ACCIDENT REPORT

Report on the investigation of the accidental

discharge of carbon dioxide on board

SD Nimble

resulting in serious injury to a

shore-based service engineer

at Her Majesty's Naval Base

Faslane

23 August 2011

MAIB

MARINE ACCIDENT INVESTIGATION BRANCH

LESS SERIOUS MARINE CASUALTY REPORT NO 23/2012 August 2012

Extract from

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2012 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012 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 14(14) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012, 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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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AB	-	Able bodied seaman
BA	-	Breathing Apparatus
BUTEC	-	British Underwater Test and Evaluation Centre
Circ	-	Circular
CoC	-	Certificate of Competency
COSWP	-	Code of Safe Working Practices for Merchant Seamen
CO_2	-	Carbon Dioxide
CPR	-	cardio-pulmonary resuscitation
DNV	-	Det Norske Veritas
DoC	-	Document of Compliance
gt	-	gross tonnage
HM	-	Her Majesty's
IACS	-	International Association of Classification Societies
IMO	-	International Maritime Organization
IMS	-	Integrated Management System
ISM Code	-	International Code for the Safe Management of Ships and the Prevention of Pollution
ISO	-	International Organisation for Standardization
kg	-	kilogramme
kW	-	kilowatt
l	-	litre
L&G	-	L&G Marine - Fire and Safety Services
LR	-	Lloyd's Register
LRQA	-	Lloyd's Register Quality Assurance
MCA	-	Maritime and Coastguard Agency
MOD	-	Ministry of Defence
MSC	-	Maritime Safety Committee
OEFL	-	Ocean Engineering (Fire) Limited
OHSAS	-	Occupational Health and Safety Management System
PFI	-	Private Finance Initiative

QHM	-	Queen’s Harbourmaster
RMAS	-	Royal Maritime Auxiliary Service
RN	-	Royal Navy
SHE	-	Safety Health and Environmental (Policy)
SLMS	-	Serco Limited Marine Services
SOLAS	-	International Convention for the Safety of Life at Sea, 1974, as amended
TUTT	-	twin unit tractor tug
UR	-	unified requirement
USCG	-	United States Coast Guard
UTC	-	Universal time, co-ordinated
VHF	-	Very High Frequency

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

SD Nimble

SYNOPSIS

On 23 August 2011, a shore-based service engineer was seriously injured on board the tug *SD Nimble* when six cylinders of carbon dioxide were accidentally discharged shortly after the tug had slipped from her berth in Her Majesty's naval base in Faslane, Scotland. The engineer was testing components of the vessel's fixed carbon dioxide fire extinguishing system in the carbon dioxide cylinder room. The accidental discharge of carbon dioxide caused a depletion of oxygen levels in the cylinder room and aft hold causing the engineer to quickly lose consciousness. The tug was immediately manoeuvred back alongside and the service engineer was quickly recovered onto the open deck, where cardio pulmonary resuscitation was started. The engineer was subsequently transferred by helicopter to the Southern General Hospital in Glasgow where, following a long period of recuperation and therapy, he made a good recovery.

The findings of the MAIB investigation included:

- The release of the carbon dioxide occurred because the pilot lines from the system's control cabinet had not been isolated.
- The failure to disconnect the pilot lines was likely to have been a mistake resulting from an incorrect plan of action rather than a misidentification of the system's components.
- The service engineer's training and the monitoring of his performance were ineffective in some areas.
- The tug's crew and the service engineers worked in isolation, which resulted in the service engineers entering a potentially dangerous space and, concurrently, the vessel sailing with her main machinery space fixed fire extinguishing system inoperable.

A recommendation has been made to Lloyd's Register aimed at ensuring that, in consultation with ships' crew, service suppliers agree and implement safe systems of work prior to commencing work on board vessels. A recommendation has also been made to Ocean Engineering (Fire) Limited, which is intended to improve the monitoring and safety of its engineers.

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *SD NIMBLE* AND ACCIDENT

SHIP PARTICULARS

Vessel's name	*SD Nimble*
Flag	United Kingdom
Classification society	Lloyd's Register
IMO number	8401470
Type	Adept Class twin unit tractor tug
Registered owner	SD Marine Services Limited
Manager / Operator	Serco Limited Marine Services
Construction	Steel
Length overall	38.8m
Registered length	36.42m
Gross tonnage	384t
Minimum safe manning	Not applicable

VOYAGE PARTICULARS

Port of departure	Faslane
Port of arrival	Faslane
Type of voyage	Internal waters
Manning	5

MARINE CASUALTY INFORMATION

Date and time	23 August 2011 at 0830
Type of marine casualty or incident	Less Serious Marine Casualty
Location of incident	HM Naval Base, Faslane
Place on board	CO_2 cylinder room
Injuries	1 - shore contractor
Damage	Damage to CO_2 installation
Ship operation	Manoeuvring
Voyage segment	Departure
External environment	Light winds, sheltered water and good visibility. The sky was partly cloudy and the air temperature was 15°C.
Persons on board	5 crew and 2 shore contractors

1.2 NARRATIVE

1.2.1 Carbon dioxide (CO_2) release

Between 0715 and 0730 on 23 August 2011, the master, chief officer, chief engineer and two able seamen of the Serco Limited Marine Services (SLMS[1]) tug, *SD Nimble,* arrived on board. The tug was moored port side to alongside number 6 berth in Her Majesty's (HM) Naval Base Faslane, Scotland **(Figure 1)**.

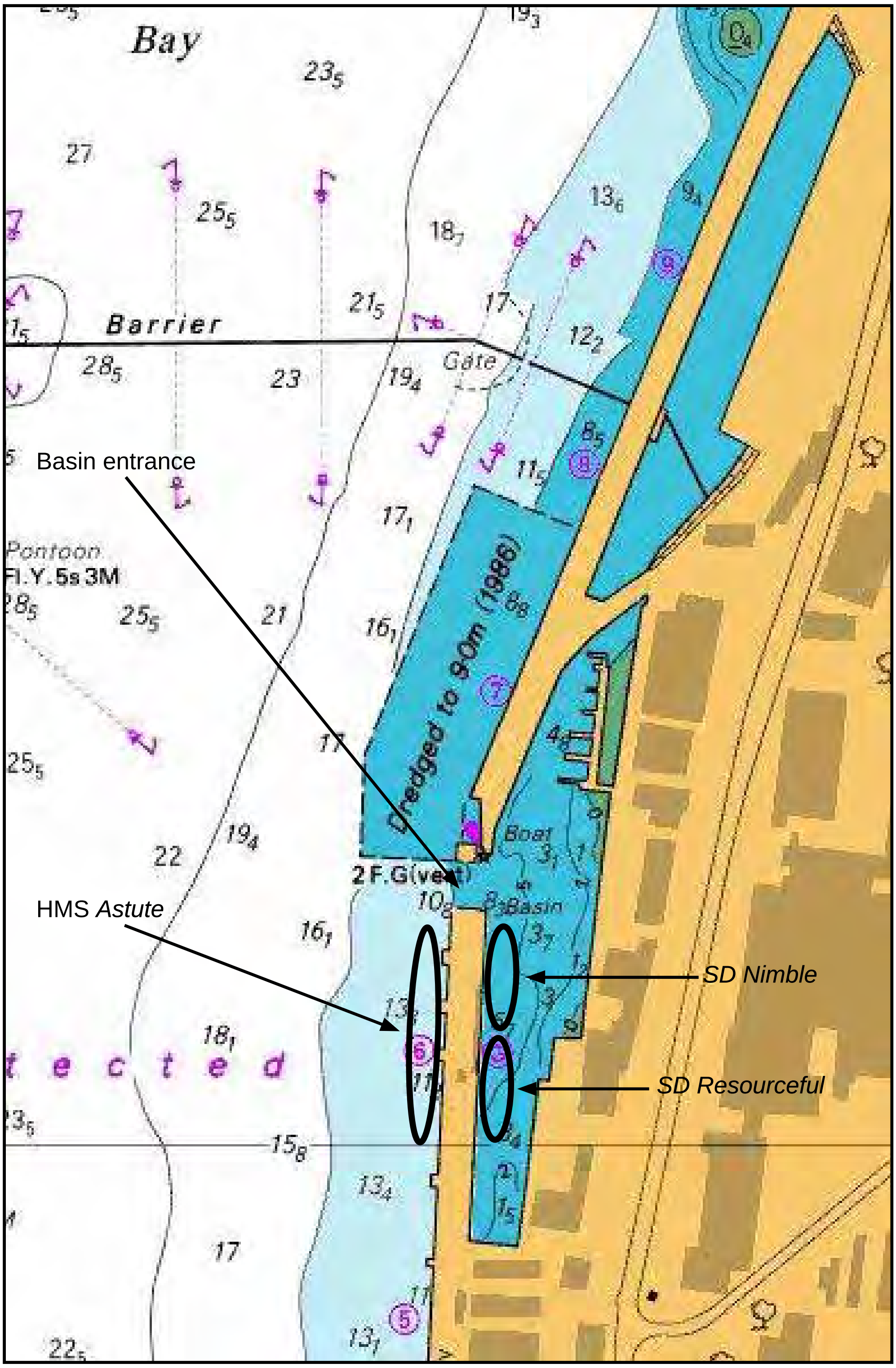

Figure 1: Extract of BA Chart 2000

[1] SLMS is a business unit operating in the Defence, Science and Nuclear division of Serco Limited.

Soon afterwards, the chief officer informed the master and the crew that representatives from Ocean Engineering (Fire) Ltd (OEFL) would be arriving on board in order to conduct the vessel's annual firefighting equipment check. He also advised that the vessel was scheduled to refuel at the refuelling jetty at 0900. These were the only activities for the vessel included in the *Daily Movement Sheets*[2] which had been collected by the chief officer the previous evening. The master then informed the crew that the tug would slip at 0830.

At 0800, two marine service engineers from OEFL's service centre in Glasgow (OEFL(Glasgow)) arrived at the vessel by van. One of the engineers was a trainee. As the engineers prepared their tools and equipment on the jetty, the more experienced or senior engineer[3] told the trainee that their first job of the day would be to service the vessel's fixed CO_2 fire extinguishing system.

At 0805, the service engineers made their way on board *SD Nimble*. The trainee stopped to talk with one of the crew who was on the deck, while the senior engineer met the chief officer who was sitting with other crew in the mess room **(Figure 2)**. The senior engineer advised the chief officer that he was on board to service the fixed CO_2 fire extinguishing system, fire hydrants and fire hoses but did not specify the order in which the work was to be undertaken. The senior engineer then met the master in the accommodation alleyway, who told him to wait in the mess room until the vessel had completed fuelling and had returned to her berth before commencing work. The conversation between the master and the senior engineer was not heard by any of the tug's crew or by the trainee engineer.

At about 0810, the chief engineer entered the engine room to start the main engine. At the same time, the two service engineers prepared to service the fixed CO_2 fire extinguishing system. As the trainee engineer readied his tools to service the CO_2 control station **(Figures 2** and **3)**, the senior engineer asked him if he knew where the CO_2 cylinder room was located. The trainee was unsure, so the senior engineer went down to the engine room and asked the chief engineer. The chief engineer was busy, and told him that once he had finished work in the engine room, which would take about 5 minutes, he would show him. The senior engineer went onto the main deck and asked an able seaman (AB) where the CO_2 cylinder room was located.

The AB escorted the senior engineer to the deck hatch leading to the aft hold **(Figure 4)**. The AB opened the hatch lid and explained where the CO_2 cylinder room was within the aft hold **(Figure 5)**. The senior engineer then entered the hold. The ventilation exhaust fans in the hold were not operating.

Meanwhile, the trainee engineer opened the doors of the CO_2 control station cabinet, which were not locked, and an alarm sounded. To silence the alarm, the trainee engineer started to secure the spring-loaded switches behind each of the cabinet's doors with tape. The chief officer was standing nearby, and shouted down to the chief engineer to let him know that the alarm was due to the service engineer opening the doors of the CO_2 control station. The chief officer then joined the master on the bridge.

[2] Daily Movement Sheets: Issued by SLMS, these documents provided detail of the expected employment of the company's vessels operating within Faslane Naval Base.

[3] For the purposes of this report, the more experienced engineer is referred to as the 'senior engineer'

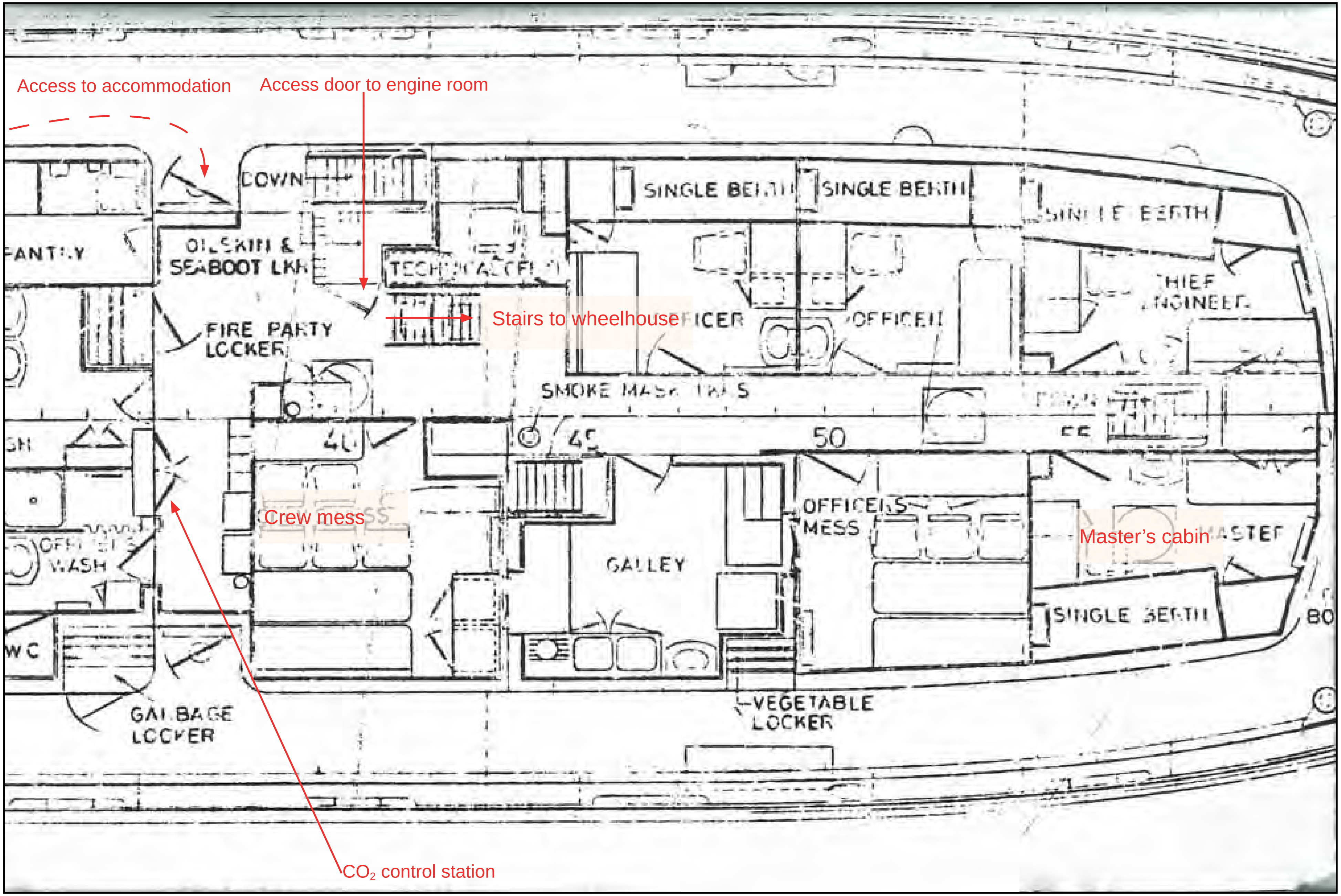

Figure 2: Plan of the accommodation area

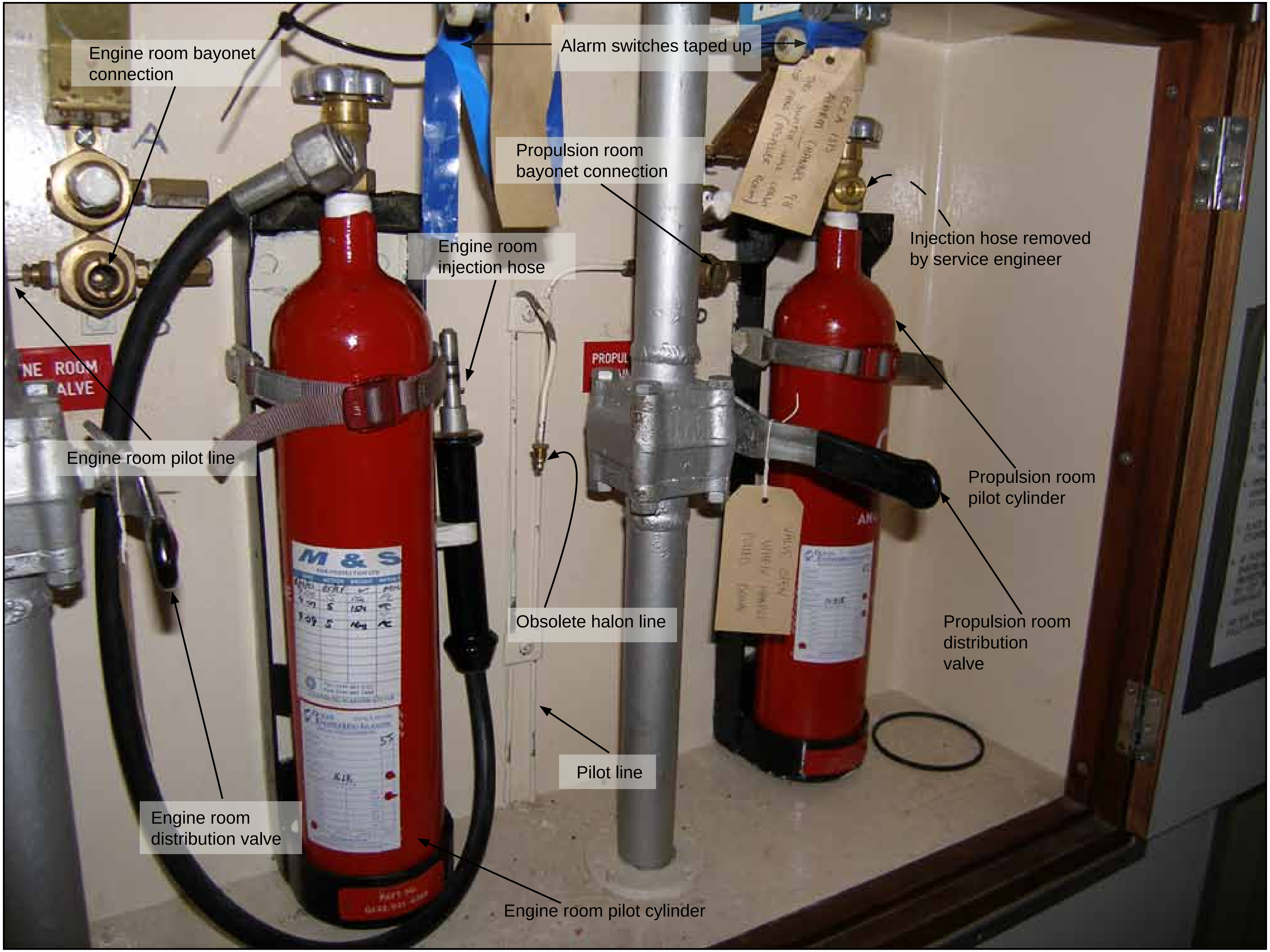

Figure 3: CO_2 control station

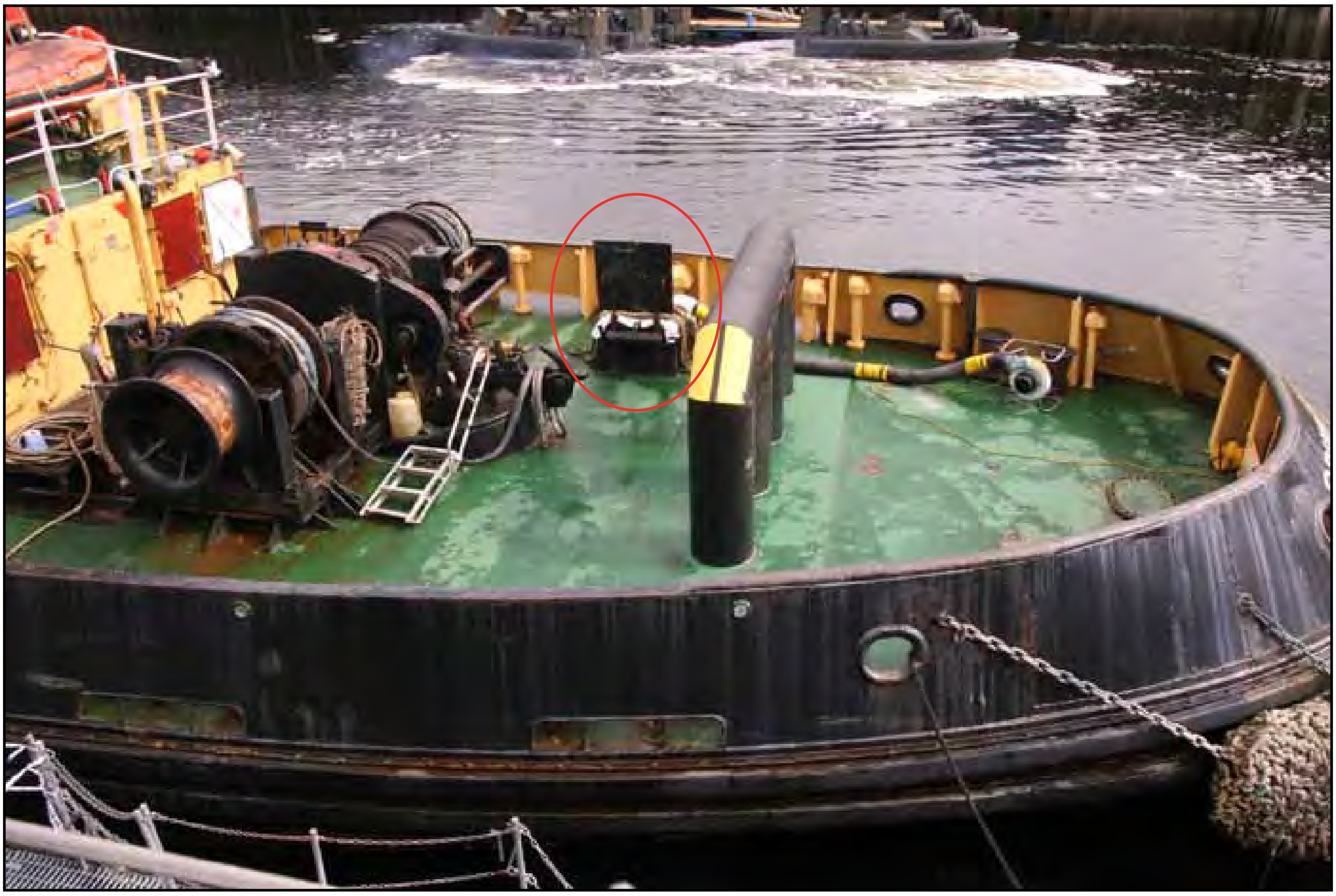

Figure 4: Aft hold hatch

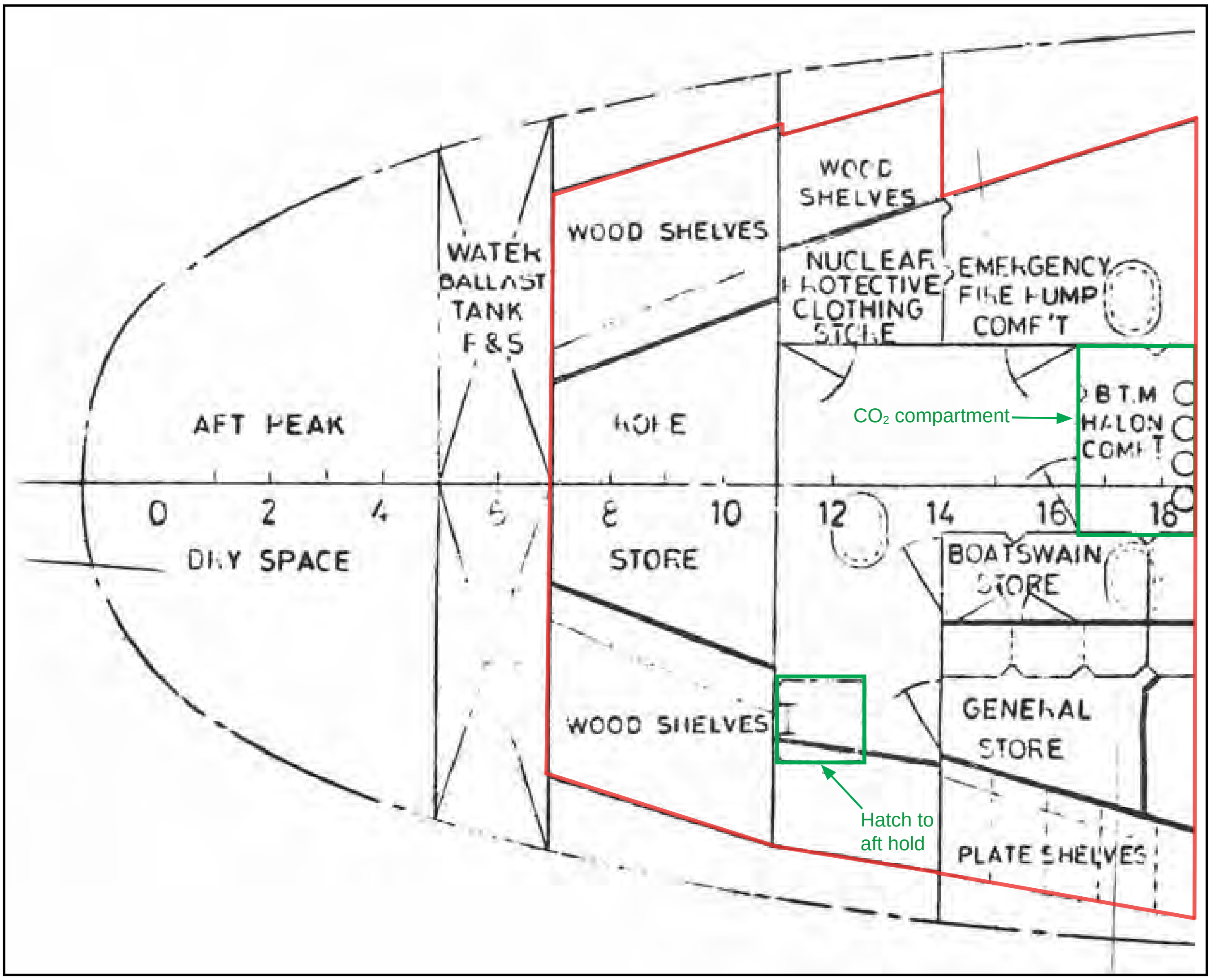

Figure 5: Plan of aft hold

The senior engineer returned to the CO_2 control station cabinet to collect his tools. He commented that it was taking the trainee a long time to tape up the spring-loaded switches. The senior engineer then returned to the CO_2 cylinder room and the trainee went ashore to collect electronic scales from the van.

Once the trainee returned on board, he weighed the two CO_2 pilot cylinders located inside the control station **(Figure 3)**. He then disconnected the discharge hose from the propulsion room[4] pilot cylinder and fitted it to a portable test cylinder.

By 0825, the tug's main engine had been started. At 0826, the master contacted the Queen's Harbourmaster (QHM) on Very High Frequency (VHF) radio and requested permission for *SD Nimble* to leave her berth and proceed to the fuelling jetty. The request was approved and the crew commenced letting go the mooring lines.

Shortly after, the trainee engineer went down to the CO_2 cylinder room to see how his colleague was progressing and he asked the senior engineer if he was ready to prove that the pilot lines between the control cabinet and the cylinders were clear. The senior engineer visually checked the system's pipework and cylinders and confirmed that he was. Both of the engineers returned to the control station, where the senior engineer checked the trainee's preparations and explained to the trainee that both pilot lines had to be checked to ensure that they were clear. The pilot line for the propulsion room was to be tested first, followed by the line for the engine room. The trainee opened the main distribution valves **(Figure 3)**. Then, following a pre- arranged plan, he started to count to 50 while the senior engineer returned to the cylinder room.

By 0830, the mooring lines were clear, and the master manoeuvred *SD Nimble* off the berth and started heading towards the basin entrance **(Figure 1)**. The trainee engineer was surprised to feel the tug moving, but continued counting. On reaching the count of 50, he connected the hose from the CO_2 test cylinder to the propulsion room pilot line via its bayonet fitting, and opened the test cylinder for 3 seconds.

Immediately, a loud bang followed by a loud rattling noise was heard by an AB standing on the aft deck; a plume of white 'smoke' was also emitted from the hatch leading into the aft hold. A crewman from *SD Resourceful* **(Figure 1)** shouted to the AB that he had seen someone enter the space moments before the bang. The chief officer also heard the loud noises from the aft deck and asked the master's permission to leave the bridge and investigate. The master soon realised that a serious accident had possibly occurred, and started to manoeuvre *SD Nimble* back alongside.

Meanwhile, the trainee engineer, unaware of what had happened, disconnected the test cylinder and counted to 20. He then connected the test cylinder's hose to the engine room bayonet fitting and again opened the test cylinder for 3 seconds.

1.2.2 The rescue

The chief officer quickly joined the AB on deck and realised that it was CO_2 escaping through the aft hold hatch rather than smoke. He also saw that the senior engineer was lying on his back on the deck of the aft hold **(Figure 6)**; he appeared to be unconscious. Both men returned into the accommodation, where they collected breathing apparatus (BA) and advised the trainee engineer of the situation.

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[4] The propulsion room houses the tug's Voith Schneider Propellers

Figure 6: Position of the service engineer from the top of the access hatch

The AB helped the chief officer to don a BA set. Both men then returned to the aft deck, where they were joined by the tug's second AB and the trainee engineer. The chief officer climbed down the vertical ladder into the aft hold and tied a heaving line around the senior engineer's chest. The ABs hauled the senior engineer onto the main deck and put him into the recovery position. The senior engineer was not breathing and had no pulse. He also had a minor head injury.

Once *SD Nimble* was alongside, the chief engineer from *SD Dependable* and an employee of the local ship repair facility boarded and administered cardio-pulmonary resuscitation (CPR). SLMS was informed of the accident by the chief engineer via VHF radio, and the message was relayed to the naval dockyard emergency services at 0837. Further assistance was provided by the medical team from HM Submarine *Astute*, pending the arrival of the Scottish Ambulance Service.

At 0917, the local air ambulance arrived on site. The senior engineer, who was now breathing but remained unconscious, was airlifted to the Southern General Hospital in Glasgow where he was treated for anoxic brain injury[5]. After a long period of recuperation and therapy, the senior engineer made a good recovery. However, a consequence of his injury was complete memory loss of the events on the day of the accident.

1.3 PLANNING

On 3 August 2011, OEFL (Glasgow) advised *SD Nimble*'s shore-based technical superintendent that the vessel's fixed CO_2 extinguishing system was due for its annual service on 13 September 2011. The technical superintendent requested that OEFL (Glasgow) inform SLMS when its service engineers could attend the vessel nearer to September.

On 22 August, the technical superintendent liaised with OEFL (Glasgow) and requested *SD Nimble*'s fire hoses, fire hydrants, branch pipes, fixed CO_2 fire extinguishing system, and her fire detection system be serviced the following day. The technical superintendent also advised OEFL (Glasgow) that the tug would be refuelling at 0900 and that the service engineers would have to be on board before she moved to the fuelling jetty. OEFL (Glasgow) confirmed that its service engineers would be on site from 0800.

Later during 22 August, SLMS issued the *Daily Movement Sheets* for 23 August 2011, which reflected that OEFL service engineers would be on board *SD Nimble* at 0830. The *Movement Sheets* also showed that the tug was scheduled to move a barge off the fuelling jetty before loading 25 cubic metres of fuel.

The manager of OEFL (Glasgow) briefed the senior and trainee engineers of the work to be undertaken on board *SD Nimble* the following day but did not inform them that the vessel would be moving to the fuelling jetty. The engineers had no other work scheduled for 23 August 2011. No drawings of the tug's CO_2 system were available.

[5] Injury caused by oxygen starvation

1.4 THE CO_2 SYSTEM

1.4.1 Installation

The '*high pressure marine* CO_2 *fixed fire extinguishing system*' on board *SD Nimble* was designed by Kidde Fire Protection Limited and was fitted by L&G Marine - Fire and Safety Services (L&G) in 2002. The design was approved by Lloyd's Register (LR) on 4 July 2000 to meet the classification society's rules and the requirements of the International Convention on the Safety of Life at Sea, 1974, as amended (SOLAS).

The system on board *SD Nimble* replaced a halon fixed fire extinguishing system. During the replacement, much of the halon system pipework was retained, with redundant lines being blanked off.

A '*Fire Fighting System Manual for RMAS Nimble*' was supplied by L&G and was held ashore by SLMS. The manual showed basic line diagrams of the CO_2 system, detailed drawings of a pressure actuator valve, and a simplified drawing of the pilot and atmosphere relief lines **(Figure 7)**. The manual did not contain any maintenance instructions or procedures.

1.4.2 System overview

The CO_2 was designed to be discharged via a fixed system to extinguish fires in either the engine room and/or the propulsion room. The system comprised six 67.5 litre (l) cylinders filled with 45kg of CO_2 at a pressure of 51 bar. All six cylinders would be discharged to extinguish a fire in the engine room, but only three of the cylinders would be discharged for a fire in the propulsion room. The main CO_2 cylinders were located in the cylinder room, on the port side of the aft hold **(Figure 5)**. In normal operation, activation of the system would be carried out remotely from the control panel located on the aft bulkhead of the accommodation cross alleyway, at main deck level.

1.4.3 Cylinder room

Access to the aft hold was via a vertical ladder from a watertight hatch on the main deck. The aft hold was fitted with both forced and natural ventilation. The cylinder compartment on the port side was fitted with a lock, the key to which was kept on the tug's main keyboard. A duplicate key, for emergency use, was located in a 'break glass' holder by the cylinder room's door.

The CO_2 cylinders were secured in two banks of three cylinders. For the purpose of this report, the cylinders are referred to by the numbers shown in **Figure 8**. The cylinders were remotely activated from the control station by the release of CO_2 from pilot cylinders **(Figure 3)** through small bore pilot lines which were black in colour and were connected to the main cylinders. A non-return valve was fitted into the pilot line between cylinders 3 and 4. This allowed cylinders 4 to 6 to be released into the propulsion room or all six cylinders to be released into the engine room. Each cylinder was fitted with a pneumatic operating valve which enabled the CO_2 to be released manually if required.

When the system was activated, the CO_2 in the cylinders was discharged into a common manifold via flexible hoses. The common manifold fed a distribution line fitted with a pressure gauge and a pressure relief valve set at 150 bar. To prevent the cylinders from over-pressurising, small bore lines, similar in appearance to the pilot lines, connected each cylinder to an atmosphere (overboard) line. The atmosphere line was fitted with a manually-operated ball valve which was intended to be locked shut in normal operation. Apart from a tally adjacent to the atmosphere valve, all other instructions and labels on the system had been annotated using a marker pen **(Figure 9)**.

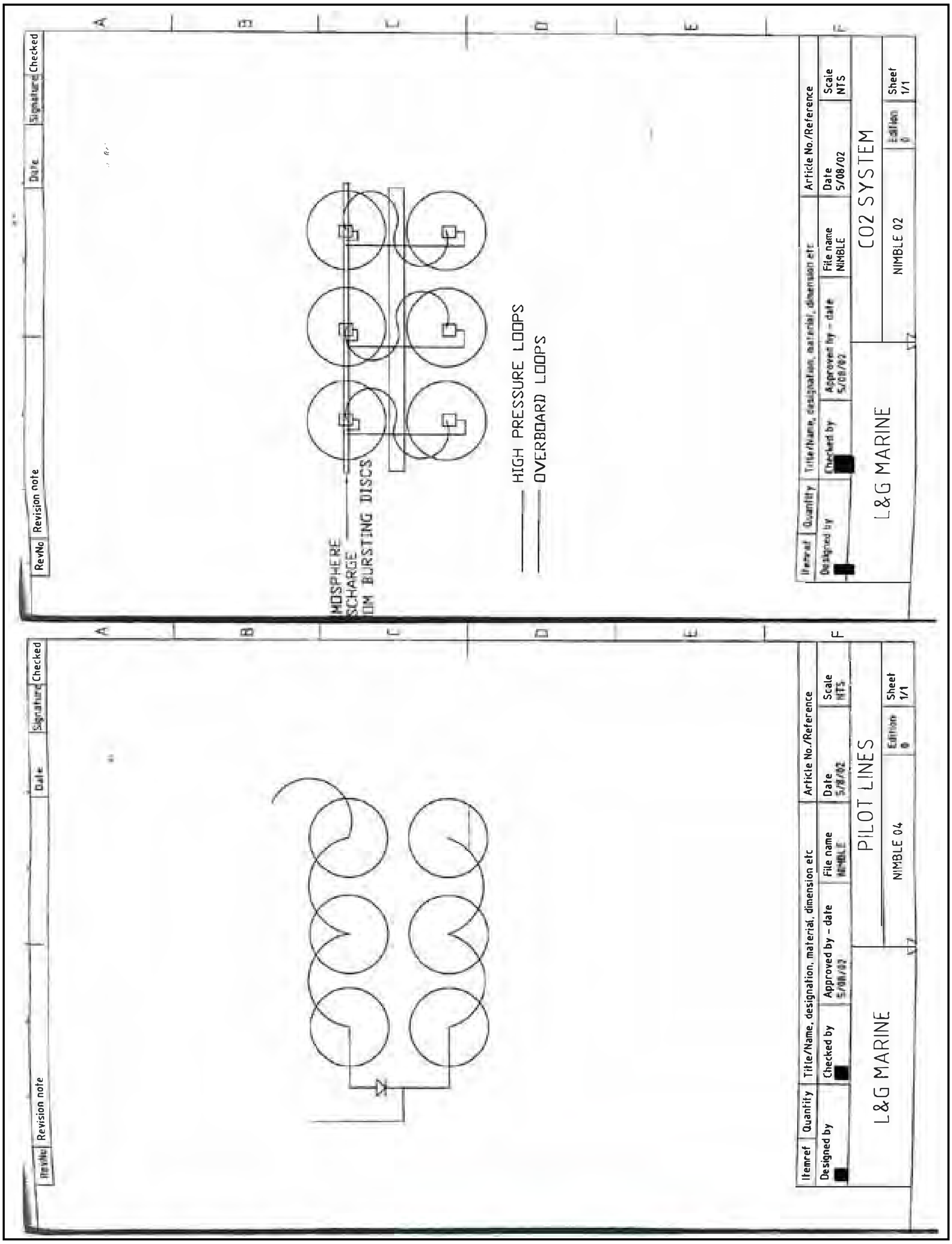

Figure 7: Drawings of the pilot and atmosphere lines

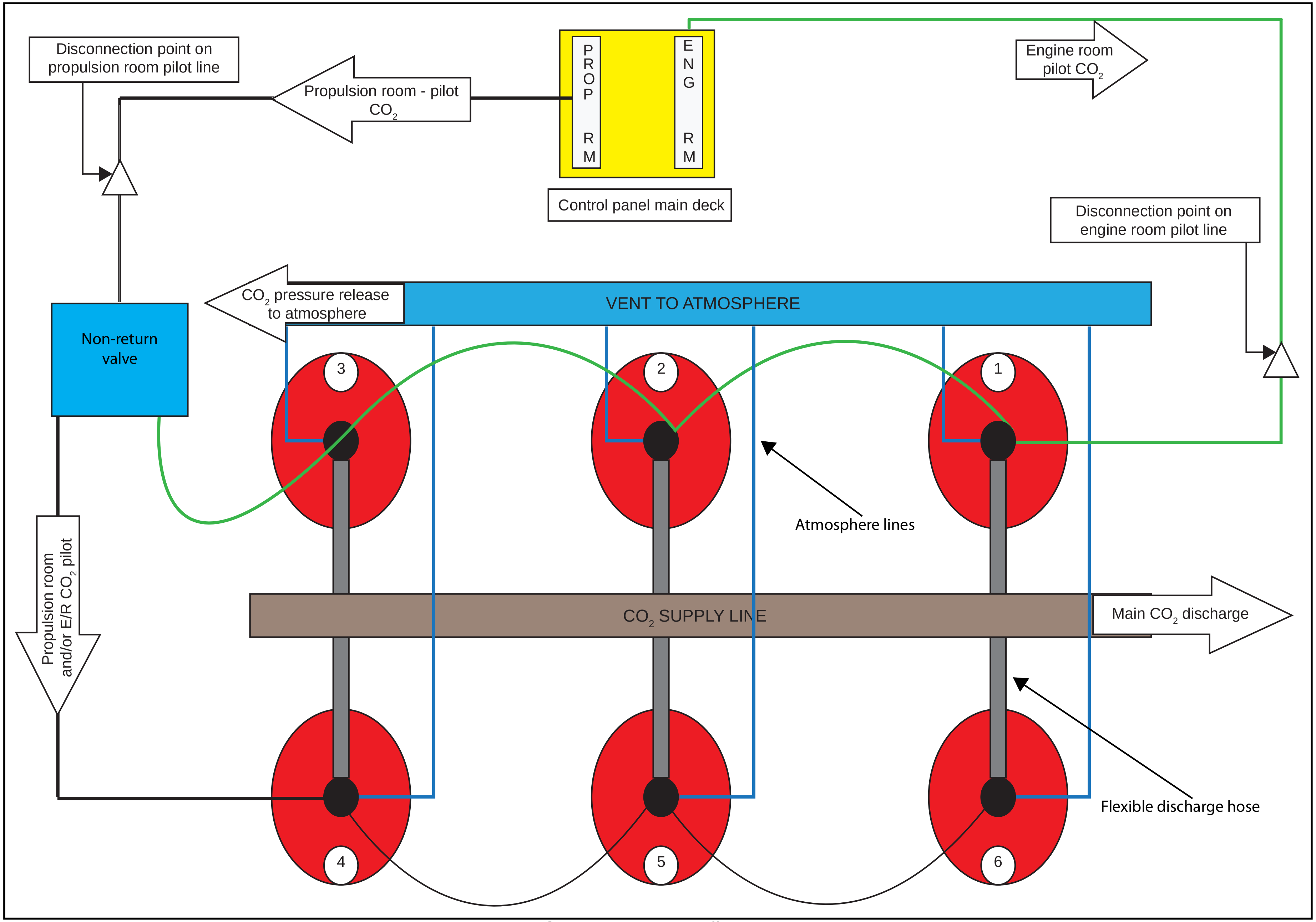

Figure 8: System diagram

Figure 9: System labels

1.4.4 Control station

The control station cabinet **(Figures 2** and **3)** was fitted with two doors that were locked with a padlock through a hasp and staple. Keys to the cabinet were kept on the tug's main keyboard, with a duplicate for use in an emergency located in a 'break glass' holder adjacent to the control station.

Spring-loaded switches activated an alarm when either cabinet door was opened. The right-hand door activated a red flashing light and a high-pitched warble alarm in the propulsion room. The left-hand door activated a similar light and audible alarm in the engine room. The alarms could also be heard in the main alleyway in the accommodation. When either cabinet door was opened an audible and visual alarm was activated on the bridge alarm panel. Unlike some other similar systems, the switches fitted to the cabinet doors did not automatically stop the ventilation fans in the engine and propulsion rooms.

The control cabinet contained two 2kg CO_2 pilot cylinders each fitted with a flexible hose with a male bayonet **(Figure 3)**. The right-hand (port) pilot cylinder activated cylinders 4, 5, and 6 into the propulsion room and the left hand (starboard) cylinder activated cylinders 1 to 6 into the engine room. The system was activated by opening either the engine or propulsion room distribution valves, inserting the male bayonet into the applicable female portal, and then opening the screw valve on the pilot cylinder. The resulting injection of CO_2 into the pilot line activated the CO_2 cylinder valves. Instructions for the activation of the system were prominently displayed inside the cabinet.

1.4.5 Pilot line test

The CO_2 cylinders and the CO_2 system were last serviced on 13 September 2010 and 5 January 2011, respectively. The annual system service included the testing of the pilot lines from the control station to the cylinders to ensure that they were free from obstructions. This was usually undertaken by disconnecting the propulsion room pilot line before the non-return valve, and the engine room pilot line before No 1 cylinder **(Figure 8)**. CO_2 was then discharged into each line from a test cylinder at the control station and the disconnected ends of the pilot lines were monitored to ensure that the CO_2 passed without difficulty.

1.5 POST-ACCIDENT EXAMINATION

Following the accident, MAIB inspectors examined the aft hold, the CO_2 cylinder compartment and the control station cabinet, and found:

CO_2 cylinder room **(Figure 10)**

- The door to the CO_2 cylinder compartment was open, with a key in the door lock.
- The six 45kg CO_2 cylinders were upright in their designated stowage and all of the cylinders were empty.
- The flexible discharge hoses from cylinders 3, 2, and 4 were lying on the deck. The end fittings of the hoses were undamaged.
- The valves on cylinders 3, 2 and 4 were not fitted with anti-recoil caps[6].
- The flexible discharge hoses were loosely connected to cylinders 1, 5, and 6 but they were disconnected from the distribution line. The fittings on the disconnected ends of the hoses were damaged.
- The atmosphere lines were disconnected from the 6 cylinders; five of the lines were still connected to the atmosphere (overboard) line. The remaining atmosphere line was fully disconnected and was lying on the deck.
- The pilot lines were intact and connected to all six cylinders and the non-return valve block.
- The valve in the atmosphere (overboard) line was shut but was unlocked.
- There was minor damage to pipework and paint.
- A screwdriver was on the deck.

[6] A brass cap that is screwed onto a CO_2 cylinder valve to prevent the accidental discharge of the gas.

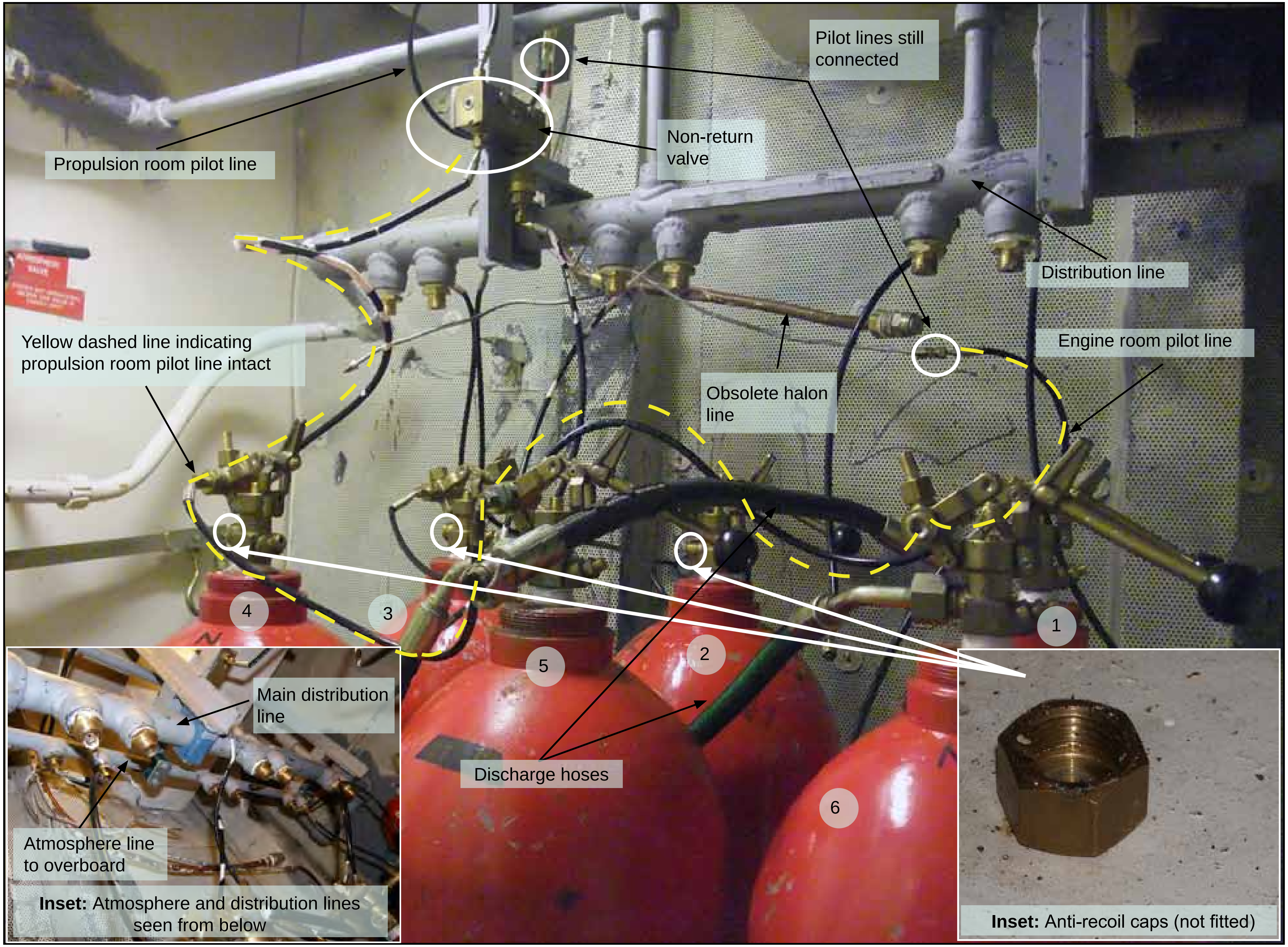

Figure 10: CO_2 cylinder room post accident

Aft hold **(Figure 11)**

- Blood was found on the deck in the vicinity of the access hatch.
- One anti-recoil cap was found on the deck.
- The ‘break glass’ key holder was lying on top of a hydraulic power pack.
- An adjustable spanner and tool bag were lying on the deck by the CO_2 cylinder compartment door. Among other items, the tool bag contained two anti-recoil caps.

Figure 11: Aft hold post-accident

Control station

- The control station doors were open with an open padlock on the hasp.
- The ‘break glass’ key holder was intact with a key inside.
- The pilot cylinder hose serving the propulsion room was disconnected.
- The pilot cylinder hose for the engine room was connected to the cylinder; its bayonet end was secured in a bracket.
- The engine and propulsion room distribution valves were open.
- The spring switches on the cabinet doors were taped back.
- A CO_2 test cylinder with hose, with a bayonet connection attached, and other equipment, were found adjacent to the control station cabinet. The equipment included a clipboard with a blank service report attached **(Annex A)**, a tool bag, scales, an adjustable spanner and one anti-recoil cap (from test cylinder).

1.6 IMMEDIATE ACTIONS

Immediately following the accident, SLMS withdrew *SD Nimble* from service. It also suspended its service agreement with OEFL and commissioned independent inspections of the CO_2 systems on board all of its vessels. The inspection of the CO_2 system on board *SD Dexterous*, a sister vessel of *SD Nimble*, identified that a pilot line and atmosphere line had been incorrectly reconnected after the system's annual service in May 2011. The inspection report stated:

- *After investigation it was identified that there was a problem with this system concerning the back row of three cylinders.* [sic]

- *The fault was located on the back left cylinder.*

- *The relief hose and actuation hose had been connected wrongly to connections on the cylinder valve, resulting in only three of the six cylinders for the engine room discharging in the event of a fire.* [sic]

1.7 OCEAN ENGINEERING (FIRE) LIMITED

1.7.1 Background

OEFL was founded in 2004, and specialised in fire safety on board ships and offshore installations. The company generally serviced rather than installed fire safety equipment, and had service centres in Penryn, Southampton and Glasgow. The company had two directors, one responsible for its operations and the other for commerce. The company signed a framework agreement with SLMS on 7 July 2010 regarding the provision of marine fire safety services on board SLMS vessels operating in the naval bases in Portsmouth, Devonport, and Faslane. The agreement was awarded by SLMS following competitive tender in which OEFL demonstrated to SLMS that it held all relevant accreditations and provided evidence that it had assessed key risks related to relevant tasks.

Lloyd's Register Quality Assurance (LRQA) certified that OEFL met the requirements of the International Standards Organisation (ISO) 9001:2008 (quality management) on 4 August 2011. The OEFL centres in Penryn and Southampton were also certified as an 'Approved Service Supplier' by LRQA on 13 January 2011, and also by Det Norske Veritas (DNV) on 23 October 2010. OEFL (Glasgow) had been subject to service supplier inspections, but had not been certified as an approved service supplier.

The company was a nominated agent for Kidde, Ultrafog and Dräger fire extinguishing systems, and for FM200 and Novec fire suppression systems.

1.7.2 Training

OEFL's training procedures are at **Annex B**. The operations director was responsible for the training of the company's engineers in the servicing of fire extinguishing equipment, including fixed installations, which was carried out on board vessels and ashore, frequently under his personal direction.

The initial training of the company's service engineers included: health and safety, personal protective equipment, methodology of testing, safe operation of equipment, accuracy of testing, and the calibration of equipment. The training emphasised that when working on pressurised systems, the first step was to *do nothing, disconnect and make safe*.

1.7.3 OEFL (Glasgow)

OEFL (Glasgow) was opened in October 2010 and, among other things, the service centre was responsible for the servicing of the fire safety equipment on board SLMS vessels operating in Faslane. The LRQA certificate schedule **(Annex C)** approved the service centre for '*Procurement and supply, stockholding and service of portable fire equipment including breathing apparatus'*.

The centre's staff comprised its manager, and two marine service engineers, one of whom was a trainee. The manager was a senior technician who joined OEFL in September 2010. He had previously served 13 years in the Royal Navy (RN) as a marine engineer, leaving as a petty officer. The manager had accompanied the operations director during the service of fixed CO_2 fire extinguishing systems on eight occasions. He was included in OEFL's list of engineers authorised to service Kidde, Ultrafog and Dräger fire extinguishing systems.

The senior engineer injured on board *SD Nimble* on 23 August 2011 joined OEFL in October 2010. He had previously served in the RN for 30 years, leaving as a chief petty officer. The senior engineer was well rested and there is no evidence to indicate that he had consumed any alcohol during the evening of 22 August or immediately before his arrival on board *SD Nimble*.

Company training records show that the senior engineer had previously accompanied the operations director during the service of fixed CO_2 fire extinguishing systems on five occasions. The operations director approved the service engineer to service fixed CO_2 systems in January 2011 and audited his work in April 2011.

The senior engineer completed the annual service of the CO_2 system on board *SD Dexterous* on 5 May 2011. The annual service of the CO_2 system on board *SD Nimble* was the sixth service of a fixed CO_2 fire extinguishing system for which he had been in charge. He had attended manufacturers' training courses covering the servicing of fire extinguishers and BA, but he was not included in the company's list of engineers authorised to service Kidde, Ultrafog and Dräger fire extinguishing systems.

The trainee engineer joined OEFL in March 2011. He had served 23 years in the RN as a weapons engineer and left as a chief petty officer in May 2010. He was employed by OEFL largely because of his knowledge of electrical engineering, which was considered to be advantageous for the servicing of ships' fire alarm and detection systems. The trainee engineer had accompanied the senior engineer during the annual CO_2 system service on board *SD Dexterous* on 5 May 2011.

When working on board SLMS vessels, the service engineers were frequently allowed to work without supervision from ships' crews. OEFL provided all of the tools and equipment required by its engineers, including hand-held radios and an ample supply of anti-recoil caps used on pressurised cylinders.

1.8 SERVICE PROCEDURE AND INSTRUCTIONS

1.8.1 Service report

OEFL's service engineers were required to complete a CO_2 system service report on the work they had undertaken on the system. The service report **(Annex A)** served as a checklist that helped to ensure the work was carried out in a safe and systematic way. The first item on the service report required confirmation that the system had been isolated.

1.8.2 Risk assessment

A risk assessment on the servicing of CO_2 systems was completed by the operations director **(Annex D)**. The hazards identified included:

- *Accidental discharge of the system*
- *Accidental discharge of the cylinders when testing the system*
- *Alarms causing emergency evacuation slips trips and falls.*

The corresponding control measures identified were:

- *Lock off system before commencing work* [sic]
- *Inform personnel in the engine spaces*
- *Fit anti-recoil caps immediately after disconnecting discharge hose from cylinder, and before removing cylinders.* [sic]
- *Inform all personnel of testing taking place and ignore all alarms till further notice.* [sic]

As part of the risk assessment process, the operations director produced a method statement for the servicing and testing of pneumatic CO_2 extinguishing systems **(Figure 12)**. The method statement assumed that work was to be carried out in compartments that opened horizontally out onto an open deck. It was OEFL's policy to use two service engineers to service fixed CO_2 extinguishing systems.

1.8.3 Safety health and environment

OEFL's Safety Health and Environmental (SHE) policy statement addressed, inter alia, work on vessels whilst lying alongside, and the procedure to be followed when entering a confined space. Examples of confined spaces included: cargo, ballast and freshwater tanks, fuel, hydraulic and lubricating oil tanks, pump rooms, void spaces, bilges and sewage tanks. CO_2 cylinder rooms were not included, but the policy statement advised that other spaces may need to be considered as confined spaces.

OCEAN ENGINEERING (FIRE) Ltd

METHOD STATEMENT - CO2 SYSTEMS.

Date		Name of Installation	CO2 extinguishing systems	Representative	
Scope of Work	Service test and certificate CO2 Extinguishing system-pneumatic				
Status of work area	Open deck	Special Precautions	Ensure system made safe before commencing		

Item		Frequency
1	Report to supervisor on arrival-ensure all personnel informed of alarms	BC
2	Isolate system CO2 system to prevent discharge	BC
3	Remove CO2 high pressure hoses and fit anti recoil caps to cylinders	
4	Open operation boxes-check operation of alarms	
5	Pressurise manifold with pilot cylinder and check operation of pressure switch	
6	Operate pilot cylinder for main valve and observe correct operation	
7	Close main valve and repressurise manifold, check main valve holds pressure	
8	Operate pilot cylinder for first shot-observe correct cylinders operate	
9	Reset 1st shot cylinders	
10	Operate pilot cylinder for second shot-observe correct cylinders operate	
11	Reset cylinders	
12	Operate main valve and blow through pipework with pilot cylinder-observe all nozzles clear	
13	Check all distribution pipe work for security at brackets and tightness during blow through	
14	Remove cylinders for weighing or level check using liquid leveller-record level on cylinders.	
15	Rebuild system, connect all hoses prepare system for operation	OC
16	Report to Supervisoron completion and report status of system- ensure all personnel are aware of completion	OC
SYSTEM STATUS DURING WORKS		
Codes	D - Daily , BC-Before commencing work, ES -End of Shift ,OC On completion	

Prepared By: Sign [redacted] Print [redacted] Accepted By: Sign .... Print ....

Figure 12: OEFL method statement

1.8.4 Work instruction

OEFL's work instruction '*W1:02 – 'Onboard ship working'* detailed the responsibilities of supervisory staff. Included in the actions to be taken before a service engineer commenced work were:

- *Discuss the scope of the work to be carried out*
- *Discuss safety issues with regard to work on fire fighting systems*
- *Inform crew of alarms operated when testing*
- *Request any necessary assistance required* [sic]
- *Establish a point of contact for queries relating to the works*
- *Find out and inform his engineers on emergency procedures on the vessel* [sic]

1.9 *SD NIMBLE*

SD Nimble is one of nine Adept class twin unit tractor tugs (TUTT) which are managed by SLMS and are operating in the Portsmouth, Devonport and Faslane naval bases. *SD Nimble* and her sister tug *SD Dexterous* were based in Faslane.

The allocation and composition of the tug's crew was dependent upon her work programme. Although both a day and a night crew were usually nominated, *SD Nimble* was not manned overnight between 22 and 23 August 2011. The crew allocated on 23 August usually manned *SD Mars,* which had been temporarily relocated to Devonport. Apart from one of the ABs, all of the tug's crew had previously served on board *SD Nimble* and *SD Dextrous*.

The master held a II/2 Certificate of Competency (CoC)[7] (less than 3000 gt) and had worked on board tugs for 23 years. He had been master for 17 years and had gained experience on many of SLMS's vessels. The chief officer held a II/3 CoC endorsed as chief officer on vessels between 500 and 3000gt. He had been at sea since 1970 and had been employed by SLMS for about 1 year. The chief engineer held a III/3 CoC endorsed as chief engineer on vessels between 750 and 3000kW. He had been employed as chief engineer by SLMS for 11 months. The two ABs had worked for SLMS for 5 years and 8 months respectively.

1.10 SERCO LIMITED MARINE SERVICES (SLMS)

1.10.1 Background

In 2007 the Serco Group plc (Serco) was awarded a 15 year private finance initiative (PFI) contract by the UK Ministry of Defence (MOD) to deliver marine services to the RN. The marine services provided include:

- Provision of tugs and pilot boats in the Portsmouth, Devonport and Faslane naval bases
- Passenger transfer to and from ships
- Loading of stores and removal of waste from the ships
- Protection of the environment in the event of oil or other spillages
- Provision and maintenance of buoys and moorings
- Support to deep water training services
- Marine support to the British Underwater Test and Evaluation Centre (BUTEC) in the Kyle of Lochalsh.

The company manages over 100 vessels including tugs, harbour workboats, passenger ferries, and specialist support vessels. Many of SLMS's vessels, including *SD Nimble*, had been operated by SLMS on behalf of the MOD

[7] In accordance with the requirements of the International Convention on the Standards of Training, Certification and Watchkeeping for Seafarers (STCW)

(MOD) through the Royal Maritime Auxiliary Service (RMAS) from 1996 when their ownership was transferred to SLMS in April 2008. Many of the crews on board the vessels managed by SLMS, including the master of *SD Nimble*, had previously been employed by the RMAS.

1.10.2 Safety management

SLMS's vessels are managed in compliance with the International Code for the Safe Management of Ships and Prevention of Pollution (ISM Code). This is not required for many of the company's vessels due to their size and role, but was applied by SLMS to its fleet on a voluntary basis.

In June 2010, SLMS implemented its Integrated Management System (IMS) on board its vessels in line with the requirements of ISO 9001-2008, ISO 14001 (environmental management), and OHSAS 18001[8]. *SD Nimble* was provided with the IMS in a digital format in May 2011. The content of the IMS was similar to the vessel's previous operations manual. Although SLMS provided initial training to its vessels crews in the use of the new digital system, many crew members struggled to come to terms with its implementation (others had also previously struggled to come to terms with the paper manuals which the digital system replaced). Further training and nurturing of some crew in the use of the IMS was ongoing.

In May 2010, *SD Dexterous* suffered a fire in her engine room. The resulting MAIB preliminary examination[9] identified a lack of vessel 'ownership' by the vessel's crew due to their allocation to different vessels on a daily or weekly basis. Consequently, the MAIB highlighted to Serco Marine Services the risks associated with frequent movement of crew between vessels, particularly the impact this could have on individuals' knowledge of specific vessels.

Between 29 September and 1 October 2010 the Maritime and Coastguard Agency (MCA) carried out Document of Compliance (DoC) audits in SLMS's offices in Portsmouth and Greenock. The audit report concluded that '*the company had put a lot of effort into improving the safety management system and its consistent application'*.

1.10.3 Safe systems of work

The IMS required a permit to work to be issued when SLMS and/or contractors undertook: maintenance work on machinery, entry into confined/enclosed spaces, processes deemed to be high risk, and some lone working activities.

A Code of Practice for Contractors, written by Serco Defence Science and Nuclear provided comprehensive guidance, instructions and procedures for Serco employees and contractors. The code required a contractor to provide written hazard identification information and a risk assessment of his/her proposed activity. Although this code was available to SLMS at the time of the accident, it had still to be incorporated into the IMS.

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[8] A specification for international occupational health and safety management system

[9] http://www.maib.gov.uk/publications/completed_preliminary_examinations/completed_preliminary_examinations_2010/sd_dexterous.cfm

The 'Adept Class TUTT Safety Case Report' was prepared by Serco Assurance in November 2005, and was reviewed in 2010. The safety case considered the hazard of asphyxiation caused by the inadvertent release of CO_2 into the engine room with a member of the crew present. The single control measure identified was the use of the permit to work system, which required the insertion of a spectacle flange. The control measure was not incorporated into the IMS.

1.11 REGULATION AND GUIDANCE

1.11.1 The Safety of Life at Sea Convention (SOLAS)

SOLAS Chapter II/2 states that the storage room for CO_2 cylinders of a fixed firefighting system should preferably be entered from the open deck, but that it can be located no more than one deck below the open deck. Where a CO_2 cylinder room is not accessed from an open deck, SOLAS requires that the room is fitted with mechanical ventilation designed to exhaust air from the bottom of the space and sized to provide at least six changes of air per hour.

1.11.2 International Maritime Organization (IMO)

The IMO Maritime Safety Committee (MSC) Circular (Circ) 850 dated 8 June 1998, provides guidelines for '*shipowners, shipmasters, ships' officers and crew and other parties concerned*' on the maintenance and inspection of fire protection systems and appliances. The circular recommends a non-exhaustive list of maintenance requirements ranging from weekly testing and inspections through to 5 year services.

IMO MSC.1/Circ 1318 dated 11 June 2009, provides guidelines for '*ship designers, shipowners, equipment manufacturers, and other parties concerned*' on the maintenance and inspection of fixed carbon dioxide fire extinguishing systems. The guidelines are intended to supplement manufacturers' maintenance instructions, and highlight:

- The need for strict safety precautions to be followed to prevent placing people at risk.
- The development of a safety plan between service engineers and ship's crew.
- Effective communications system between service engineers and ship's crew.
- Measures to prevent accidental discharge of the CO_2 system.
- All personnel notified of the impending work.
- Maintenance, inspection procedures and instructions to be included in the ship's onboard maintenance plan.

1.11.3 Standards for service suppliers

The International Association of Classification Societies (IACS) unified requirement (UR) Z17 - *Procedural Requirements for Service Suppliers* includes firms engaged in the service and maintenance of fire extinguishing equipment and systems. The UR states:

> *'The supplier shall have the professional knowledge of fire theory, fire fighting and fire extinguishing appliances sufficient to carry out the surveys and to make the necessary evaluations of the condition of the equipment'.*

The UR sets a standard for service suppliers, which is demonstrated by suppliers providing appropriate documentation, implementing a quality system in accordance with the ISO 9000 series, and through the completion of a successful audit. With regard to training, the requirement states:

> *The supplier is responsible for the qualification and training of its personnel to a recognised national, international or industry standard as applicable. Where such standards do not exist, the supplier is to define standards for the training and qualification of its personnel relevant to the functions each is authorised to perform. The personnel shall also have adequate experience and be familiar with the operation of any necessary equipment. Operators/technicians/inspectors shall have had a minimum on one (1) year tutored on-the-job training. Where it is not possible to perform internal training, a program of external training may be considered as acceptable.*

and

> *Supervision – The supplier shall provide supervision for all services provided. The responsible supervisor shall have had a minimum two (2) years experience as an operator/technician/inspector within the activity for which the supplier is approved.*

1.11.4 Dangerous spaces

The Code of Safe Working Practices for Merchant Seamen (COSWP) defines a dangerous space as:

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

The code advises that:

> *'The atmosphere of any enclosed or confined space is potentially dangerous'*

and

> *'If in any doubt, such a space should be regarded as dangerous and appropriate action taken'*

For shore workers, the Confined Spaces regulations 1997, define a confined space as:

any place, including any chamber, tank, vat, silo, pit, trench, pipe, sewer, well or other similar space in which, by virtue of its enclosed nature, there arises a reasonable foreseeable specified risk

A specified risk includes:

'the loss of consciousness or asphyxiation of any person at work arising from gas, fume, vapour or the lack of oxygen'.

1.12 PREVIOUS ACCIDENTS

1.12.1 MAIB database

The accidents and incidents involving the accidental discharge of fixed halon and CO_2 systems between 1991 and 2011, which are held in the MAIB's database, are shown in **Figure 13** and **Figure 14**.

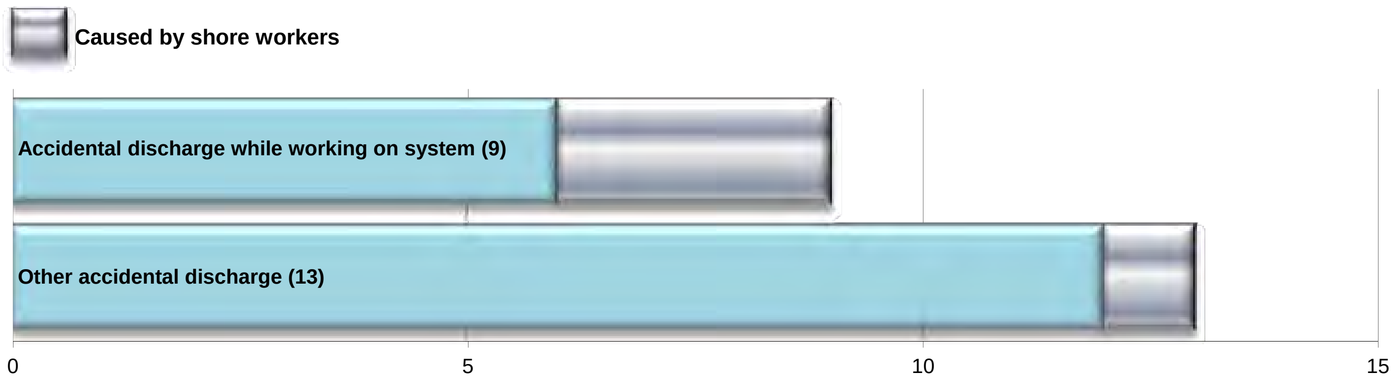

Figure 13: Accidents and Incidents involving accidental discharge of fixed halon/CO_2 fire extinguishing equipment 1991 to June 2011 (22)

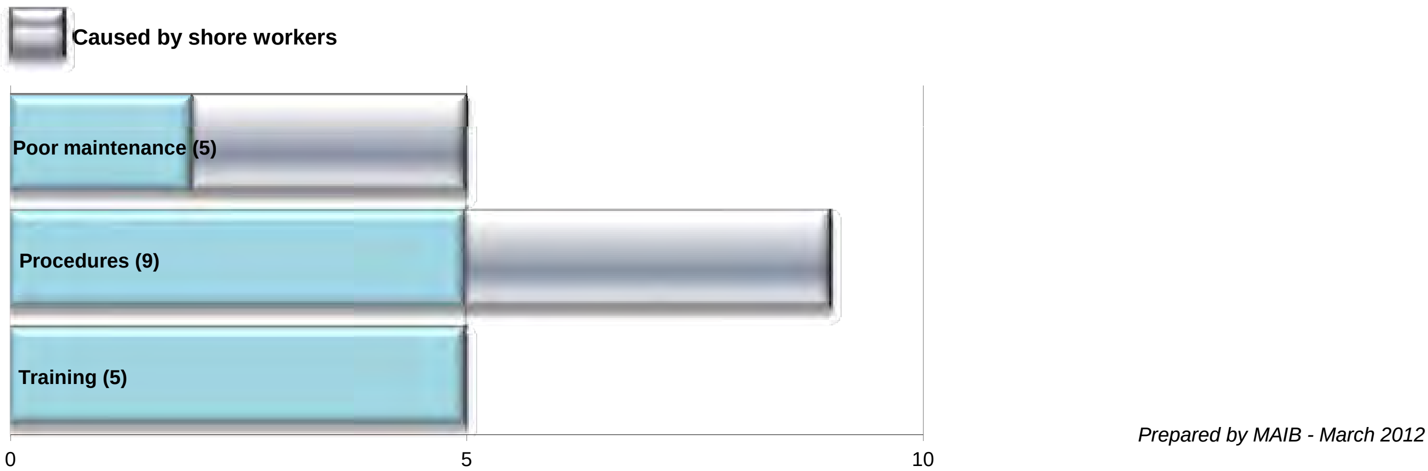

Figure 14: Accidents and Incidents involving accidental discharge of fixed halon/CO_2 fire extinguishing equipment 1991 to June 2011 - contributory factors (19)

1.12.2 YM People

In 2004, the release of 5,060kg of CO_2 on board the Hong Kong registered containership *YM People* killed the vessel's master, chief engineer, chief officer and third engineer. All of the deceased were in the CO_2 cylinder room and were attempting to release CO_2 trapped in the system manifold. The CO_2 had been trapped in the manifold while the chief engineer was preparing the system for inspection and maintenance. The accident report[10] recommended that the system's manufacturer should review its service manual to include sufficient warning and instructions concerning the accidental activation of CO_2 cylinders.

1.12.3 United States Coast Guard (USCG) circular

The USCG navigation and inspection circular 09/00 (amended in 2005)[11] was published in response to the number of casualties and fatalities resulting from inadvertent operation or malfunction of CO_2 systems while being serviced or tested. The circular summarised that most of the casualties could have been avoided if '*personnel involved were more familiar with the design and operation of approved carbon dioxide systems and had followed pre-planned safety precautions*'.

[10] www.mardep.gov.hk/en/publication/pdf/mai040927.pdf

[11] http://www.uscg.mil/hq/cg5/nvic/pdf/2000/NVIC%2009-00,Change%201.pdf

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 SYSTEM ACTIVATION

The CO_2 system on board *SD Nimble* discharged when the trainee engineer injected CO_2 from the test cylinder into the propulsion room pilot line. The pressure of the CO_2 in the pilot line opened the valves of cylinders 4, 5 and 6, allowing the release of their contents. Twenty seconds later, the injection of CO_2 into the engine room pilot line resulted in the discharge of the CO_2 from cylinders 1, 2, and 3. The release of the CO_2 was unintended and occurred because the pilot lines from the control cabinet had not been isolated from the CO_2 cylinders which remained inter-connected.

The contents of all of the six CO_2 cylinders (270kg) were discharged into the cylinder room because the discharge hoses between the cylinders and the distribution line had either been disconnected at both ends (cylinders 2, 3 and 4), or from the distribution line only (cylinders 1, 5 and 6). As the CO_2 was discharged from cylinders 1, 5 and 6, the discharge hoses would have thrashed about due to the pressure of the CO_2, damaging their end fittings and adjacent pipework **(Figure 10)**. As the service engineer is likely to have been close to the cylinders when the CO_2 was discharged, it is possible that his head wound was caused by one of the flailing discharge hoses.

It is evident from the escape of the CO_2 through the deck hatch, that the CO_2 rapidly filled the cylinder room and the aft hold. The location in which the senior engineer was found **(Figure 6)** indicates that he tried to escape. However, he would have quickly been overcome by his inhalation of CO_2 which would have been rapidly increasing in concentration.

2.3 RESCUE

SD Nimble's crew responded very quickly following the discharge of the CO_2 and their endeavours to rescue the senior engineer were very effective. In particular, the chief officer's decision to don a BA before entering the aft hold was crucial. Had he entered the gas-filled and oxygen depleted space without BA, as many mariners have done to their cost in a number of previous similar situations, he too would have been overcome. In addition, the rapid recovery of the engineer onto the open deck, the quick return of the vessel back alongside, and the medical assistance given prior to the arrival of the air ambulance all contributed to the senior engineer's survival.

2.4 SERVICE PROCEDURE

2.4.1 Starting work

After the senior engineer arrived on board *SD Nimble*, he appears to have started work on the CO_2 system despite being told by the master to wait in the mess room until the vessel had completed fuelling and had returned to her berth. However, as the senior engineer has no recollection of the events of the morning of his accident, his understanding of the instruction cannot be determined.

Nonetheless, he is unlikely to have deliberately ignored the master's instruction as the servicing of the CO_2 system would have been readily apparent. Moreover, given the senior engineer's seagoing experience, he would have been aware of the potential impact on safety of working on the vessel's fixed firefighting system while the vessel was underway and when she was refuelling.

The senior engineer had not been fully briefed on *SD Nimble*'s schedule by his manager the previous evening, and before he had arrived on board he had decided to start work on the CO_2 system first. As the work on board *SD Nimble* was the only work scheduled for the engineers that day, he was not constrained by any time pressures. Therefore, had the engineer understood the master's instruction, it is difficult to understand why he did not delay the annual service or negotiate to start work on less safety-critical tasks. By asking the chief engineer and then the AB the location of the cylinder room, the senior engineer did not disguise his intent. It is possible that the senior engineer removed the key for the cylinder room from the 'break glass' holder rather than get a key from the ship's crew. However, had he done so, given that one of the tug's ABs knew that he was in the aft hold and had directed him to the cylinder room, his use of the emergency key was unlikely to have been intended to help hide his activities.

2.4.2 Making the system safe

OEFL's risk assessment covering the servicing of CO_2 systems **(Annex D)** identified the hazard of accidental gas release. The control measures listed, namely to *'lock off the system'* before commencing work and to inform personnel in the engine spaces, were appropriate. The company's method statement **(Figure 12),** written in support of the risk assessment, and the service report form **(Annex A)** also make it clear that CO_2 systems must be isolated in order to prevent their accidental discharge.

In this case, the CO_2 cylinders could have been isolated from the pilot lines by disconnecting the propulsion room pilot line before the non-return valve, and the engine room pilot line prior to cylinder 1 **(Figures 8** and **10)**. Instead, the senior engineer disconnected the atmosphere lines from the cylinders and disconnected all of the discharge hoses from the distribution line, neither of which was necessary to test and prove the pilot lines from the control cabinet. After taking this action, the senior service engineer checked the system by eye and assessed that it was safe to prove the pilot valves. As the pilot lines remained connected, it clearly was not.

2.5 SYSTEM KNOWLEDGE

Due to the senior engineer's memory loss, the reasoning behind his configuration of the CO_2 system prior to testing is unknown. He was well rested and there is no evidence to suggest that there was anything unusual about his behaviour on the morning of the accident.

It is possible that the senior engineer misidentified the atmosphere lines for the pilot lines. The lines were of the same bore and colour and, as no system diagrams were available, a slip[12] of this nature was possible. Indeed, the post-accident inspection of the CO_2 system on board *SD Dexterous* shows that the senior service engineer had made a similar error 3 months earlier.

However, the senior engineer's removal of all of the atmosphere lines, his disconnection of the discharge hoses, and that his visual check failed to identify the pilot lines were still connected to the cylinders before the system was tested, very strongly indicates that he did not fully understand how the CO_2 system operated. The failure to disconnect the pilot lines was therefore more likely to have been a mistake[13] resulting from an incorrect plan of action rather than the misidentification of some of the system's pipework. The senior engineer's attempt to isolate the system before testing was a 'rule-based' action, emphasised in his training and OEFL's procedures, but the act of isolating the system was 'knowledge-based'. Therefore, the effectiveness of the senior engineer's training, and his competency to service fixed CO_2 systems, are questionable.

OEFL's use of two engineers to service a fixed CO_2 extinguishing system was intended to allow the engineers to oversee each other's work and improve safety. In this case, the trainee engineer had insufficient knowledge of the CO_2 system to detect the senior engineer's mistake. The oversight and scrutiny by a second trained service engineer might have been more successful in this respect.

2.6 TRAINING

There are no international or national standards or qualifications regarding the training of service engineers engaged in surveys and maintenance of fire extinguishing systems and equipment, and very few appropriate training courses. Consequently, the onus for ensuring that service engineers are properly trained rests firmly with the service supplier. In view of the number of differing systems an independent service engineer might be expected to maintain, variations in the training methods and procedures adopted by service suppliers are inevitable to some degree. During this investigation, the MAIB identified significant differences in the way service engineers were trained by several service suppliers based in the UK.

OEFL's senior engineer had been trained in the servicing of CO_2 systems to the satisfaction of the service supplier's operations director, following a syllabus and a process formalised in the company's quality management system and approved by LRQA. However, although the operations director had assessed the engineer to be competent to service CO_2 systems, and had audited his work in April 2011,

[12] A slip is an unintentional incorrect action

[13] A mistake results from conscious decision-making based on an incorrect or deficient plan

the shortcomings in the engineer's servicing of the CO_2 system on board both *SD Nimble* and *SD Dexterous* indicate that both the senior engineer's training and the monitoring of his performance had been ineffective in some areas.

The senior engineer had not completed 1 year's training and did not have 2 years' experience as a technician involved in this activity. Similarly OEFL's (Glasgow) branch manager had less than 12 months' experience with the company. Consequently, neither the manager nor the senior engineer's training and experience met the IACS requirements for supervisors and technicians.

As highlighted in the USCG circular (paragraph 1.12.3) and emphasised by the fatalities which occurred on board *YM People* (paragraph 1.12.2), training is critical to the safe operation and maintenance of fixed CO_2 systems. On this occasion, the senior engineer's mistake on board *SD Nimble* resulted in his serious injury, but the similar mistake he made when reconnecting the CO_2 system on board *SD Dexterous* would have prevented the system from being used as designed and could have resulted in even more serious consequences.

Although the ineffectiveness of service engineers' training has not been identified as a contributory factor in the accidents and incidents included in **Table 2**, it is inevitable that errors made by service engineers when servicing fixed firefighting systems will not become evident until the systems involved are needed in an emergency or the next service. Consequently, if errors have been made by service technicians they are likely to remain undetected or unreported.

2.7 SYSTEM INFORMATION

It is advantageous for service engineers to have system drawings and/or maintenance instructions at hand when working on a fixed fire extinguishing system. This information is usually provided by manufacturers to their own service agents, but not to independent service suppliers. Although many independent service suppliers take the opportunity to copy system drawings when on board vessels in order to assist future services on similar installations, it is not uncommon for service suppliers to service fixed firefighting systems for which they have not received type-specific training and without reference to a system's drawings.

In this case, the drawings of *SD Nimble*'s CO_2 system **(Figure 7)** were held ashore. However, they were very basic and would have been of little assistance even if they had been available on board or requested by OEFL. The cylinder valves shown were not the same as the type fitted, and detail of the pilot and atmosphere lines was very limited. The CO_2 system on board *SD Nimble* was not complex but, given the similarities between the pilot and atmosphere lines, the provision of accurate and detailed system drawings, or even a locally produced schematic diagram posted in the cylinder room, might have helped the senior engineer understand the system layout.

2.8 CONTRACTOR/CREW INTERFACE

2.8.1 Preparation

Although the arrangements for the servicing of the CO_2 system on board *SD Nimble* were finalised on the day before the service occurred, the manager of OEFL (Glasgow) had sufficient time to brief his engineers, and SLMS was also able to include the planned activity on its *Daily Movement Sheets*. However, the service engineers were not informed of the vessel's movements before their arrival on board, and the tug's crew were not provided with any detail of the work the service engineers would be undertaking. Given the previously identified difficulties in getting temporary crews to take 'ownership' of SLMS vessels, along with the difficulties in getting some SLMS crews to implement the IMS on board their vessels, a more pro-active approach by the vessel's technical managers was warranted. A visit to the vessel before departure could have apprised the crew fully of the arrangements and helped to generate a better awareness of the safety considerations and precautions required before any work commenced or the vessel got underway.

2.8.2 Responsibilities

The voluntary adoption of the ISM code and the introduction of the IMS on board its vessels by SLMS were positive steps. However, at that time the IMS did not include any guidance on the control of contractors, which was available in the Serco Code of Practice (paragraph 1.10.3) or the need for a 'permit to work' when maintaining the CO_2 system, which had been identified in the TUTT safety case. As a result, key elements of best practice were not adopted and most of the important safety precautions detailed in IMO MSC.1/Circ 1318 (paragraph 1.11.2) were not taken.

Nevertheless, *SD Nimble*'s master was responsible for the safety of his crew and the safety of the service engineers working on board his tug. Although it was his intention that the OEFL engineers were not to start work until *SD Nimble* had returned from re-fuelling, the master did not relay his intent to the crew. Consequently, the chief officer did not stop the trainee engineer when he saw him working on the CO_2 control station, which was already unlocked, and the senior engineer was directed to the aft hold by one of the tug's ABs.

However, the senior engineer also had a responsibility for the safety of himself and his trainee, and the safety of the vessel's crew in relation to the work he was undertaking. With regard to OEFL's work instructions (paragraph 1.8.4), the senior engineer on board *SD Nimble* did not:

- Discuss with tug's officers the safety issues associated with the servicing, or establish a point of contact.

- Inform the tug's crew of the opening of the control cabinet or of the alarms that might be activated.

- Inform the chief engineer in the engine room that he was about to test the system.

- Find out and inform the trainee engineer of the tug's emergency procedures.

In effect, the crew and the service engineers worked in isolation. The crew were comfortable with the engineers' activities and allowed them to work unsupervised. Similarly, the senior engineer expected to work without any input from the ship's crew. As a consequence, the service engineers entered a potentially dangerous space and the vessel sailed with her fixed firefighting system dismantled.

The potential of the cylinder room on board *SD Nimble* to be a dangerous space was not recognised. OEFL's method statement assumed that the CO_2 cylinders were sited off an open deck, and the aft hold was routinely used by the crew. However, the cylinder room was not fitted with a CO_2 monitoring system, and overnight the ventilation fans in the aft hold had been switched off and the aft hold hatch had been closed. In such circumstances, the need for the guidelines on entry into enclosed spaces contained in COSWP to be followed, and for safe systems of work to be put in place by the vessel and by the contractors was compelling.

SECTION 3 - CONCLUSIONS

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

1. The release of the CO_2 was unintended and occurred because the pilot lines from the control cabinet had not been isolated from the CO_2 cylinders which remained inter-connected. [2.2]

2. The failure to disconnect the pilot lines was likely to have been a mistake resulting from an incorrect plan of action rather than the misidentification of the system's components. [2.5]

3. The oversight and scrutiny of the senior engineer by a second trained service engineer might have detected the senior engineer's mistake. [2.5]

4. The senior engineer's mistakes when servicing the CO_2 systems on board *SD Nimble* and *SD Dexterous* indicate that his training and the monitoring of his performance were ineffective in some areas. [2.6]

5. The senior engineer's training and experience did not meet the IACS requirements for a service technician. [2.6]

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

1. The crew and the service engineers worked in isolation, which resulted in the service engineers entering a potentially dangerous space and the vessel sailing with its fixed fire extinguishing system dismantled. [2.8.2]

2. Many of the important safety precautions detailed in IMO MSC.1/Circ 1318 regarding the maintenance of fixed fire extinguishing systems were not taken. [2.8.2]

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

1. It is possible that the engineer misidentified the atmosphere lines for the pilot lines which were of the same bore and colour. [2.5]

2. If errors are made by service technicians during the servicing of fixed fire extinguishing systems they are likely to remain undetected or unreported. [2.6]

3. Service suppliers frequently service fixed firefighting systems for which they have not received type-specific training and for which no system drawings are available. [2.7]

4. The provision of accurate and detailed system drawings, or even a locally produced schematic diagram posted in the cylinder room, might have helped the senior engineer understand the system layout. [2.7]

5. The service engineers were not informed of the tug's planned movements before their arrival on board, and the tug's crew were not provided with any detail of the work the service engineers would be undertaking. [2.8.1]

SECTION 4 - ACTION TAKEN

4.1 ACTIONS TAKEN BY OTHER ORGANISATIONS

Serco Limited Marine Services has:

- Revised and reinforced its control of contractors and permit to work procedures across the fleet.

- Completed a series of toolbox talks, which include the circumstances of this accident, and intends to conduct further training sessions covering the lessons learned.

- Introduced daily briefings for masters.

- Initiated a review and assessment of ships' fixed firefighting system drawings. A ship technical design specialist has been contracted to produce the required documents.

- Briefed masters on the documentation to expect from visiting contractors.

- Started to review the emergency key arrangements on board its vessels. It is intended that a key safe will be installed on the bridge, and a key log will be maintained.

- Started to install CO_2 monitoring systems on vessels where CO_2 cylinders are located below decks.

- Introduced the policy that, where any person(s) not a member of a ship's crew are required to work on CO_2 systems in an enclosed compartment, that compartment will be considered a confined or enclosed space.

- Started to install signage on its vessels indicating that all contractors and visitors must report to the master.

- Started to colour code the pipework of CO_2 systems on board its vessels, and to display system drawings adjacent to the system. The same colour coding is being applied to other safety-critical systems.

Ocean Engineering (Fire) Limited has:

- Sent a safety memorandum to its engineers reinforcing the need for safety when handling CO_2 systems.

- Interviewed its engineers to ensure that the procedure for making systems safe was clear and being followed at all times with particular reference to ADEPT class vessels.

- Audited its engineer’s procedures.
- Introduced a task book for trainees which details:
    - The vessels serviced and the work carried out.
    - The full list of vessels attended and the status of the trainee servicing the vessel.
    - A sign off page clearly verifying an engineer’s competence to service different types of system.

SECTION 5 - RECOMMENDATIONS

Lloyd's Register is recommended to:

2012/141 Propose to IACS that UR Z17 be amended to reflect the importance of service suppliers' procedures being sufficiently robust to ensure that safe systems of work are agreed and implemented with ships' crews prior to commencing work on board vessels.

Ocean Engineering (Fire) Limited is recommended to:

2012/142 Take steps to improve the monitoring and safety of its service engineers, and the adoption of safe systems of work, taking into account the lessons to be learned from this accident, particularly:

- The availability of system information
- The storage of CO_2 cylinders below decks
- Vessel movements and activities
- The requirements of UR Z17.

Marine Accident Investigation Branch
August 2012

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

Annex A

OEFL service report

OCEAN ENGINEERING (Fire) Ltd

CO_2 SYSTEM SERVICE REPORT

DATE:		VESSEL:	SD NIMBLE	PORT:	FASLANE

							Test Date
Cylinder in system No.		Cylinders removed for test No		Capacity		Kg/lbs	
Pilot cylinders in system No.		Cylinders removed for test No		Capacity		Kg/lbs	
Also Comprising No.		Cylinders removed for test No		Capacity		Kg/lbs	

Job No:	3084 JG	BRANCH:	GLASGOW	PROTECTED SPACE	

WORK CARRIED OUT	Present ☐ In Order	Not Present ☐ N/A	COMMENTS
System isolated before commencing service	☐ In Order	☐ N/A	
Cylinders liquid level checked / weighed	☐ In Order	☐ N/A	
All discharge valves and/or heads on cylinders visually inspected	☐ In Order	☐ N/A	
Connecting lines from discharge and/or heads visually inspected	☐ In Order	☐ N/A	
Non-return valves checked on opening under pressure	☐ In Order	☐ N/A	
Manifold and pipelines in distribution valves tested for leaks under pressure	☐ In Order	☐ N/A	
Main - distribution valves operating correctly	☐ In Order	☐ N/A	
5 Yearly open up amd internal inspection of main valve	☐ In Order	☐ N/A	Last inspection:
Spring switch and audio / visual alarm tested	☐ In Order	☐ N/A	
Ventilation shutdowns tested	☐ In Order	☐ N/A	
Pressure operated devices functioning correctly	☐ In Order	☐ N/A	
Discharge lines(s) leading from distribution valve(s) to different compartments visually inspected	☐ In Order	☐ N/A	
Discharge line(s) leading to the different compartments blown clear and checked	☐ In Order	☐ N/A	
All electrical connections safe and in working order	☐ In Order	☐ N/A	
Smoke sampling system cleaned, inspected, adjusted and tested	☐ In Order	☐ N/A	
Door(s) to CO2 room, hinges, locks, control box(s) key locker(s) etc. inspected	☐ In Order	☐ N/A	
All indicating plates on installation, distribution valves(s), smoke detector(s) & release system checked	☐ In Order	☐ N/A	
Installation sealed with inspection and date labels	☐ In Order	☐ N/A	
Results of inspection,defects, instructions for use and maintenance discussed with ships offical in charge	☐ In Order	☐ N/A	
System left in working order	☐ In Order	☐ N/A	

Further Comments:

Engineer's Signature ____________________

Engineer's Name ____________________

OEFL training procedures

Reference: OP: 04

Training

1. Purpose and application

1.1 To ensure that all personnel are adequately trained in the tasks allocated to them and shall include appropriate training in the management of Ocean Engineering (Fire) Ltd quality management system.

2. The operations director is responsible for the training policy tyhat will ensure that staff receive adequate training for their respective job functions, including any actions thta affect the QA policy. The operations director will ensure that the training is carried out and that the training matrix is kept up to date. Statutory and regulatory requirements that affect the company are understood by all staff and that staff are aware of the quality objectives.

3. Procedure

3.1 The operations director will arrange for each new employee to receive an induction course which will include :

- Instructing the new employee on quality system management and procedures relevant to their work.
- Obtaining signatures of new employees for issue procedures.
- Explain all operations that take place as part of their role.
- Explain the quality policy of Ocean Engineering (Fire) Ltd.
- Explain company rules and disciplinary procedures, and statutory requirements
- Explain quality objectives

3.1.2 The company will maintain a skills matrix in which all employees competencies are noted.

3.2 The operations director will asses staff training needs on a regular basis, and as a minimum annually.

3.3 Copies of employees certificates will be held in personnel files of the relevant employee

3.4 The following requirements are in place for the regulatory requirements of Lloyds register of shipping and Det Norske Veritas, for which the company holds certificates as service suppliers to shipping.

3.5

Training Programmes for Inspectors,

Operators and Technicians

The company operates an in house training regime for operators of test equipment.

This takes the following format.

1) Assistant technician training
2) Assistant technician monitored phase, working with a trainer or experienced technician
3) Regular audit of operations and notation of tests
4) Re training after periods of non-operation or introduction of new equipment.

Technician Training

The operators training course includes

1) Health and safety aspects of the equipment, including PPE
2) Philosophy of the results achieved and the method of testing
3) Safe operation of the equipment
4) Means of ensuring accuracy of the process
5) Maintenance and required calibration of the equipment

The monitored phase includes:

1) Observing a trained operative using the equipment

2) Making out the records for the test
3) Operating the equipment under the direction of an experienced technician

Auditing of practical testing and notation is carried out as follows:

1) Random observation of operators by the company quality officer on a regular basis
2) All paperwork and certificates to be signed off by a senior technician

Retraining will take place as follows

1) If an operatives name does not appear in the certificate log for a period of 2 months
2) If the equipment is modified or renewed in any way.

Training of inspectors and auditors will be carried out in the form of courses to update own service capability by external suppliers of training, were necessary, and by in house training by senior auditors as appropriate to the area covered.

Annex C

LRQA certificate schedule

LRQA
Business Assurance

CERTIFICATE OF APPROVAL

This is to certify that the Quality Management System of:

Ocean Engineering (Fire) Ltd
Penryn, Cornwall
United Kingdom

has been approved by Lloyd's Register Quality Assurance
to the following Quality Management System Standards:

ISO 9001:2008

The Quality Management System is applicable to:

Design, manufacture, procurement, supply and service of ship's fixed fire fighting systems. Procurement and supply, stockholding and service of portable fire equipment including breathing apparatus.

This certificate is valid only in association with the certificate schedule bearing the same number on which the locations applicable to this approval are listed.

Approval
Certificate No: LRQ 4002403

Original Approval: 15 July 2005

Current Certificate: 4 August 2011

Certificate Expiry: 14 July 2014

[redacted]

Issued by: Lloyd's Register Quality Assurance Limited

UKAS MANAGEMENT SYSTEMS
001

LRQA
Business Assurance

CERTIFICATE SCHEDULE

Ocean Engineering (Fire) Ltd
Penryn, Cornwall
United Kingdom

Head Office	Activities
Penryn, Cornwall United Kingdom	Design, manufacture, procurement, supply, and service of ship's fixed fire fighting systems. Procurement and supply, stockholding and service of portable fire equipment including breathing apparatus.

Locations	
Southampton, Hampshire United Kingdom	Procurement and supply, stockholding and service of portable fire equipment including breathing apparatus.
Glasgow, Scotland United Kingdom	Procurement and supply, stockholding and service of portable fire equipment including breathing apparatus.

Approval
Certificate No: LRQ 4002403

Original Approval: 15 July 2005

Current Certificate: 4 August 2011

Certificate Expiry: 14 July 2014

UKAS MANAGEMENT SYSTEMS
001

Annex D

OEFL risk assessment

RISK ASSESSMENT

JSA NR:

(Sev) HAZARD SEVERITY	(L/hood) LIKELIHOOD OF OCCURRENCE: V.LOW	LOW	MED	HIGH	V.HIGH
NEGLIGIBLE	LOW	LOW	LOW	LOW	MED
MODERATE	LOW	LOW	LOW	MED	HIGH
SERIOUS	LOW	LOW	MED	HIGH	HIGH
MAJOR	LOW	MED	HIGH	HIGH	HIGH
CATASTROPHIC	MED	HIGH	HIGH	HIGH	HIGH

(Risk) RISK RATING	
LOW	No immediate action required, Proceed with care.
MEDIUM	Hazard to be investigated in conjunction with line manager / supervisor with a view to reducing the risk
HIGH	Task must not be undertaken. Immediate action must be taken to eliminate the risk or substantially reduce the risk.

Location: Devonport

Job: Fire detection and CO2 system service

TASK	HAZARD	PERSONS AFFECTED	RISK L/hood	RISK Sev	RISK Risk	CONTROL MEASURES List those provided and required	RISK L/hood	RISK Sev	RISK Risk
Testing fire detection	Alarms generated - unwanted emergency evacuations, slips trips and falls	All personnel on board	h	s	h	Inform all personnel of testing work in progress ignore all alarms till further notice	l	m	l
Testing of fire detection	Alarms ignored during testing-possible- fire risk	All personnel on board	m	s	ma	Heightened awarenss of fire risks during testing	l	m	l
Completion of testing	Alarms status not informed to supervisor, risk of alarms being ignored	All personnel on board	m	s	m	Inform supervisor at end of testing and give status of system	l	m	l
CO2 detection testing	High CO2 content in room alarm not working	OE engineers	l	m	ma	ensure space is ventilated before entering	l	n	l
CO2 system service	Accidental discharge of system.	Personnel in engine spaces	m	ma	h	Lock off system before commencing work Inform personnel in engine spaces	vl	ma	l
CO2 system service	accidental discharge of cylinders when testing system or removing cylinders from system	OE personnel	m	ma	m	Fit anti recoil caps immediately after disconnecting discharge hose from cylinder. and before removing cylinders.	vl	n	l
CO2 system service	Alarms causing emergency evacuation, slips trips and falls	Personnel in engine spaces	m	mo	m	Inform all personnel of testing taking place ignore alarms till further notice	m	n	l

ASSESSOR(S): [redacted]

SUPERVISOR'S SIGNATURE

DATE OF ASSES:

DATE OF REVIEW

Commen

REVISION NUMBER: 1

TPB

Marine Accident Report

INVESTORS IN PEOPLE