows: Oxygen (O_2) 15.9% by volume, Nil Carbon Monoxide (CO), Nil Hydrogen Sulphide (H_2S) and Nil flammables. The chain locker cover was immediately closed and the foc'sle store secured, so as to preserve evidence.

1.4 SPECIALIST ANALYSIS AND OPINION

1.4.1 Atmosphere analysis by Health and Safety Executive specialists

On 26 September, specialist inspectors from the Health and Safety Executive (HSE) attended *Viking Islay* to take air quality measurements, and obtained air samples from the chain locker.

Samples were taken from three different depths within the chain locker, on both the port and starboard sides. Their findings are summarised below:

- Atmosphere measurements (samples taken)

  O_2: 15 - 19%; Nitrogen (N): 78 - 82%; Argon: 1 - 1.1%; Carbon Dioxide (CO_2): 0.07 - 0.14 ppm; CO: 0 - 4 ppm, H_2S: 0 ppm.

- The reduced concentration of O_2 was consistent with that obtained by a direct reading instrument on-site.

- The slightly increased levels of CO_2 might be due to microbial action on organic materials in the chain locker. However, these concentrations are within acceptable limits.

- The analysis of the samples also indicated very low concentrations of volatile organic compounds, within acceptable limits.

1.4.2 HSE opinion

There were no significant amounts of toxic gases in the chain locker, and the internal steel surfaces (including the anchor chains) were heavily rusted.

The increased concentration of Argon (compared to the air reference value of 0.97%) indicated depletion of O_2, rather than another gas displacing or diluting air within the chain locker.

Iron and steel when exposed to moist air will react with O_2 in the air to form iron oxide (rusting). Rusting requires both O_2 and water and is accelerated in the presence of salt. The corrosion of the steel within the chain locker caused the O_2 to be consumed in the process of rust formation, and this resulted in an O_2 deficient atmosphere.

The atmospheric measurements reported were taken 3 days after the accident. In the interim, the space had been opened, and rescuers wearing BA had been working in the space. As a consequence, the air quality measurements taken were not representative of the atmosphere in the chain locker at the time of the accident.

The chain locker was tightly sealed with, effectively, no natural ventilation being present prior to the entry by the three crewmen. It is difficult to estimate the concentration of O_2 at the time of the accident, but based on the speed of effect and available data from other incidents it is likely that O_2 concentrations in the chain locker at the time of the accident were below 10%.

In the opinion of the specialist HSE inspector, the depleted O_2 concentration in the chain locker was the primary reason for the collapse and subsequent death of the three crewmen.

1.4.3 Medium term O_2 depletion

In order to assess whether the O_2 depletion found in the chain locker could have been caused by corrosion, and to provide an estimate of the O_2 levels possible at the time of the accident, an expert was consulted[7].

Expert analysis concluded that corrosion within the sealed chain locker (since the locker had last been certified gas-free) could have led to a loss of O_2 resulting in an atmosphere that was unable to support human life; levels as low as 4.4 % (by volume) were estimated to have been possible.

The full report is at **Annex A**.

1.4.4 The physiological effects of reduced oxygen

In a normal ambient atmosphere the expected O_2 level would be around 20.9%, by volume.

In general, O_2 deficiency leads to a loss of mental alertness and a distortion of judgment and performance. This happens within a relatively short time, without the person's knowledge and without prior warning.

The following table[8] indicates the effects of O_2 deficient atmospheres on humans. These values are approximate and can vary. Note that exposure to an atmosphere containing less than 18% by volume of O_2 poses a significant risk.

Asphyxia – Effect of O_2 Concentration	
O_2 (volume %)	**Effects and Symptoms**
18-21	No discernible symptoms can be detected by the individual.
11-18	Reduction of physical and intellectual performance without the sufferer being aware.
8-11	Possibility of fainting within a few minutes without prior warning. **Risk of death below 11 vol%.**
6-8	Fainting occurs after a short time. Resuscitation possible if carried out immediately.
0-6	Fainting almost immediate. Brain damage may occur, even if rescued.

Table 1

7 Opinion provided by the Research Institute for Industry at the University of Southampton.

8 Reference source - University of Oxford http://www.admin.ox.ac.uk/safety/s403.shtml

1.5 INVESTIGATIONS AT IMMINGHAM

Once the atmosphere samples had been taken, the foc'sle store was force ventilated (using portable fans obtained from ashore) and then certified by the attending analyst as safe for entry.

On entering the foc'sle store an empty EEBD was found, and a notice was seen posted up on the after bulkhead of the compartment, near to the manholes **(Figure 6)**. The notice appeared to have been made onboard during the period 2002 – 2005. The ship's crew did not know when the notice had been posted.

Figure 6

Sign attached to aft bulkhead of foc'sle store

A reminder of the correct size of spanner needed to open the manhole covers was seen, handwritten in marker pen, near the openings **(Figure 7)**.

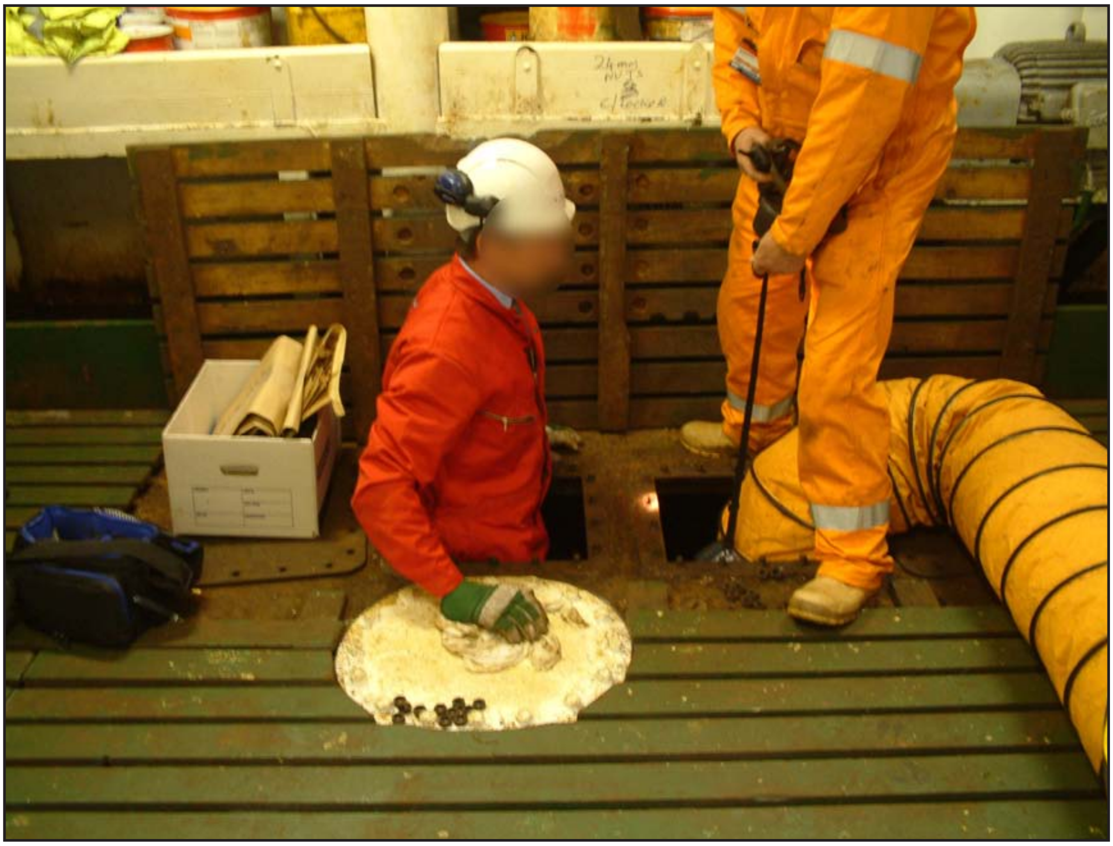
Being aware of the most probable cause of the accident, both chain locker manhole covers were removed, the foam broken out of both spurling pipes and the space was force ventilated. The analyst re-tested the space and certified it safe to enter; the manhole openings were noted to be particularly small **(Figure 8)**.

The inside of the chain locker was inspected, measured and photographed. The main part of the chain was found piled in the middle of the space in a fairly solid lump, probably indicating that it had not moved for an extended period of time. No significant foreign objects were found, other than small amounts of textile material, probably rags used to plug the spurling pipes prior to applying expanded foam. Some salt water was present in the bilges at the bottom of the chain locker, below the false floor **(Figure 9)**.

Figure 7

Foc'sle store looking aft

Figure 8



Foc'sle store - showing cramped access to chain locker

Figure 9

Chain locker - showing anchor chain

Both anchors were walked back to their bitter ends to clear the chain from the locker and the water residues removed. Once the atmosphere within the empty locker had again been verified as safe for entry, a full condition survey of the space was conducted. This revealed the locker to be structurally sound but with a minor level of corrosion to the steel surfaces overall. No significant quantities of mud or organic material were found. The bilge suction was blocked, and reportedly had not been functioning for some time; the chain locker bilge line was subsequently found to be disconnected from the bilge system within the bow thruster room.

1.6 ACTIONS BY THE MARITIME AND COASTGUARD AGENCY

1.6.1 Detention of *Viking Islay*

Viking Islay was boarded by surveyors from the local Maritime and Coastguard Agency (MCA) Marine Office who detained the vessel on 25 September, following discovery of the following major non conformities with the owner's International Management Code for the Safe Operation of Ships (ISM Code) Safety Management System (SMS):

- The Permit to Work system (PTW) was not being followed
- The oxygen/gas testing equipment was inappropriate for the task

Viking Islay was released from detention by the MCA on 21 October 2007.

1.6.2 General inspections of other Vroon ships

A representative sample of ten Vroon ships was targeted for general inspection. At the time of writing, this action was not complete, however some evidence was found of anchor chains on other vessels having been tied off as they had been on *Viking Islay*.

1.6.3 Safety Management Certificate DOC audit

The MCA carried out the scheduled second annual verification audit of the Vroon Document of Compliance (DOC) in November 2007. It was then agreed that an additional verification audit would be programmed for spring 2008, after the general inspection programme of other Vroon vessels had been completed.

1.7 THE ERRV OR "STANDBY VESSEL" BUSINESS AND *VIKING ISLAY*

1.7.1 The ERRV business

The requirement for ERRV vessels arises from the Prevention of Fire and Explosion and Emergency Response (PFEER) Regulations (1995) which requires the duty holder to ensure a good prospect of recovery to a "Place of Safety" for all manned offshore installations.

ERRVs provide:

- Safety cover for helicopter movements, over the side (of the rig or platform) working and platform abandonment
- Guard ship duties (to protect both surface and sub sea installations from damage)
- An emergency response centre/frontline command and control centre, to be used in the event of an offshore disaster.

1.7.2 ERRV *Viking Islay* – ship certification

Certification for the ship to be operated as a conventional vessel was issued by the MCA and Lloyd's Register (LR). The Cargo Ship Safety Equipment Certificate (SEC) was issued by the MCA.

The certificate of Survey of Vessel Standing by Offshore Installations, required to allow a vessel to operate as an ERRV, and issued under the terms of a UK Offshore Operators Association (UKOOA) approved code of practice, was issued in January 2003, to expire in January 2008. The survey was undertaken by the MCA Aberdeen Marine Office.

All certification was valid, and there were no relevant conditions of class at the time of the accident.

The ISM certificates, both the DOC for the owners Vroon and the Safety Management Certificate (SMC) for *Viking Islay*, were issued by the MCA. There were no observations or non-conformities relevant to this accident at the time of the last audit.

The Minimum Safe Manning Document was issued by the MCA. This required a crew of six to operate in the near coastal area[9]; but due to ERRV operational requirements *Viking Islay* had a crew of 12 at the time of the accident.

1.7.3 Entering the chain locker and securing the anchor chain

The last fully documented entry to the chain locker was in June 2006, to allow steelwork repairs to be undertaken by shore contractors. The Vroon SMS was correctly used at that time.

No evidence was found of the Vroon SMS system being used by the crew when entering the chain locker to secure the chains. However there was evidence that this task had been done before, probably on many occasions. There was also evidence that this practice had occurred on other Vroon ships.

1.8 VROON OFFSHORE SERVICES LTD - THE MANAGERS AND OPERATORS

Although a relatively new company, Vroon has a long pedigree in the North Sea standby business. BUE North Sea and Viking Standby Services merged in 2002, and this company traded as BUE Viking from 2002 to 2005. BUE Viking became Viking Offshore Services in 2005, which in turn became Vroon in May 2007.

As part of the Vroon expansion and investment strategy, both the DPA and DDPA were recruited from the offshore industry, instead of the ERRV industry. The DPA was a graduate engineer with Merchant Navy and offshore project management experience. The DDPA, who was a graduate safety professional, was also the Quality, Health, Safety and Environment Manager.

1.9 MANNING

Many of the men on board *Viking Islay* had served with Vroon, or its previous incarnations, for many years and were regulars on this ship. Most of them had extensive experience serving on board stand by vessels.

The whole crew worked a 28 days on board, 28 days on leave routine. Watchkeepers worked conventional 4 hours on, 8 hours off watches while at sea, and the deck department was enhanced by two day workers.

Viking Islay was manned by a mixture of British and Polish nationals (both officers and crew). English was the nominated language for all operations within the Vroon fleet.

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9 Within 150 miles from a safe haven in the UK.

1.10 PERSONNEL

1.10.1 The master

The master was a British national aged 64. Originally serving on board fishing vessels, he had achieved his Fishing "Skipper Full" certificate of competency (CoC) in 1974, and had served as skipper/master on board both fishing and various offshore vessels for many years. He had served with Vroon since 2002.

In 2000, he was required to convert his fishing vessel CoC, due to the changes introduced by the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978 (STCW) (as amended). As a part of this conversion process, he had completed an ERRV command and control course. At the time of the accident, the master held STCW II/2 Master CoC which was limited to use on Standby, Seismic Survey and Oceanographic Research Vessels only.

1.10.2 The chief mate

The chief mate was a British national aged 55. He originally went to sea on board fishing vessels in 1975, and had served with Vroon since 1997. In 2001, he had been required to convert his original fishing vessel "Second Hand Full and Special" CoC to an STCW II/2 Chief Mate; limited to Standby, Seismic Survey and Oceanographic Research Vessels only. He had completed an ERRV Command and Control course.

1.10.3 The day work seamen - the first two victims

- Mr Robert Ebertowski

  Mr Ebertowski, a Polish national aged 40, held a Seaman Grade 1 AB qualification. He had, through a Polish crewing agency, worked on board various foreign ships, including several trips as an engineer on LPG carriers before joining the ERRV industry. He had worked for Vroon since March 2005 and had been on contract service with Vroon since 2007.

- Mr Robert O'Brien

  Mr O'Brien, a British national aged 59, held a Seaman Grade 1 AB qualification. He was also the ship's nominated Advanced Medical Aid responder (AMA). Seafaring was his second career, having previously served many years in the UK armed forces as an army medic. He had worked for Vroon for 7 years.

1.10.4 The 8/12 seaman - the third victim

Mr Finlay MacFadyen, a British national aged 46, held a Seaman Grade 1 AB qualification. He had previously served many years as a motorman/oiler in the British Merchant Navy. He had worked in the ERRV industry for several years and for Vroon for almost 2 years.

1.11 *VIKING ISLAY*'S SAFETY EQUIPMENT

1.11.1 Atmosphere testing equipment

Prior to this accident, *Viking Islay* had been equipped with a Crowcon EIKON personal O_2 alarm. It was not possible to use this instrument to measure the oxygen levels in a space before first entry. It was designed as a personal alarm unit to provide individual users with a warning should the oxygen level within an enclosed space reduce to a hazardous level. The Crowcon EIKON held on board *Viking Islay* had a limited shelf life and had become time expired. Accordingly, in February 2007, ship's staff had ordered a replacement as described below:

> *EKON H_2S gas monitor: make Crowcon* [sic].

As a consequence, Vroon supplied the ship with a disposable single gas monitor for the protection of personnel against toxic H_2S hazard[10] as a replacement.

The crew of *Viking Islay* were unaware that the original O_2 "meter" was in fact a personal gas alarm and not an atmosphere testing device, and that the replacement personal gas alarm supplied by Vroon detected H_2S and not O_2 levels.

1.11.2 Other equipment

Viking Islay had no portable vent fans or portable lighting at the time of the accident.

Viking Islay was provided with a dedicated air compressor in order to re-fill BA cylinders on board. This allowed more realistic drills to be undertaken, as the crew were able to become practised in the use of BA, yet retain the ship's emergency response capability at all times.

1.12 EMERGENCY ESCAPE BREATHING DEVICES

1.12.1 Requirement to provide Emergency Escape Breathing Devices

Viking Islay carried five Sabre Emergency Life Support Apparatus (ELSA), in accordance with statutory requirements[11] to carry EEBDs. These devices provide personnel with breathing protection against a hazardous atmosphere, while escaping to a place of safety. IMO MSC Circular 849 specifically forbids the use of EEBDs for entering oxygen deficient voids or tanks.[12]

1.12.2 EEBDs provided on board *Viking Islay* – Sabre ELSA type

The Sabre ELSA is a self-contained, open circuit, compressed air, constant flow EEBD. It comprises a compressed air cylinder with a combined reducer/cylinder valve, attached to a close fitting escape hood by a breathing hose. The whole unit is contained within a stowage bag ready for immediate use. The high-visibility bag is clearly marked *ESCAPE USE ONLY* **(Figures 10 and 11)**.

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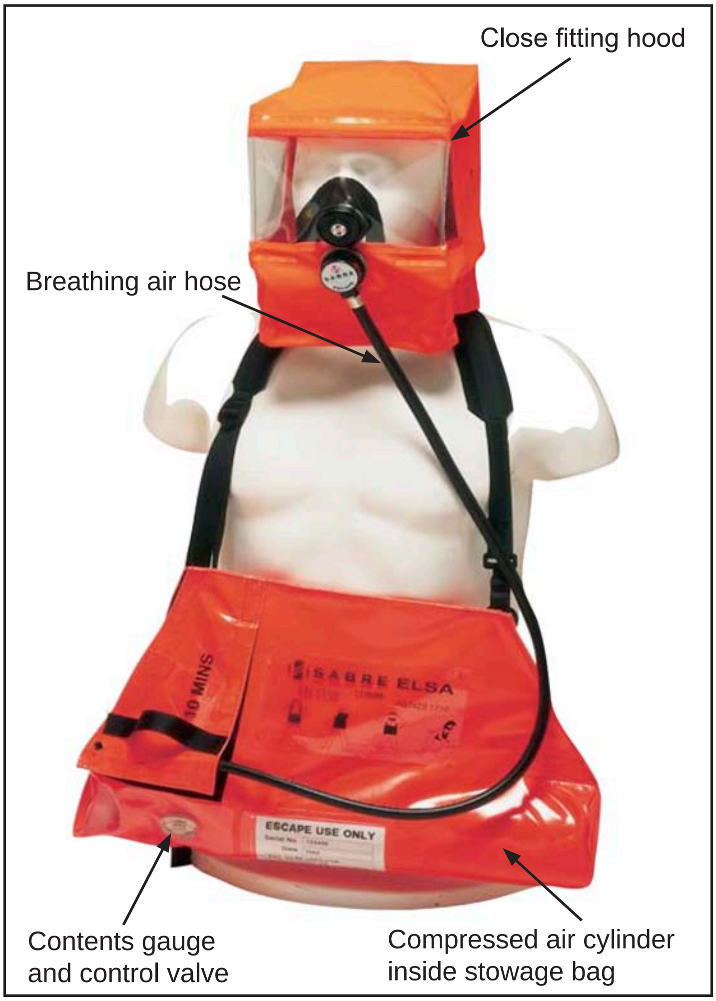
10 Hydrogen Sulphide [H_2S], an extremely hazardous, toxic gas. It is a colourless, flammable gas that can be identified, in relatively low concentrations, by a characteristic rotten egg odour. The gas occurs naturally as a product of decaying sulphur-containing organic matter, particularly under low oxygen conditions. Many petroleum industry jobsites are potential locations of this gas.

11 SOLAS 74 Chapter II-2, Part D, Reg 13, paragraph 3.4. Promulgated by IMO MSC/Circ.849 of June 1998, this amended regulation required EEBD to be carried on board most vessels. This SOLAS amendment was given effect within UK regulations by SI 2003 No.2951, the Merchant Shipping (Fire Protection) Regulations (Amendment) Regulations 2003.

12 Paragraph 2 of the Annex to MSC/Circ.849 of June 1998 states: *An EEBD is a supplied-air device only used for escape from a compartment that has a hazardous atmosphere…EEBD's are not to be used for fighting fires, entering oxygen deficient voids or tanks, or worn by fire fighters.* This is repeated in Annex 1 of MGN 215 (M+F), dated March 2002.

Figure 10



Sabre ELSA type EEBD

Figure 11

Sabre ELSA type EEBD

The 10 minute duration of the ELSA is achieved by means of a reducer/cylinder valve which restricts the flow of air from the cylinder to the mask, so that once activated a steady flow of air is provided to the wearer[13]. It is not a demand valve system.

The ELSA user instructions state:

> *In general, constant flow escape breathing apparatus is NOT suitable for use where:*
>
> - *There are unknown hazards,*
> - *There are no planned escape routes,*
> - *Escape routes that require physical exertion, e.g. ladders, tunnels and hatches.*

No evidence was found that there was any technical fault with the ELSA used in the fatal rescue attempt.

1.12.3 Limitations of constant flow EEBDs

One significant disadvantage of the constant air flow arrangement is that it is possible for a wearer undertaking particularly strenuous activity to require a greater flow of air than the EEBD can supply. This might result in the hood collapsing in on the wearer's face, producing an unpleasant suffocating sensation.

It is not widely known that the limitations of the air supply provided by the ELSA (or other similar constant flow type EEBDs) could be exacerbated by a wearer with a high air demand; for example a person with a particularly large tidal volume[14], or one whose ventilation was increased due to exertion and/or stress.

It is also possible that an inadequate air supply could be due to hood volume rather than gas flow rate. If the wearer's tidal volume exceeds that which is available within the EEBD hood (due to the difference between the volume of the hood and that of the wearer's head), the hood could tend to collapse in upon the wearer's face.

1.12.4 Requirement to provide training for EEBDs

The requirement to provide training for EEBDs carried on board ships is given in both SOLAS and UK legislation[15]. However the content of the training and its degree of realism is not prescribed.

1.12.5 EEBD training on board *Viking Islay*

EEBDs were provided for all vessels in the Vroon fleet about 5 years ago, and a training regime was instigated. Vroon records confirm that the majority of the crew on board *Viking Islay* at the time of the accident (including the victim who entered the chain locker wearing EEBD), had received training in June 2006. The training focused

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13 Manufacturers quote 38 litres per minute.

14 The tidal volume of the lungs is the quantity (volume) of air inhaled and exhaled with each normal breath.

15 SOLAS Chapter II-2, Regulation 15, paragraph 2.2.2: *Training in the use of the EEBDs shall be considered as part of onboard training.* Also in UK legislation: SI 2003 No.2951. The Merchant Shipping (Fire Protection) Regulations (Amendment) 2003. *Training in the use of EEBDs shall be included in the onboard training of each crew member as soon as possible…after he first joins the ship.*

on the EEBD as a means of supporting an individual in escaping from a smoke-filled environment, and stressed that the units were to be used for escape purposes only. The limited duration was highlighted, but no mention was made of the potential for an inadequate air flow under certain circumstances and the ship's personnel were not given the opportunity to use the equipment in circumstances where this limitation would become apparent.

The ship did not have the capability to recharge any EEBDs used on board. Additional sets were specifically provided for training purposes only, and supplied to the ship when a shore-based trainer attended.

A fleet-wide programme of enhanced refresher training was underway, but had not been completed on board *Viking Islay* at the time of the accident.

1.13 THE VROON OFFSHORE SAFETY MANAGEMENT SYSTEM

1.13.1 The Safety Management System (SMS)

Much of the Vroon SMS was inherited from BUE Viking, and a review process was on-going.

Office staff stated that the intent of the SMS with respect to entering dangerous enclosed/confined spaces for the purposes of routine work was that they should only be undertaken when in port, and with the support and guidance of shore-based specialists. This was the reason why individual ships were not provided with the equipment necessary to effect safe entry. However, no documentary evidence was available to support Vroon's intended policy of restricted entry only, other than the risk assessment that had been written on board.

Viking Islay was supplied with the documentation required by the Vroon SMS to effect safe entry into an enclosed/confined space. Prior to entering the chain locker the SMS required the following to be completed:

1. Risk Assessment
2. Toolbox-talk Risk Identification Card (TRIC)
3. Permit To Work (PTW)

1.13.2 Risk Assessment for tank/space entry

The SMS risk assessment for tank/space entry carried on board *Viking Islay* did not make the company policy regarding enclosed/confined spaces completely clear, and individual ships were authorised to amend their own risk assessments. Page 1 (taken from the SMS) gives details of the control measure required, while page 2 (produced on board) states:

> *Tanks must not be entered until chemist has ensured space is gas free, and oxygen level sufficient*.

(Annex B)

Viking Islay's risk assessment for tank/space entry had several errors, including a mismatch between the risk assessment and the equipment actually available on board. For example, the control measures mention ventilating the space, but not testing the atmosphere. The document was marked BUE Viking Ltd 2003. The SMS risk assessment did not tally with the enclosed/confined space rescue checklist, which specifically required that the atmosphere be tested **(Annex C)**.

1.13.3 Toolbox-talk Risk Identification Card (TRIC)

TRIC was an "offshore" work system, adopted as an additional safety measure by Vroon and other offshore operators, which aimed to make the generic risk assessment appropriate for a particular job, on a particular day. The process formalised the 'toolbox-talk' by identifying hazards not covered by the risk assessment, along with any control measures required, and recorded them on the TRIC. A card was required to be completed for any non-routine task or when there had been any change to the planned work scope. It was Vroon's intention that as a final safeguard, the master's signature on the TRIC was required before work commenced. However, the format of the TRIC, and the associated instructions within the Vroon SMS, did not make this step completely clear.

In an attempt to make the system effective, Vroon had provided its fleet with guidance on how many TRICs it expected to be completed monthly. On board *Viking Islay*, this had been interpreted as a "target", resulting in the cards being completed for arguably non hazardous operations such as transferring food from the ship's store rooms to the galley. However, a TRIC was not completed for the entry into the chain locker.

Another sign that completion of the TRIC was treated as an administrative function rather than an important safety tool was that the master was signing them on a routine basis, instead of signing the cards as they were compiled and before the relevant task was undertaken.

1.13.4 Permit to Work system

A valid risk assessment must be in place before a PTW can be granted. The Vroon SMS stated that the master or responsible officer had the overall responsibility for ensuring that PTW forms were completed before any work was carried out.

The responsible officer issuing the permit had to complete all sections, and then sign the certificate of checks. In order to comply with the terms of the PTW, the responsible officer would have to visit the work site.

1.13.5 Internal vessel audit

Staff from the Vroon Heath, Safety and Environment department carried out an internal audit of *Viking Islay* on 1 March 2007. Safe working practices and the PTW system were reported as satisfactory, as was the ship's emergency preparedness.

1.13.6 Safety coaches

Vroon employed two safety coaches who were ex-seafarers, specifically to go to sea on board their ships in order to evaluate onboard practices and identify improvements where applicable. The coaches had managed to spend significant periods of time on board the majority of the Vroon fleet. Vroon records show no coaching visits to *Viking Islay* prior to the accident.

1.14 ENTRY INTO DANGEROUS SPACES REGULATIONS

1.14.1 The Merchant Shipping (Entry into Dangerous Spaces) Regulations 1988

The Regulations[16] apply to United Kingdom (UK) ships and other nations' ships while they are in a UK port. Within the Regulations, "dangerous space" means:

> *Any enclosed or confined space in which it is foreseeable that the atmosphere may at some stage contain toxic or flammable gases or vapours, or be deficient in oxygen, to the extent that it may endanger the life or health of any person entering that space.*

The Regulations require that the entrances to unattended dangerous spaces are secured against entry; that procedures for entry into dangerous spaces are laid down and observed; that drills are periodically carried out; and that equipment for testing dangerous spaces is carried where entry into a dangerous space might be necessary.

1.14.2 Duties under the Entry into Dangerous Spaces (EDS) Regulations

- The employer shall ensure that procedures for ensuring safe entry and working in dangerous spaces are clearly laid down; and
- The master shall ensure that such procedures are observed on board the ship
- No person shall enter or remain in a dangerous space (except in accordance with safe procedures)
- In fulfilling their duties under these regulations, the employer, master and any other person shall take full account of the principles and guidance contained in the Code of Safe Practice for Merchant Seamen (COSWP) **(see 1.15).**

1.14.3 Drills

The EDS regulations require the master to ensure that drills simulating the rescue of a crew member from a dangerous space are held at intervals not exceeding 2 months, and that a record of such drills is entered in the official logbook. This applies to tankers of 500 Gross Registered Tons (GRT) and over, and to any other ship of 1000 GRT and over. As *Viking Islay* was 928 GRT this regulation did not apply; however the Vroon SMS incorporated a requirement to conduct this type of drill, and they were regularly undertaken on board *Viking Islay*.

The scenario provided as an example in the Vroon SMS emergency response manual, describes an incident during which one of the crew becomes unconscious when working in a confined space. A standby man outside the space raises the alarm and then enters the space and also falls unconscious. The drill seeks to provide practice in confined space rescue, use of BA and first-aid. For reasons of safety during drills, *Viking Islay* used the ship's laundry as the confined space, having interpreted 'confined' to mean 'awkward' or 'restricted', rather than 'dangerous'.

1.14.4 Atmosphere testing equipment required

The EDS regulations require the employer to ensure that each ship, where entry into a dangerous space may be necessary, shall carry or otherwise have available an oxygen meter and such other testing device as is appropriate to the hazard likely to be

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16 SI 1988/1638. See : http://www.mcga.gov.uk/c4mca/mcga-mld-page.htm?textobjid=D397CBD0CAB6BD81

encountered in any dangerous space on board. The regulations also require that the master ensures that the oxygen meter, and any other testing device provided on board, are maintained in good working order and, where applicable, regularly serviced and calibrated according to the manufacturers' recommendations.

1.15 CODE OF SAFE WORKING PRACTICES FOR MERCHANT SEAMEN (COSWP)

1.15.1 Background and Legislation

The COSWP is published by the MCA, and is mandatory for UK ships[17]. Regulations place a duty on the ships' operators to ensure that sufficient copies of the COSWP are carried on every ship to which the regulations apply, based on the number of workers on the ship. Printed copies of the current code were available in *Viking Islay*'s wheelhouse and mess room.

The chapters particularly relevant to this accident include:

- Chapter 6: Means of access and safe movement
- Chapter 10: Emergency procedures
- Chapter 16: Permit to work systems
- Chapter 17: Entering enclosed or confined spaces

The full text of the relevant sections of the COSWP is not included in this report, but can be viewed on the MCA website.

1.15.2 Vroon induction programme

An induction programme that Vroon provided to all new sea staff highlights the importance of the COSWP, and focuses specifically on risk assessment and the company's PTW system.

1.16 DANGERS OF ENCLOSED/CONFINED SPACES - OTHER ADVICE AND GUIDANCE

1.16.1 Marine Guidance Note 309

Although primarily aimed at the fishing industry, Marine Guidance Note[18] (MGN) 309 (F) gives advice that might be useful to other small ships, particularly those with limited crew numbers. It highlights that all spaces receiving little or no ventilation should be treated as potentially dangerous, and that one common cause of low O_2 levels is corrosion or rusting.

17 The Merchant Shipping (Code of Safe Working Practices for Merchant Seamen) Regulations 1998, S.I 1998/1838. See: http://www.mcga.gov.uk/c4mca/mcga-mld-page.htm?textobjid=DBB616EB3DACD5BC

18 MGN 309 (F) See: http://www.mcga.gov.uk/c4mca/mcga-mld-page.htm?textobjid=6BAA95EDEA5ACC7D

1.16.2 Further guidance on dangerous enclosed/confined spaces

While the MCA's COSWP should be considered as the definitive information source on this topic for UK seafarers, much other information is available, e.g.

- International Maritime Organization (IMO) publication, Assembly Resolution A.864 (20) Recommendations for Entering Enclosed Spaces Aboard Ships. This document includes an example of an enclosed space entry permit.
- Many flag states have relayed this information to ship-owners, for one example see footnote[19].
- The International Association of Classification Societies (IACS) provides guidance for ship surveyors[20].
- Various Protection and Indemnity clubs have issued advice and guidance to their members and ships' crews.
- The HSE provides guidance for shore-based industries[21].

1.17 SIMILAR ACCIDENTS

1.17.1 MAIB statistics

IMO Assembly Resolution A.864(20): *Recommendations for Entering Enclosed Spaces Aboard Ships* was adopted in 1997 following widespread industry concern over the number of fatalities that had occurred resulting from ship's personnel entering spaces in which the atmosphere was oxygen depleted, toxic or flammable. MAIB records show that 15 deaths and 31 reportable injuries, as a result of accidents in circumstances similar to the *Viking Islay* accident, have occurred on UK registered vessels, or in UK waters, during the period since IMO Assembly Resolution A.864(20) was adopted.

MAIB is currently investigating two other accidents in which three men died under broadly similar circumstances.

1.17.2 Marine Accident Investigators' International Forum (MAIIF)

Concerned at the continued loss of life due to improper confined space entry procedures, MAIIF tasked the Department of Maritime Affairs, Vanuatu, with the collection and dissemination of material relating to confined space entry, in anticipation of a paper on the subject being submitted to the IMO.

At the time of drafting this investigation report, Vanuatu had collated data from six administrations which listed 63 separate confined space incidents, resulting in 44 deaths and 63 injuries on board vessels of 15 different flag states, during the period 1993 to the current date. The data also identified that deaths due to lack of oxygen or toxic atmosphere were occurring in spaces other than those routinely identified as dangerous compartments.

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19 This example also warns against the incorrect use of EEBDs for rescue purposes: http://vanuatuships.com/content/view/150/2/

20 See: http://www.iacs.org.uk/document/public/Publications/Guidelines_and_recommendations/PDF/REC_72_pdf212.pdf

21 See: http://www.hse.gov.uk/confinedspace/

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 FATIGUE

The effect of fatigue on the master and crew of *Viking Islay* was assessed. The crew were fresh from 28 days leave; the two day workers had had a full night's rest. Mr MacFadyen had been off-watch for his full 8 hours, albeit to some (not fully known) extent disturbed by the noise made by the anchor chain. However, if his rest had been severely disturbed, he would have been able to temporarily move from his cabin to a quieter location to sleep (e.g. the ship's hospital or survivor accommodation); there was no evidence to suggest that he had done this. Also, other members of the crew did not report significant sleep disturbance caused by the noise from the chain locker, indeed some were not aware of the noise at all. Therefore fatigue was considered not to be a contributory factor to this accident.

2.3 MANNING & PERSONNEL

2.3.1 Manning levels

Viking Islay was manned well in excess of the vessel's minimum safe manning document. A lack of manpower on board *Viking Islay* was not a contributory factor to this accident.

2.3.2 Crew nationalities and languages spoken on board *Viking Islay*

All of those interviewed had satisfactory spoken English skills; there is no evidence to suggest that language difficulties played any part in this accident.

2.4 THE HAZARD

Air quality measurements showed that at the time of the accident the atmosphere in the chain locker was O_2 deficient, and that no other gaseous hazards existed. Subsequent expert analysis has shown that this deficiency was due to depletion, rather than displacement or dilution of the O_2, and that the O_2 levels could have been sufficiently low – around 4.4% - so as to cause instantaneous collapse of any person breathing such an atmosphere. This supports the recollections of the witness who saw Mr MacFadyen collapse in this way. It is therefore very likely that the first two victims were similarly overcome.

The chain locker had no natural ventilation other than via the spurling pipes, and it was practice on board *Viking Islay* for these to be sealed with expanding foam once the vessel was clear of harbour and had secured her anchors for sea. Over the 18 months since the compartment had last been gas-freed and proven for normal atmosphere, the rusting of the inner surfaces of the compartment and the chain would have been steadily depleting the O_2 in the air. Rusting is invariably found within chain lockers, given the intermittent presence of damp conditions and exposed steel. The breaking free of the anchor chain to enter and leave harbour, sometimes followed by a crew member entering the space to re-secure the chain, would have freshened the atmosphere a little, but certainly not enough to restore O_2 percentages to normal atmospheric levels.

The deterioration in O_2 levels would have been slow and progressive. That crew members had been able to successfully enter the chain locker over that 18 month period can be accounted for in three ways. Firstly, a crew member only needed to descend part way down the ladder to tie off the anchor chains, and would therefore have been near to the entrance opening and so in the freshest air. Secondly, on previous visits to the chain locker, members of the crew might well have experienced some of the effects of the lack of O_2 but not recognised the symptoms **(table 1, page 12)**. Thirdly, it is likely that the chain locker was last visited to tie off the chains sometime before the summer. There was therefore an extended period during which O_2 was being depleted and no-one was opening up the compartment.

2.5 THE INITIAL ACCIDENT

It was likely that Mr Ebertowski, being a younger fitter man and the junior rating of the two, entered the chain locker to tie off the chain. This was a one man job, and the restricted space available within the chain locker meant it was unlikely that two men would have entered in the first instance.

The leading hand, Mr O'Brien, would have stood by at the entrance, maintaining radio contact with the wheelhouse. It was possible that the atmosphere was such that Mr Ebertowski was overcome immediately he entered the space. It is also possible that he dropped something that caused him to go right down to the bottom of the chain locker, and caused his collapse there. With Mr Ebertowski lying at the bottom of the chain locker, it would then have been necessary for anyone attempting to rescue him to descend into that area.

Witnesses' descriptions of the way Mr MacFadyen raised the alarm as he ran down through the accommodation, indicate that he probably was already aware of the first victim, and possibly had been told by Mr O'Brien that he was entering the chain locker to try to rescue Mr Ebertowski.

2.6 THE CONSEQUENT RESCUE ATTEMPT

Mr MacFadyen's ill fated rescue attempt began well, but ended tragically. This was due to several reasons.

2.6.1 Training, drills and rescue procedures

The training regime for dangerous enclosed/confined space rescue on board *Viking Islay* did not prepare the crew for an accident of this nature. The crew had been drilled in the rescue of a person from a confined space, specifically the ship's laundry. While a useful drill in itself, it did not prepare them for a dangerous space rescue, especially one with a noxious atmosphere.

More appropriate drills could have included the particular difficulties of recovering an unconscious casualty from a very confined compartment, and negotiating an unusually narrow access hatch. The crew would thus have been given opportunities to learn effective rescue techniques, and to practice using the equipment necessary for those techniques. Such drills might also have identified that the size of the access was a problem when wearing BA, and allowed that problem to be resolved. It is noteworthy that the extraction team that boarded the vessel from *ENSCO 92* were better able to cope with the unusually small entrance as they had drilled for such an eventuality.

2.6.2 Command and control

The forward control point (FCP) for the rescue was, in effect, the foredeck. Given the limited working area inside the foc'sle store, and its proximity to the chain locker which contained, at that time, an unidentified hazard, this was not unreasonable. However, the hatch opening from the foc'sle store to the chain locker was the most significant physical obstacle the rescue party had to negotiate, and the officer in-charge of the FCP, the mate, had not identified this because he could not clearly see Mr MacFadyen struggling to get through it.

Had the mate realised the difficulty Mr MacFadyen would have negotiating the entrance, wearing a breathing apparatus, he could have detailed a smaller man for the task, or arranged for his breathing apparatus to be passed through the hatch separately. Certainly, he would have been able to stop Mr MacFadyen attempting to enter the chain locker, wearing an EEBD.

Many of the benefits to be gained from more effective training have been covered above. However, such training would also have allowed command and control by the person in-charge of the FCP to be rehearsed and, where appropriate, enhanced.

2.6.3 EEBD limitations

Mr MacFadyen had received EEBD training in the previous year, and was likely to have been well aware of the time-limited air supply provided by the EEBD. In a desperate attempt to rescue his shipmates, he probably took a chance with the EEBD, thinking that 10 minutes would be sufficient time in which to help them.

However, he was unlikely to have been aware that the rate at which air was supplied to the face mask was restricted, unlike the demand system on a breathing apparatus, and that it was possible to 'over breathe' an EEBD while conducting strenuous activity.

In electing to wear an EEBD rather than a BA, Mr MacFadyen took two chances with his life. The first, that the 10 minute EEBD would last long enough to enable him to help the victims and then to retreat before his air supply ran out. The second, that the EEBD would be able to provide him with an air supply adequate for the task he faced. For good reason, the use of an EEBD for rescues, or for otherwise entering a dangerous atmosphere, is forbidden.

While it is possible that the facemask became dislodged, the more likely explanation for Mr MacFadyen's collapse inside the chain locker was that, experiencing the suffocating effect of the restricted air supply as he climbed down into the chain locker, he removed the EEBD face mask to take a deep breath. In doing so, he breathed in the noxious atmosphere of the chain locker and collapsed instantaneously.

Had Mr MacFadyen been able to rehearse an escape wearing an EEBD prior to this accident, he might have been more alert to its limitations. Then, once it was clear he could not enter the chain locker in breathing apparatus, he might have notified the officer in-charge of the FCP and sought an alternative plan.

The EEBD training provided by Vroon satisfied statutory requirements. However, those requirements were not effective in revealing the true limitations of this type of equipment as they did not require realistic drills in their use.

As part of its fleet-wide programme of refresher training Vroon should include an opportunity for all crew members to experience wearing an EEBD, ideally under conditions of some physical stress.

To further enhance this training, the syllabus should include adequate instruction on both the time and air flow rate limitations of these devices and consideration should be given to providing its fleet with the capability to recharge EEBDs on board ship, so continuation training on EEBDs can be conducted during the 28 day periods on location offshore.

2.7 SUBSEQUENT RESCUE EFFORTS

2.7.1 The master

The master quickly realised the scale of the problem facing his ship, and correctly made an early call for external assistance. When this was forthcoming from *ENSCO 92*, he used his skills and experience to good effect in promptly manoeuvring *Viking Islay* close enough to the rig for the rescue party to transfer on board quickly and safely.

2.7.2 The *ENSCO 92* rescue team

By the time the *ENSCO 92* team were available to help, they were undertaking a recovery operation rather than a rescue.

The extraction team from the rig were able to enter the chain locker using very similar equipment to that which was available to the ship's crew. This indicates that *ENSCO 92*'s training and drills were more effective than those undertaken on board *Viking Islay*.

2.8 COMPANY POLICY ON DANGEROUS ENCLOSED/CONFINED SPACES

2.8.1 Operational requirement for entry to dangerous spaces

It was Vroon's policy that dangerous spaces should only be entered in port (with appropriate specialists in attendance). Accordingly, the company did not provide the specialist equipment required for members of the crew to safely enter such spaces when their vessels were at sea.

Although the reason why the crew on *Viking Islay* had elected to enter the chain locker could not be considered an urgent task, there will be occasions when entry into the space at sea is necessary. These could include, for example, inspection for damage, to free a bight in the anchor chain, to unblock the bilge strainer, and to release the bitter end. Evidence was found on other Vroon vessels that entry into the chain locker was considered necessary on occasions.

While the Vroon policy restricting confined space entry to port was clear to shore-based staff, it did not take account of scenarios that could require crews to enter confined spaces while at sea. Neither did the policy provide guidance on which spaces were to be considered confined/dangerous, and under what conditions. In these respects, the policy was unrealistic and provided the crew with insufficient practical guidance for the conduct of day-to-day operations.

2.8.2 Shipboard equipment

The result of the company's policy on entering dangerous enclosed/confined spaces was that Vroon did not supply *Viking Islay* with the equipment required to make a safe entry to a dangerous enclosed/confined space. The ship was provided with a single personal H_2S alarm, but ship's staff had no means of testing an enclosed/confined compartment's atmosphere before entering it; neither did the ship carry the equipment to force ventilate any compartment before entry if it proved necessary.

2.8.3 Actions following the accident

Following the accident, Vroon issued a safety alert re-affirming the company's policy of using shore based support for planned work in dangerous enclosed/confined spaces. The document also stated that a master should only consider initiating a dangerous enclosed/confined space entry at sea as a last resort, and only after he has exhausted all other solutions. Therefore, it should be necessary to contemplate entering dangerous enclosed/confined spaces only in extreme circumstances, and only once a risk assessment, TRIC and PTW had been completed. If the ship did not have the capability to do the job safely, then the job should not take place.

However, as a result of the MCA's inspection and subsequent detention of *Viking Islay*, Vroon has equipped her with the equipment necessary to effect safe entry to dangerous enclosed/confined spaces.

2.9 HAZARD PERCEPTION AND RISK ACCEPTANCE

2.9.1 The chain locker

A simple inspection, taking only a few minutes, would have shown that *Viking Islay*'s chain locker was effectively a tank, made completely air tight by the application of expanding foam to seal the spurling pipes. Even without the expanding foam it was, without doubt, a potentially dangerous enclosed/confined space, and with the foam in place its airtight integrity was assured. Therefore, as written, the Vroon SMS process for entering a dangerous space should have been followed, and the chain locker only entered in port with specialists in attendance.

Evidence suggests that on *Viking Islay* entry into the chain locker had, over time been undertaken to tie off the noisy anchor chain on many occasions. Nothing has been found to indicate that either Mr Ebertowski or Mr O'Brien deliberately ignored the potential hazards of the chain locker, or that they agreed to take a calculated risk in conducting this task. Instead, it is perhaps because this task had evolved into a familiar process that they did not recognise the potential risk Mr Ebertowski was taking when he entered the chain locker. It is clear that the locally produced sign, posted on the aft bulkhead **(Figure 6)** had been of limited effect in informing the crew's perception of the compartment and its hazards.

Other crew members on *Viking Islay* were found to have mixed perceptions of the hazard posed by the chain locker, and of the risks faced when entering that compartment. Some were clear that the chain locker was a dangerous space; while some other crew members, including the master, were not aware that the chain locker was a dangerous enclosed/confined space. Some crew members had done similar tasks in similar spaces (both on *Viking Islay* and other ships) and admitted that they would have continued to do so had it not been for this accident. More than one crew member expressed shock and surprise that three men could die simply by entering a chain locker.

Viking Islay and other Vroon vessels did not maintain a register of spaces to which crew members could refer if in any doubt about appropriate precautions to be taken for operations in, or entry to any given space. Had they done so, any ambiguity about the status of the space or activity would have been removed, and appropriate actions could then have been followed.

2.9.2 Approval of the task

The master, who had not visited the chain locker, did not consider that it was an enclosed/dangerous space. Perhaps for this reason, he did not consult with the mate, who would normally be in-charge of deck department activities, before approving the task. This notwithstanding, entry to the chain locker was not a frequent occurrence, and it would therefore have been appropriate to have required the seamen to complete the TRIC procedure before commencing the task. Properly completed, the TRIC would likely have alerted the master to some of the potential hazards, and he might then have given the issue more consideration before granting permission to proceed. Unfortunately, the TRIC procedure on board had become a retrospective administrative process instead of a proactive safety mechanism, so it is unsurprising that it was not completed as part of the task approval procedure.

2.9.3 The would-be rescuers

The situation for the would-be rescuers was quite different, and doubtless the adrenaline-fuelled instinct to help fallen shipmates was overwhelming. The phenomenon of multiple deaths during accidents involving dangerous confined spaces is well known; the COSWP specifically cautions seafarers against such rescue attempts.

In Mr O'Brien's case, his problem was immediate; his colleague had fallen/collapsed at the bottom of the chain locker. He raised the alarm, and immediately entered the space to render assistance. Whether he had any suspicions about the hazard he faced is not known. Either way, his attempt to rescue his colleague was instinctive but, tragically, ill-fated.

Mr MacFadyen was faced with a different problem. He had probably received a warning on the VHF radio of the first casualty, had himself raised the alarm on board, and was the first on scene. There he saw two apparently unconscious casualties whose condition was unknown. Having tried to enter the space wearing a BA, and finding it impossible, Mr MacFadyen donned an ELSA, a piece of equipment inappropriate for the task, and entered the space. It cost him his life.

Drills and training on board ships have two important purposes. Firstly, they provide an opportunity to test and prove procedures and equipment in realistic settings. Secondly, and most importantly, they practice the crews in sets of procedures that they can fall back on during emergency situations, when there is great urgency, and often noise and confusion. Without this bedrock of training, Mr MacFadyen was ill-prepared for his part in the rescue, and he resorted to instinct.

2.10 THE SHIP - SHORE DISCONNECT

It was evident that key working practices impacting on the safety of *Viking Islay* and her crew were at variance with specific requirements laid down in the Vroon SMS. However, the company's own internal audit system had not detected the disconnect between Vroon's performance expectations, as detailed in its SMS, and the actual work practices being observed by members of *Viking Islay*'s crew.

The difficulty for Vroon, which has been experienced by many other companies, was ensuring that its policies and procedures were being carried out effectively at sea. The particular hazards associated with confined space entry were addressed during dedicated crew training sessions held before oncoming crews embarked their vessels. However, in the case of the crew members who lost their lives on *Viking Islay,* this training was ineffective.

Vroon had also tried to verify and improve the effectiveness of its SMS by employing safety coaches, who carried out monitoring and training, both in port and at sea. However, *Viking Islay* had not been visited as a part of this programme at the time of the accident. Subsequently, having identified that this was partly due to the trading patterns of its fleet, Vroon has employed additional coaches in order to accelerate the training programme.

2.11 SIMILAR ACCIDENTS

Arguably, there can be few aspects of personal safety on board ships that have received more attention than the importance of following the correct procedures before entering an enclosed space. Very sadly, accidents such as that which occurred on board *Viking Islay*, continue to happen.

The lessons below have deliberately been copied from an MAIB Safety Digest article following a similar fatal accident in 2002[22]. They remain as valid now as they did then. Tragically, if learnt, they would have prevented this accident too.

> *1. Anyone who has been at sea for some time in merchant ships will be all too familiar with stories of people who have entered enclosed spaces without taking the necessary precautions, and died as the result. The lessons from such incidents have been hammered home time and time again and still it happens. Although it is impossible to know exactly what victims are thinking before they make an entry, it is feasible to assume they think the space is sufficiently safe to warrant entry. After all, it looks all right, so what could possibly go wrong?*
>
> *2. Some spaces are evidently dangerous, and there are very sound rules in place to prevent accidents. Consult the IMDG code to know the properties and characteristics of dangerous bulk cargoes before entering a space where such cargo is being, or has been carried. Follow the excellent advice in the Code of Safe Working Practices for Merchant Seamen, which documents the procedures for entering enclosed spaces. The main points are: the space must always be tested before and during each entry, personnel should be standing by with safety equipment at the entrance, and the space should be well ventilated.*

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[22] See MAIB Safety Digest 1/2002 http://www.maib.gov.uk/cms_resources/Safety%20Digest%201_2002.pdf

3. Other spaces are not necessarily quite so obvious. They include void spaces not normally entered, compartments that might have been flooded, or areas separated from dangerous cargo by a portable bulkhead. If in doubt, assume the space is potentially dangerous and take the necessary precautions. Remember 3.5% of oxygen looks exactly the same as the 18% which is the minimum required for human beings to breathe safely. Anything below that can lead to loss of life.

4. Never ever carry out an entry alone. A well-formulated plan should always be followed. A short-cut could prove fatal.

5. And one final point. If you see someone lying motionless at the bottom of a ladder in an enclosed space, don't rush in to carry out a rescue without taking all the appropriate precautions. Failure to do so will only result in more fatalities.

SECTION 3 - CONCLUSIONS

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

1. EEBD training provided by Vroon was not sufficiently realistic to give the crew a complete understanding of the limitations of the constant flow type EEBDs provided on board *Viking Islay*. (2.6)

2. Statutory requirements for EEBD training were not sufficiently robust to ensure that the full extent of the limitations of this type of equipment were revealed, and required no realistic drills in their use. (2.6)

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

1. *Viking Islay* was not provided with the equipment necessary to test the atmosphere of the chain locker. (2.4, 2.8)

2. Some crew members on board *Viking Islay* were not aware that the chain locker was a dangerous enclosed/confined space, or that the O_2 level within the chain locker could be dangerously depleted by corrosion, to the point that the atmosphere could become lethal. (2.5, 2.8, 2.9)

3. The training regime for dangerous enclosed/confined space rescue on board *Viking Islay* did not adequately prepare the crew for an accident of this nature. (2.6)

4. Command and control at the FCP was not fully effective, and best use was not made of the human and equipment resources available on board. (2.6)

5. Normal checks and routines that should have prevented this accident were not applied. (2.9)

6. Vroon office staff were clear that the company policy was that confined space entry should not occur unless specialist advice and support was available. However, the policy did not take account of scenarios that could require crews to enter confined spaces while at sea. Neither did the documentation provide guidance on which spaces were to be considered confined/dangerous, and under what conditions. In these respects, the policy was unrealistic and provided the crew with insufficient practical guidance for the conduct of day-to-day operations. (2.8)

7. The Vroon SMS was not being correctly implemented with respect to dangerous spaces on board *Viking Islay*, and audits and inspections had not detected this. (2.9, 2.10)

8. Vroon shore-based management were not aware of the working practices that had developed on their ship. (2.10)

SECTION 4 - ACTION TAKEN

4.1 VROON OFFSHORE SERVICES

Vroon Offshore Services has:

- Provided *Viking Islay,* and other ships in the Vroon fleet, with portable atmosphere testing equipment. Key onboard personnel have been trained in its use. Personal gas monitors have also been supplied to the Vroon fleet, to be worn by personnel entering a space once it has been tested and certified safe to enter.

- Issued a series of internal safety alerts that address the issues raised by this accident:

  - Safety Alert 15/07: Details the immediate safety lessons from this accident and identified the need to reinforce Vroon safety systems and processes including hazard recognition, risk assessment and the PTW system. This document unequivocally states that once the TRIC has been completed, and before the job starts, the card should be reviewed and signed off by the master. It required whole crew briefs on all Vroon vessels. The brief emphasised Vroon policy regarding dangerous enclosed/confined space entry requirements, reminding crews that the COSWP is integral to the Vroon SMS. This safety alert also gave detailed definitions of enclosed or confined spaces.

  - Safety Alert 16/07: Provided additional clarification in response to questions from the fleet about SA15/07. It reinforced Vroon confined/enclosed space entry requirements and repeated the definitions of dangerous spaces that were given in the previous alert.

  - Safety Alert 18/07: Gave details of the Vroon fleet-wide compartment assessment programme, together with a questionnaire designed to assist masters in completing the assessment of compartments on Vroon ships. If doubt existed as to whether any given space was, or had the potential to become dangerous, the questionnaire was to be completed and submitted to Vroon headquarters for assessment. The intention was to compile a register of dangerous spaces for each vessel in the Vroon fleet. Such spaces will be clearly marked as dangerous, and reference to the register will identify appropriate precautions to be taken.

- Commissioned an independent third party consultancy company to undertake an audit of the Vroon SMS, its fleet and, where necessary, revisit risk assessments.

- Undertaken to recruit additional staff to reinforce the Vroon safety management team: two training/development masters (to sail on board Vroon ships), a marine manager shipboard standards and an additional Quality Safety Health and Environment advisor.

- Begun the testing and evaluation of portable vent fans and lighting equipment. Vroon will then decide which is the most suitable, in terms of portability and electrical safety.

4.2 THE MARITIME AND COASTGUARD AGENCY

The Maritime and Coastguard Agency has:

- Conducted an ISM SMC additional verification audit on *Viking Islay*, and found two major non-conformities. However, because a full review of the PTW system was ongoing, and as the second crew (the crew on board at the time of this accident) had not been audited, the non-conformities were downgraded from major to minor, rather than closed out.

- Witnessed tank entry and rescue, fire, and abandon ship drills on board *Viking Islay*, and found them to be satisfactory.

- Commenced a series of general inspections on a number of other ships in the Vroon fleet.

- Scheduled an ISM DOC audit of Vroon during spring 2008.

- Issued an Operational Advice Note to ensure that MCA surveyors remind ships' crews, particularly those in the short-sea sector, about safe procedures concerning entry to dangerous enclosed/confined spaces. When carrying out surveys, inspections or ISM audits, surveyors have been requested to include checks:

  - That the content of the SMS is appropriate and is being applied

  - That confined space rescue drills have been correctly carried out

  - That the master is fully aware of his particular responsibilities regarding confined spaces on board his ship

  - To ensure that testing equipment is fit for purpose, is calibrated and in-date, and that the crew have been trained in its use

  - That those persons responsible for issuing permits to work for entry into enclosed spaces are aware of section 17 of the COSWP.

4.3 MARINE ACCIDENT INVESTIGATION BRANCH

The MAIB has:

- Issued a Safety Flyer, giving a summary of the findings of this investigation to the marine, offshore and fishing industries via representative organisations in order to heighten owners', operators' and seafarers' awareness over the dangers of entry into enclosed/confined spaces.

SECTION 5 - RECOMMENDATIONS

Vroon Offshore Services Ltd is recommended to:

2008/135 Review its training regime for the use of EEBDs on board all vessels in its fleet. Such training should include practical "hands-on" experience of both equipment capabilities and limitations, and should be undertaken in a safe, yet realistic environment. In order to achieve this recommendation within reasonable timescales, it may be necessary to arrange additional equipment and training to allow the safe re-charging and re-packing of any EEBD used for training purposes while the vessel is at sea.

The Maritime and Coastguard Agency is recommended to:

2008/136 Review the guidance currently available to seafarers regarding the limitations of constant flow type EEBDs, and publish any such additional guidance on the subject as the MCA deems necessary.

2008/137 Consider changes to regulation and guidance regarding the nature and extent of training and drills in the use of EEBDs on board ships. It is recommended that awareness of the correct use of EEBDs is firmly reinforced by practical "hands-on" experience of actual equipment capabilities and limitations, to be undertaken in a safe, yet realistic environment. The use of "dummy" EEBDs for training purposes should be discouraged.

Marine Accident Investigation Branch

July 2008

Annex A

Report by the Institute for Industry

Introduction

This report concerns the anchor drop chain locker on the Viking Islay vessel. A briefing meeting and discussion was held with MAIB's on 26th October 2007. A simplified calculation is performed to examine whether corrosion of the exposed locker steelwork and anchor chain steel surfaces could lead to appreciable consumption of oxygen from the atmosphere inside the compartment. An opinion is provided on the feasibility of significant oxygen depletion via corrosion.

Calculations and Notes

A number of assumptions, notes and estimates are made:

a) The anchor drop compartment was essentially sealed for an extended period of time, such that the lower levels of the chain locker experienced a very small air movement. It is known that closed cell polymeric foam was inserted between the anchor chain and its surrounding guide tubes. A sealed manhole cover would then provide an essentially closed compartment from the viewpoint of air movement.

b) Photographs and inspection notes indicate that the internal locker surfaces and anchor chain were covered with red rust; some black oxide was reported under the red rust film (corresponding to a lower oxygen level under the red rust). Seawater ingress has occurred (seawater was noted under the perforated plate in the bottom of the locker) and the surfaces were actively corroding.

c) An estimate of the exposed area of the steel surfaces undergoing corrosion is made. This includes contributions from the anchor chain and internal compartment steelwork.

d) From photographs provided (15 November letter from MAIB, the exposed surface area of the starboard anchor chain can be estimated as 90 m^2. It is assumed that the port anchor chain has a similar area such that the total chain area is 180 m^2. 10% of this value is subtracted to allow for overlap of the chain links, leading to an effective total chain area of 162 m^2.

e) Photographs also indicate that the majority of the internal surfaces of the locker were actively corroding (red rust is evident) and the MAIB have estimated the relevant surface area as 70 m^2. The total estimated area of steel exposed is then 232 m^2.

f) Consumption of oxygen in the compartment air occurred mainly via corrosion of the exposed steel.

g) A constant rate of corrosion with time is assumed.

h) The corrosion of steel is a redox process where simultaneous degradation of iron (by dissolution or oxide formation) together with oxygen reduction occurs. A complex series of corrosion products results from such corrosion but the process may be simplified to formation of an iron(II) hydrated oxide (via a two-electron oxidation of iron) by reaction with oxygen:

$$2Fe^{2+} + 0.5O_2 + 3H_2O = 2FeO.OH + 4H^+$$

i) The reacting quantities are 2 mole (112 g) of iron reacting with 0.5 mole (16 g, 12.4 litres) of oxygen.

j) The density of iron is taken as 7.86 g cm^{-3}.

k) The period for corrosion may be taken as approximately 15 months (between the last known, recorded inspection on 6th June 2006) and the date of the incident (23rd September 2007).

l) The locker enclosed air volume has been estimated by MAIB at 22.9 m^3.

m) A typical averaged corrosion rate of mild steel in a humid, atmospheric seawater environment is taken as 36 microns per year (E. Mattson book). This is equivalent to 36 x (15/12) = 45 microns over a 15 month period.

n) This penetration of steel is equivalent to a metal loss of (7.86 g cm^{-3}) x (0.0045 cm) x (232 x 10^4 cm^2) = 82.1 x 10^3 g steel.

o) Such a mass loss of steel represents an equivalent oxygen consumption of (82.1 x 10^3 / 112.7) x 12.4 litres = 9.0 x 10^3 litres, assuming ideal gas behaviour. The oxygen volume consumed is then 9.0 m^3.

p) The percentage reduction in oxygen level in the enclosed locker is 100 x (9.0 m^3/22.9 m^3) = 39.5 %. This is equivalent to reduction in the oxygen level of the atmosphere from a nominal 21 % by volume to only 12.7 % by volume.

q) In practice, the corrosion rate (hence the degree of oxygen depletion) is likely to have been higher due to parts of the steel being immersed in seawater (rather than simply exposed to a humid seawater atmosphere). The resultant increase in corrosion rate is difficult to estimate but might be a factor of 2, resulting in a lowering of the oxygen level in the tank to just 4.4 % volume - which would not sustain breathing.

Conclusions & Opinion

1. A simplified calculation has been carried out to estimate the possible degree of oxygen consumption from the anchor chain locker due to corrosion of steel components.
2. The results indicate that such corrosion, in a sealed compartment, could lead to sufficient loss of oxygen to result in an air atmosphere which had insufficient oxygen to support continued breathing by personnel.
3. In principle, there are several possible explanations for the deaths experienced in the chain locker, namely, (a) a toxic atmosphere (there was no evidence of toxic gases in the air bag sample taken, (b) displacement of oxygen in the atmosphere by a non-breathable gas (e.g., CO_2 or N_2 – but there is no evidence to support this) or (c) depletion of oxygen, over a period of time, by the corrosion reaction with exposed steelwork.
4. In my opinion, (c) <u>oxygen loss by corrosion of steel is feasible</u> and may have provided a mechanism for substantial depletion of oxygen in the lower levels of the locker, leading to an atmosphere which would not sustain breathing. Death by asphyxiation would then be likely to follow.

Reference

E. Mattson, Basic Corrosion Technology for Scientists and Engineers, 2nd edition, The Institute of Materials, 1996 (Appendix 1).

Extract from *Viking Islay* Risk Assessment

RISK ASSESSMENT

No. 37

RISK RATING (R) See explanations at right		LIKELIHOOD OF OCCURRENCE (L)				
		V.LOW	LOW	MED	HIGH	V.HIGH
HAZARD SEVERITY (S)	NEGLIGIBLE	LOW	LOW	LOW	LOW	MED
	MODERATE	LOW	LOW	LOW	MED	[redacted]
	SERIOUS	LOW	LOW	MED	[redacted]	[redacted]
	MAJOR	LOW	MED	[redacted]	[redacted]	[redacted]
	CATASTROPHIC	MED	[redacted]	[redacted]	[redacted]	[redacted]

RISK RATING (R)	
LOW	No immediate action required. Proceed with care.
MEDIUM	Hazard to be investigated in conjunction with Ships Safety Officer/HoD with a view to reducing the risk
[redacted]	

LOCATION	ON BOARD	JOB	CONFINED SPACE ENTRY

TASK (1)	HAZARD (2)	PERSONS AFFECTED (3)	RISK (4)			CONTROL MEASURE (5) List those provided and required	RISK (6)		
			L	S	R		L	S	R
Tank/space entry	Asphyxiation	Person(s) involved in task	High	Major	High	Toolbox talk. Competent person in charge. Proper PPE to be worn. Permit to work to be completed before entry. Space to be well ventilated. Space to be isolated and sign posted. Emergency procedures in place. B.A. sets at hand. Minimum persons in the space to do the task. Accesses to be kept clear. Good communication. Only enough persons to do the task enters	Low	Moderate	Low
Tank/space entry	Fire / Explosion	All crew	Medium	Major	High	Ensure that space atmosphere has been tested for oxygen and gases. Fire extinguisher at hand, fire mains charged up.	Low	Moderate	Low
Tank/space entry	Fall	Person(s) involved in the task	Medium	Major	High	Ensure that ladders inside space are in good order. Safety harness to be worn. PPE to be worn.	Low	Moderate	Low
Tank/space entry	Poor lighting	Person(s) involved in the task	Medium	Serious	Medium	Ensure lighting to the space is adequate. Extra lighting if required	Low	Moderate	Low

ASSESSOR (S)		DATE ASSESSED	24/01/05	MASTERS SIGNATURE
		REVIEW DATE	08/06/06	
		SHEET		
		REVISION		

VIKING

FORM BVL/HSE08/01/01

K ASSESSMENT Continuation Sheet

 No. 37

LOCATION	ON BOARD	JOB	CONFINED SPACE ENTRY

TASK (1)	HAZARD (2)	PERSONS AFFECTED (3)	RISK (4)			CONTROL MEASURE (5) List those provided and required	RISK (6)		
			L	S	R		L	S	R
						TANKS MUST NOT BE ENTERED UNTILL CHEMIST HAS ENSURED SPACE IS GAS FREE, AND OXYGEN LEVEL SUFFICIENT.	Low	Negligible	Low
							Low	Negligible	Low

Annex C

Forms and Emergency Checklists

EMERGENCY CHECK LIST – ENCLOSED SPACE RESCUE

SHIP NAME	**DATE**		
ACTION	**PERSON**	**✓ X N/A**	**TIME**
Inform bridge/sound alarm	Witness/oow		
Muster all personnel	All		
Do not enter space	Witness		
Brief 1st officer	Witness		
Don breathing apparatus/lifeline	Two trained personnel		
Check atmosphere	1st officer		
Ascertain reason for casualty (Illness, Fall, Electric Shock)	1st officer		
Reach casualty as soon as possible	Team		
Give air to casualty or get casualty to air (if atmosphere unsafe)	Team		
If atmosphere safe identify cause	Team		
Do not move if badly injured and atmosphere safe	Team		
Arrange first aid	1st officer/AMA		
Get medical advice	Master		
Arrange stretcher	Cook		
Place casualty on stretcher if safe	Team		
Continue supplying air/first aid	Team		
Report to company	Master		
Arrange evacuation	Master		

Signed: - ____________________________
Responsible Officer

For Drill Purpose ☐
Tick Box
Form VOSL/S08/12/01