ACCIDENT REPORT

MAIB
MARINE ACCIDENT INVESTIGATION BRANCH

Report on the investigation of

the enclosed space accident

on board the fishing vessel

***Sunbeam* (FR487)**

in Fraserburgh, Scotland

on 14 August 2018

resulting in one fatality

VERY SERIOUS MARINE CASUALTY REPORT NO 19/2020 DECEMBER 2020

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

2/E	-	Second engineer
BA	-	Breathing Apparatus
°C	-	Degrees celsius
CFC	-	Chlorofluorocarbon
CoC	-	Certificate of Competency
EMT	-	Element Materials Technology
EU	-	European Union
Freon	-	A registered trademark name for a refrigerant, aerosol propellant, or organic solvent consisting of one or more of a group of chlorofluorocarbons and related compounds
FSM Code	-	Fishing Safety Management Code
gt	-	Gross tonnage
IMO	-	International Maritime Organization
HCFC	-	Hydrochlorofluorocarbon
IFVC	-	International Fishing Vessel Certificate
ILO	-	International Labour Organization
kg	-	kilogram
LR	-	Lloyd's Register
m	-	metre
m3	-	cubic metre
MARPOL	-	The International Maritime Organization's International Convention for the Prevention of Pollution from Ships, 1973 as amended
MCA	-	Maritime and Coastguard Agency
MCIB	-	Marine Casualty Investigation Board of the Republic of Ireland
MFV	-	Motor Fishing Vessel
MGN	-	Marine Guidance Note
MSN	-	Merchant Shipping Notice
ppm	-	parts per million
R22	-	Chlorodifluoromethane refrigerant
RO	-	Recognised Organisation
RSW	-	Refrigerated Salt Water
SMS	-	Safety Management System

STS	-	Star Technical Solutions
UTC	-	Universal co-ordinated time

TIMES: all times used in this report are UTC + 1 unless otherwise stated

Sunbeam (FR 487)

SYNOPSIS

At about 1350 on 14 August 2018, a second engineer working on board the trawler, *Sunbeam*, was found collapsed inside a refrigerated salt water tank; although rescued from the tank, he could not be resuscitated.

Sunbeam was in Fraserburgh and the evidence available strongly indicated that the second engineer had entered the tank to sweep away residual water. When he was found, three of his crewmates went into the tank to help him; they all suffered breathing difficulties and one also collapsed. Two other crew members then donned breathing apparatus and rescued their struggling crewmates; the second engineer could not be resuscitated.

This fatal accident happened because the second engineer entered the tank, which was an enclosed space, without any of the safety precautions normally associated with such an activity; there was no ventilation, the atmosphere was not monitored and he was working alone without communications. Entry into *Sunbeam*'s refrigerated salt water tanks without appropriate safety precautions had been normalised by the crew; however, on this occasion, the atmosphere could not support life because Freon gas had leaked into the tank through corroded tubes in the evaporator of the vessel's starboard refrigeration plant. Although the Freon gas leak was less foreseeable than other potential hazards in refrigerated salt water tanks, this accident highlights the critical importance of safety precautions and procedures for any enclosed space.

Sunbeam had been subject to regular surveys by both the Flag State and its recognised organisation; however, a lack of clarity regarding responsibility for assessing refrigeration equipment resulted in an inconsistent level of oversight of this machinery. Additionally, fishing vessels were excluded from UK regulations for personnel entry into dangerous spaces, and guidance on enclosed space working was not included in the Maritime and Coastguard Agency's Code of Practice for Fishing Vessels of 24 metres in length and over.

This report makes recommendations to the Maritime and Coastguard Agency to: implement measures for the safe conduct of enclosed space entry on board fishing vessels by extending the application of the Merchant Shipping (Entry into Dangerous Spaces) Regulations 1988 to include fishing vessels, and make corresponding updates to the relevant codes of practice; and, review its Letters of Delegation to its Recognised Organisations with respect to the survey of machinery items.

Since the accident, the International Labour Organization's Fishing Convention 188 has come into force and an industry voluntary Fishing Safety Management Code has been developed to assist owners in complying with the Convention. A safety recommendation has, therefore, been made to the owners of *Sunbeam* to implement a safety management system on board, in accordance with the Fishing Safety Management Code. The Scottish Pelagic Fishermen's Association has also been recommended to encourage its members to maintain safety management systems compliant with the Fishing Safety Management Code.

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *SUNBEAM* AND ACCIDENT

SHIP PARTICULARS	
Vessel's name	*Sunbeam*
Flag	United Kingdom
Classification society	Lloyd's Register of Shipping
Fishing number	FR487
Type	Pelagic trawler
Registered owner	*Sunbeam* Fishing Ltd
Manager(s)	*Sunbeam* Fishing Ltd
Construction	Steel
Year of build	1999
Length overall	56.17m
Registered length	49.39m
Gross tonnage	1349
Minimum safe manning	Not applicable
Authorised cargo	Fish

VOYAGE PARTICULARS	
Port of departure	Fraserburgh
Port of arrival	Fraserburgh
Cargo information	None
Manning	11

MARINE CASUALTY INFORMATION	
Date and time	14 August 2018, 1350
Type of marine casualty or accident	Very Serious Marine Casualty
Place on board	Refrigerated salt water tank
Injuries/fatalities	1 fatality
Damage/environmental impact	Release of Freon ozone depleting refrigerant gas
Ship operation	Maintenance
Voyage segment	Alongside
External & internal environment	Clear, daylight, good visibility. Air temperature 18ºC
Persons on board	10

1.2 BACKGROUND

Sunbeam was a UK-registered pelagic fishing trawler that was based in Fraserburgh, Scotland. *Sunbeam* had nine refrigerated salt water (RSW) tanks **(Figure 1)** to store and preserve its catch. On Friday 10 August 2018, having caught and landed its quota of herring, *Sunbeam* returned to Fraserburgh and the crew began preparing for a forthcoming refit that was to include the replacement of the vessel's refrigeration plants. Once alongside, *Sunbeam*'s crew carried out preparations for the refit, which included pumping out all the water from the RSW tanks and opening the tank hatches before going home for the weekend.

1.3 NARRATIVE

On Monday 13 August 2018, *Sunbeam*'s crew returned on board and spent most of the day assisting a Lloyd's Register (LR) surveyor who was conducting an annual survey. Before going home for the evening, the crew applied some foam cleaner to the empty RSW tanks in preparation for deep cleaning the following day.

During the following morning, the crew progressed RSW tank cleaning, but this was interrupted by a defect with the pressure washer requiring contractor assistance to repair. At about 1200, a lorry arrived to collect *Sunbeam*'s nets, so the deckhands went aft to manage the offload. Meanwhile, after finishing lunch at about 1230, *Sunbeam*'s two second engineers (2/E) decided to progress the tank cleaning. One of them entered the port forward RSW tank and began power washing, the other 2/E, Mr William Ironside, entered the aft centre RSW tank.

Having finished cleaning, and thinking Mr Ironside was standing by the tank entrance, the 2/E in the port forward RSW tank called for assistance to help pump out the water residue at the bottom of the tank. There was no response, so the 2/E climbed out of the tank to look for Mr Ironside, who was nowhere to be seen. The 2/E then went in search of his colleague; he asked the deckhands at the aft deck if they had seen him, then searched the engine control room and workshop.

Returning to the upper deck, the 2/E looked into the aft centre RSW tank **(Figure 2)** and saw Mr Ironside lying face down at the bottom of the tank, near a pool of water. The 2/E raised the alarm by shouting loudly, and other members of the crew ran to assist. The 2/E then descended the ladder into the tank and found that Mr Ironside was unconscious and not breathing. One of the deck crew also descended the ladder and assisted the 2/E with cardio pulmonary resuscitation.

On deck, one of *Sunbeam*'s two deck mates attached a fish box to the crane hook and started lowering it into the tank to use as a stretcher for rescue. As the fish box was being lowered it became snagged, so another deckhand went down the ladder to free it and then guide it to the tank bottom.

When on the ladder, the deckhand started to feel light-headed and his throat tightened; he also saw that the other 2/E had collapsed, and that the deckhand who was in the tank was behaving strangely. The deckhand who was on the ladder then climbed out of the tank. At 1357, another crew member dialled 999 on his mobile telephone and alerted the emergency services.

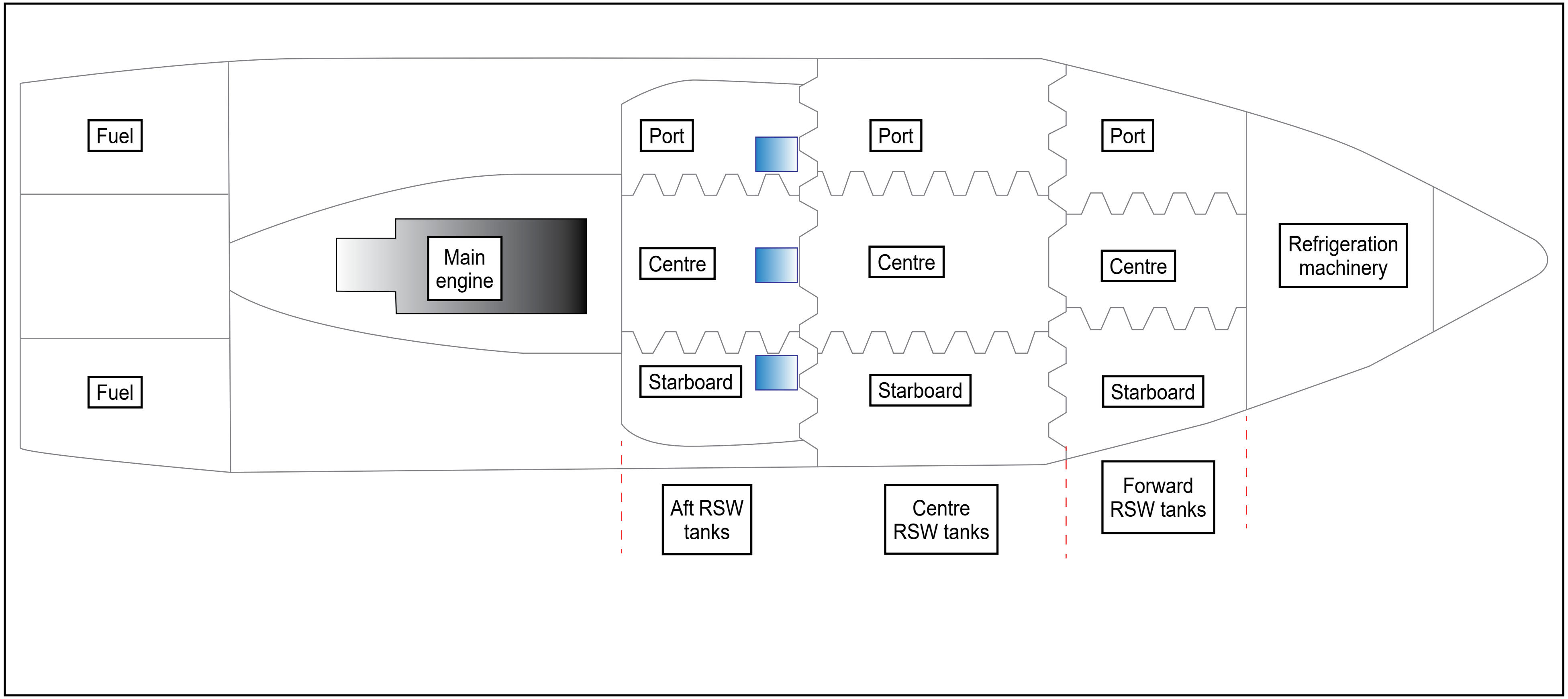

Figure 1: *Sunbeam* - general arrangement showing the layout of RSW tanks, access hatches and the refrigeration plant forward

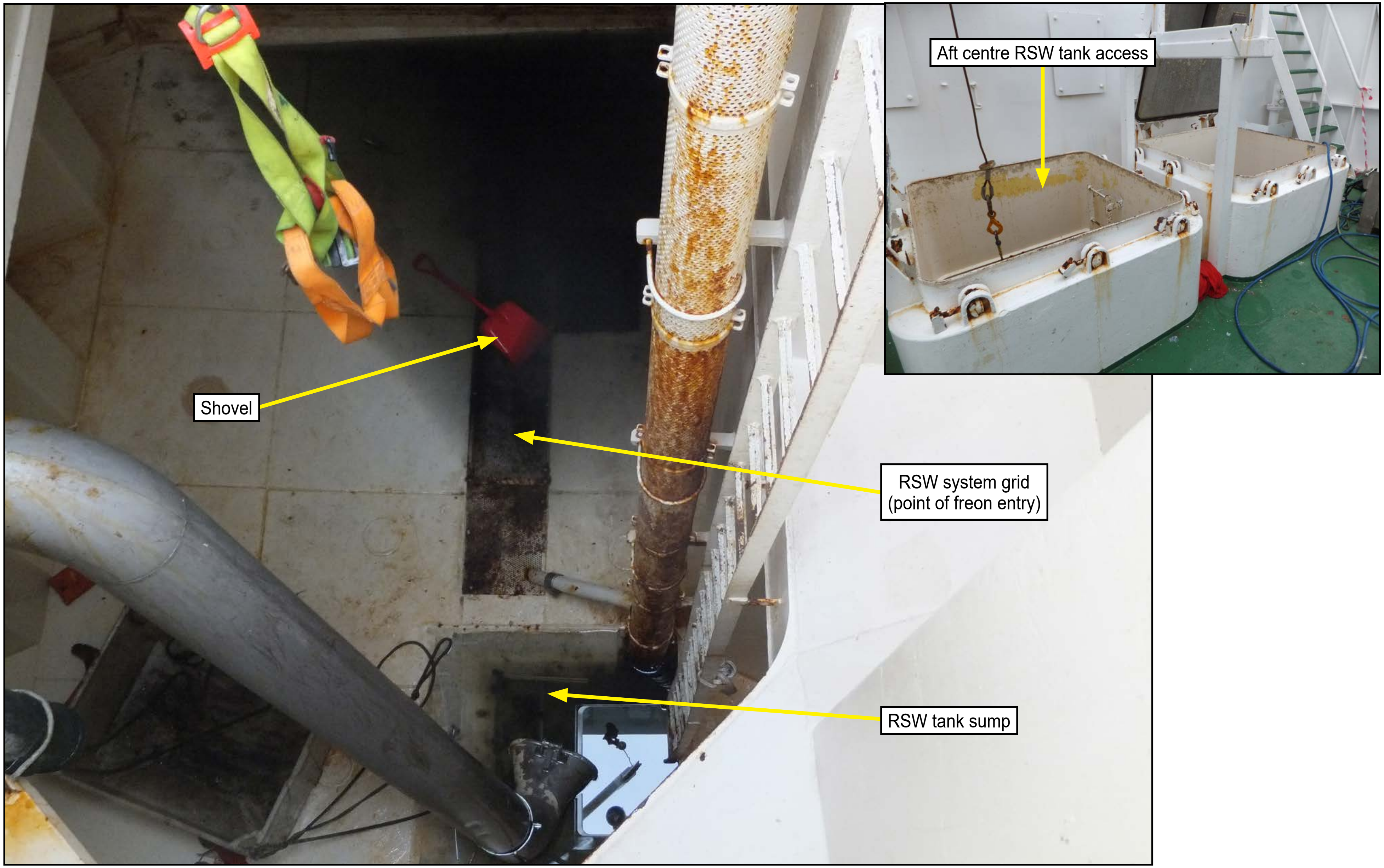

Figure 2: *Sunbeam*'s aft centre RSW tank after the accident showing the shovel and residual water with hatch access inset.

Sunbeam's two deck mates then donned breathing apparatus (BA) and entered the tank. Using a loop of rope and the crane, they recovered the distressed deckhand and both 2/Es from the tank on to the deck. Once on deck, the deckhand and the 2/E who had entered the tank to help Mr Ironside, began to recover but, despite the efforts of the crew and ambulance paramedics, Mr Ironside could not be resuscitated.

The weather at the time of the accident was fine with an air temperature of 18ºC.

1.4 INITIAL ACCIDENT SITE EXAMINATION

Soon after the accident, the local Fire and Rescue Service measured the oxygen content in the aft centre RSW tank. The measurements gave a reading of below 6%[1] oxygen content from the bottom of the tank extending up about 1.5m. The Fire Service also collected atmosphere and water samples from the bottom of the tank for laboratory analysis. These tests confirmed the presence of Freon[2] in both the atmosphere of the tank and the water residue at the tank's floorplate. The day after the accident, MAIB inspectors recorded an oxygen level of 16% in the aft centre RSW tank and normal oxygen content[3] in the other RSW tanks.

1.5 *SUNBEAM*

1.5.1 General description

Sunbeam was a 56.17m steel-hulled pelagic trawler built in Spain in 1999; it had been lengthened from its original 48.75m in 2004 to increase from six to nine RSW tanks. *Sunbeam* fished for pelagic species, mainly herring and mackerel, in the North Sea and Southern Norwegian Sea. Fishing was highly seasonal, and *Sunbeam* would routinely spend 30 to 40 weeks of the year moored alongside in Fraserburgh.

1.5.2 Crew

Sunbeam had a crew of 11; who were all UK nationals and self-employed share[4] fishermen. The skipper had been a fisherman all his working life and was one of the two shareholders in the company that owned the vessel. He held a Maritime and Coastguard Agency (MCA) Deck Officer (Fishing Vessel) Class 1 certificate of competency (CoC).

Sunbeam's two deck mates were the skipper's sons, and both were experienced fishermen. One held an MCA Deck Officer (Fishing Vessel) Class 1 CoC and the other held a Class 2 CoC. Both of the deck mates also held degrees in naval architecture and one of them occasionally worked in the oil and gas sector.

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[1] An immediate fatal hazard can exist when the oxygen content in atmosphere falls below 11%.

[2] Freon is a trademark name for several halocarbon products that have been used as refrigerants and aerosols. These include chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) such as chlorodifluoromethane. The refrigerant in use on board *Sunbeam* was Chlorodifluoromethane R22, also often referred to as 'Freon', 'Freon R22' or just 'R22'. The term 'Freon' is used throughout this report to refer to *Sunbeam*'s refrigerant, except where quoting from other sources where the term 'R22' has been used.

[3] By volume air contains 20.95% oxygen.

[4] This meant that the crew shared the value of the catch as income rather than being in the direct employment of the skipper/owner.

The deck crew consisted of three deckhands and a trainee. All three deckhands were experienced fishermen; one had worked on board *Sunbeam* for many years, one had previously owned his own pelagic trawler, and the third had been a fisherman on various types of vessel since leaving school. The trainee deckhand was on his first fishing trip.

Sunbeam had a chief engineer, two 2/Es and an assistant engineer. The chief engineer joined the vessel in January 2018 and held an MCA Engineering Officer (Fishing Vessel) Class 1 CoC. The 2/Es both held MCA Engineering Officer (Fishing Vessel) Class 2 CoCs and were long serving members of *Sunbeam*'s crew.

William Ironside, one of the two 2/Es, was well-regarded by his crew mates and was a self-motivated engineer. The postmortem report recorded his cause of death as asphyxia[5] and toxicological analysis revealed the presence of Freon in his body.

1.6 REFRIGERATED SALT WATER SYSTEM

1.6.1 System overview and function

Sunbeam's nine RSW tanks were arranged in three rows forward to aft **(Figure 1)**. The tanks' purpose was to store and preserve caught fish in chilled water. The aft centre RSW tank had an internal volume of approximately 154m³. There was no forced ventilation in the RSW tanks, and each had a single point of entry / exit at main deck level **(Figure 2)**. Seawater for the RSW tanks was chilled by two refrigeration plants. The RSW system **(Figure 3)** functioned as follows:

- Seawater was continuously circulated by pumps through the RSW tanks and the refrigeration plants' evaporators.
- The seawater was chilled by the refrigeration machinery before it entered the bottom of the tanks and then distributed evenly over the complete cross-section of the tanks through a set of perforated plates.
- The chilled seawater passed upwards through the tank and layers of fish, thus keeping the fish in suspension and cool.
- The seawater returned through suction screens in the top of the tanks to the refrigeration plants' evaporators, passing through them and repeating the circulation process through the RSW system.

RSW tank suction and discharge isolating valves were fully lugged pattern marine butterfly valves; when in the shut position, they were designed to be watertight but not gastight. At the time of the accident, all of *Sunbeam*'s RSW tanks were empty and all pipework was drained of seawater **(Figure 3)**.

1.6.2 Refrigeration plants

Sunbeam was fitted with two refrigeration plants in a dedicated compartment forward of the RSW tanks **(Figure 1)**. The refrigeration plants could be operated individually or in parallel to chill seawater. The refrigeration plants **(Figure 4)** were designed and manufactured by Technotherm A/S of Halden, Norway, and had been installed at build. The main components of each refrigeration plant were a

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[5] Oxygen deprivation causing unconsciousness or death.

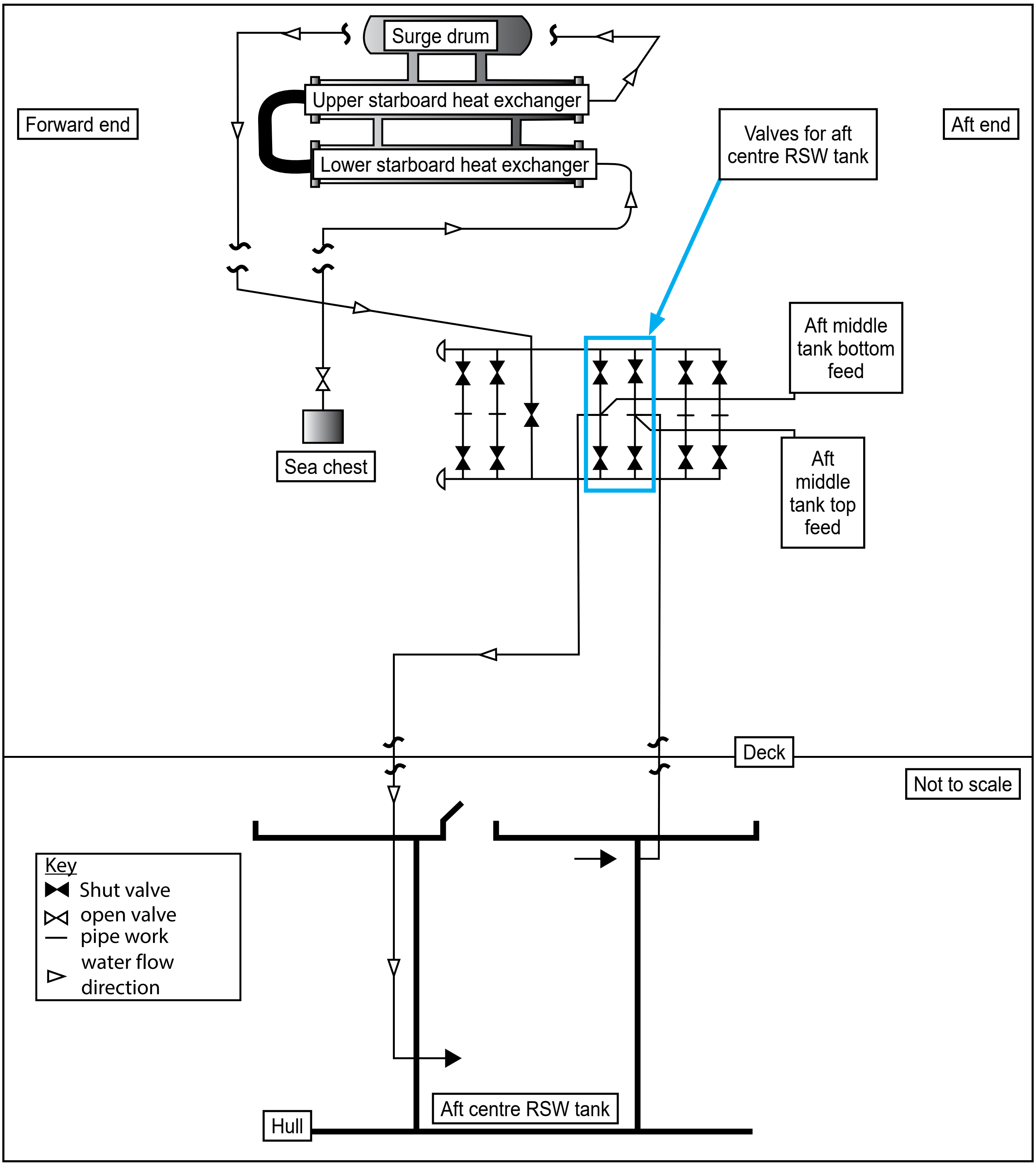

Figure 3: Schematic diagram of *Sunbeam*'s RSW system

compressor, a condenser, a liquid receiver and an evaporator. Each evaporator comprised two 'shell and tube' heat exchangers mounted horizontally, and each heat exchanger contained 142 corrosion resistant aluminium-brass alloy[6] tubes. Seawater was chilled as it passed through the evaporators' tubes with the liquid Freon refrigerant evaporated on the shell side.

On departure from harbour, *Sunbeam*'s refrigeration plants were started, and both operated in order to cool the seawater in the RSW tanks. With a typical seawater temperature between 10ºC and 15ºC at plant start-up, it would take 6 to 7 hours

[6] Alloy consisted of 76% copper, 2% aluminium, 22% zinc with a smooth bore and a finned external surface.

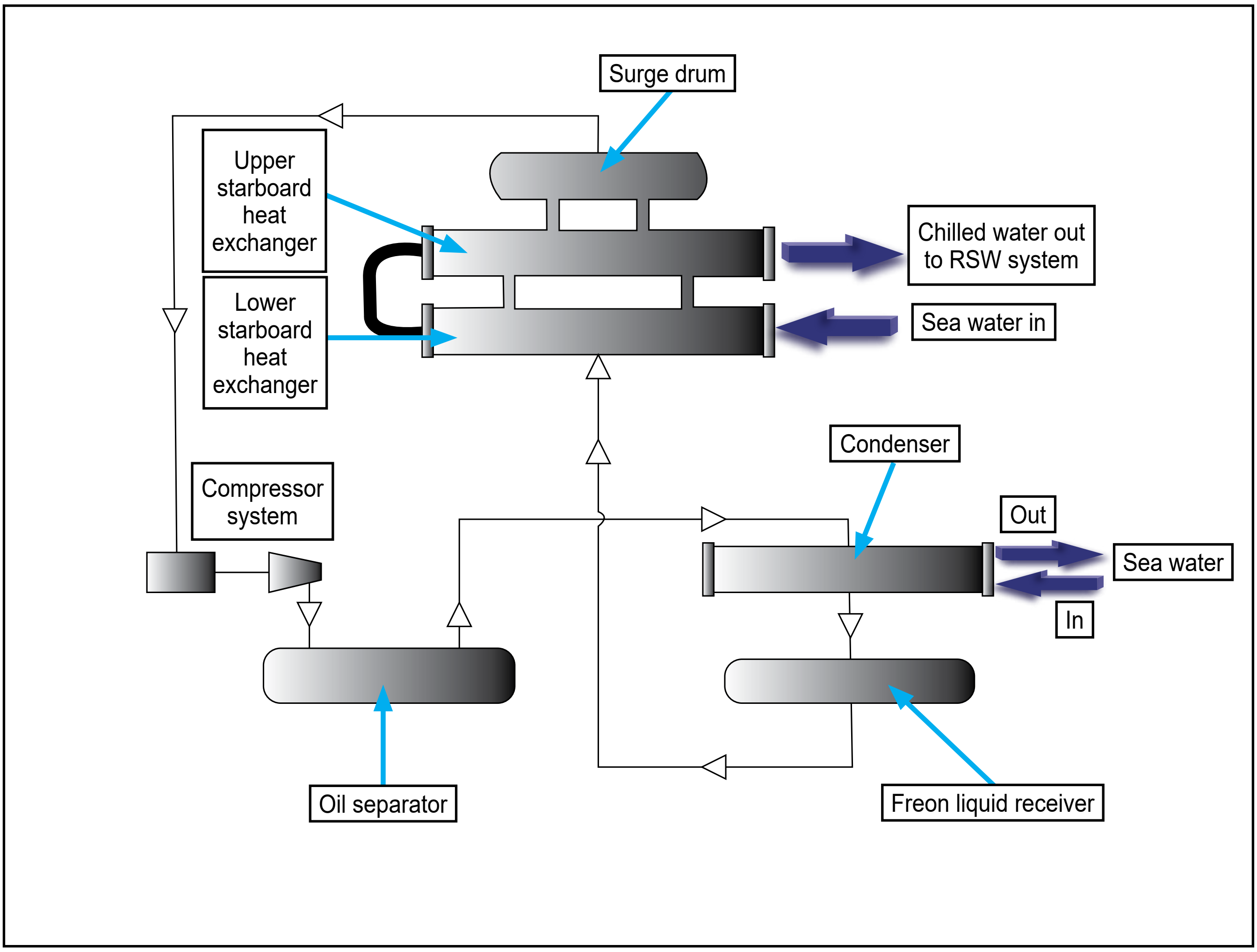

Figure 4: Schematic diagram showing one of *Sunbeam*'s two refrigeration plants

to achieve the desired chilled water temperature of 0ºC. Both plants were run until the water temperature dropped to 1ºC and then one plant was shut down. When underway, *Sunbeam*'s engineering team maintained a watch system and the refrigeration plant was regularly monitored, but no log of temperatures, pressures, fluid levels or running load was maintained.

1.6.3 Refrigerant

Sunbeam's refrigeration plants used Freon, which was a colourless, odourless ozone depleting hydrochlorofluorocarbon (HCFC). Freon existed in a gaseous form at normal atmospheric pressure and was three times denser than air.

The oxygen deprivation level for Freon was 140,000 parts per million (ppm); this limit is defined[7] as the '*concentration of a refrigerant or other gas that can result in insufficient oxygen for normal breathing*'. As a denser than air gas, the presence of Freon in an enclosed space will result in the displacement of air that creates a risk of asphyxiation due to lack of oxygen. The symptoms of oxygen deprivation are dizziness, headache, nausea or loss of concentration, and an oxygen level of less than 10% can be fatal following rapid unconsciousness without warning. At high concentrations and with prolonged exposure, Freon can also exhibit toxic properties.

[7] BS ISO 817:2014.

Use of ozone depleting substances has been gradually phased out in accordance with EU legislation[8]. Since January 2015, it has not been permitted to add Freon (new, recycled or reclaimed) into any operational equipment. Continued use of legacy equipment with Freon was permitted using the existing gas within the equipment. The replacement of Freon or maintenance that involved removal of Freon, or topping up of systems operating with it, were all banned.

Each of *Sunbeam*'s refrigeration plants was designed to be operated with 395 litres (486kg) of liquid refrigerant. Until the end of 2017 existing quantities of Freon refrigerant was decanted out of the system by the crew and stored on board in cylinders when the refrigeration plants were not in use. In January 2018, based on advice from a refrigeration engineer, the decanting procedure was discontinued, and the refrigerant remained in the plant when shut down.

Sunbeam's crew maintained an Ozone Depleting Substances Log but it contained no record of any consumption or transport (internal or external to the vessel) of refrigerant.

1.6.4 Operational use and cleaning process

When on passage to the fishing grounds, the seawater in *Sunbeam*'s RSW tanks was chilled prior to fish being stored in them. After discharging the caught fish to a shore processing plant, the tanks that had been used for holding fish were pumped dry and then washed by the crew to clear away any residual fish; the process of filling tanks and storing fish was then repeated.

On passage home to Fraserburgh, *Sunbeam*'s RSW tanks were flushed with seawater. After berthing in Fraserburgh, the RSW tanks were all pumped dry and then deep cleaned. This was usually conducted by the deckhands with the engineering crew using the bilge system to pump out the cleaning water residue.

The three aft RSW tanks had bilge suctions located at their forward end. With all the RSW tanks empty, *Sunbeam* adopted a stern trim. This meant that residual water in the aft tanks needed to be manually swept with a shovel from the aft end, where it tended to collect, to the bilge well at the forward end. Residual water and a plastic shovel were found in the aft centre RSW tank after the accident **(Figure 2)** and the vessel's bilge pumping system was found configured to pump from that tank.

1.6.5 Refrigeration plant control

Sunbeam's refrigeration plants had a control system that monitored temperatures and pressures, adjusting the compressor capacity in order to regulate the chilled water temperature. The desired chilled water temperature was adjusted by the engineers.

Each compressor was fitted with a slide valve, providing variable capacity control between 25% and 100%, representing the minimum and maximum chilling capacity. The compressors had to be started at the minimum capacity setting and, once running, could be gradually increased up to full capacity.

The refrigeration plants could be operated in either automatic or manual control. With automatic selected, the control system continually adjusted compressor capacity to deliver the desired chilled water temperature. In manual control, the

[8] EU Regulation EC/1005/2009.

plant operator set the compressor capacity by operation of a switch on the control panel. Once the operator had set the compressor capacity, it remained fixed regardless of any changes in the cooling load demand. This meant that, in manual control, the system would not respond to temperature changes in the evaporators without the crew's intervention. This situation increased the risk of water freezing inside the evaporator tubes, and consequent risk of damage to the tubes. When in manual control, all the refrigeration plants' protection devices including temperature, pressure and flow rate alarms and safety cut-outs remained active, unless over-ridden by the crew.

Since January 2018, *Sunbeam*'s crew had only operated the refrigeration plants in manual control. This was the only mode available on the port plant due to a failure of the port compressor's automatic capacity control switch. This, combined with the crew's assessment that automatic control could put an unnecessary high load on the system, resulted in both plants being operated only in manual control.

1.6.6 Refrigeration plant maintenance

Routine maintenance and defect rectification of the refrigeration plants was carried out on board by the crew utilising contractor support where necessary. There was no formal plan or onboard record of refrigeration plant maintenance although the chief engineer's diary contained some records of completed tasks.

Sunbeam's crew, in conjunction with refrigeration and control engineering specialist contractors, had made repairs and modifications to maintain the refrigeration plants. In January 2018, evaporator tube failures had been detected and repaired in the starboard evaporator; leaking tubes had been isolated with brass plugs.

1.7 TECHNICAL INVESTIGATION OF *SUNBEAM'S* REFRIGERATION SYSTEMS

1.7.1 Scope

After the accident, Star Technical Solutions Limited (STS), the technical advisory service of Star Refrigeration Limited, was commissioned to investigate *Sunbeam*'s refrigeration systems. The aim of the investigation was to provide an expert opinion on the presence of any leaks in the refrigeration plants, and the likely pathway of Freon into the aft centre RSW tank. STS's technical investigation was led by a senior consultant who had 28 years' experience in the refrigeration industry. He was a chartered engineer, a member of the Institution of Mechanical Engineers and a fellow of the Institute of Refrigeration.

1.7.2 Plant examination on site

An examination of *Sunbeam*'s refrigeration plants and a pressure test of both evaporators was conducted by STS with MAIB inspectors in attendance on 26 and 27 September 2018. Both refrigeration plants were made safe for examination through the removal of the remaining refrigerant; this was 312kg from the port plant and 178kg from the starboard plant.

The top and bottom end covers of both port and starboard evaporators' heat exchangers were removed to expose the tube plates and tube ends. In the port upper heat exchanger, 17 (of 142) tubes had been blocked at each end with brass plugs. The starboard upper heat exchanger had 27 tubes similarly plugged. Of these

27 plugged tubes, 23 had a plug in each end and 4 of the tubes[9] had a plug fitted at only one end **(Figures 5a and 5b)**. Pressure testing identified leaks on four of the tubes[10] in the starboard evaporator; one of which, tube 5, had been plugged at only one end.

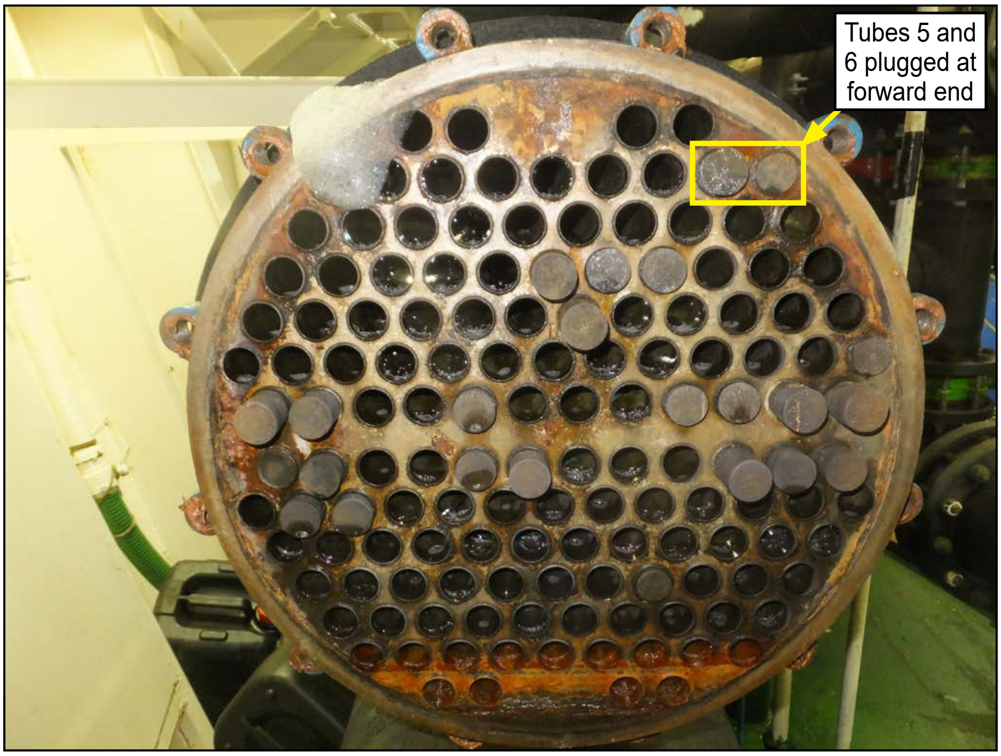

Figure 5a: *Sunbeam*'s starboard upper heat exchanger, forward end showing tubes 5 and 6 sealed with brass plugs

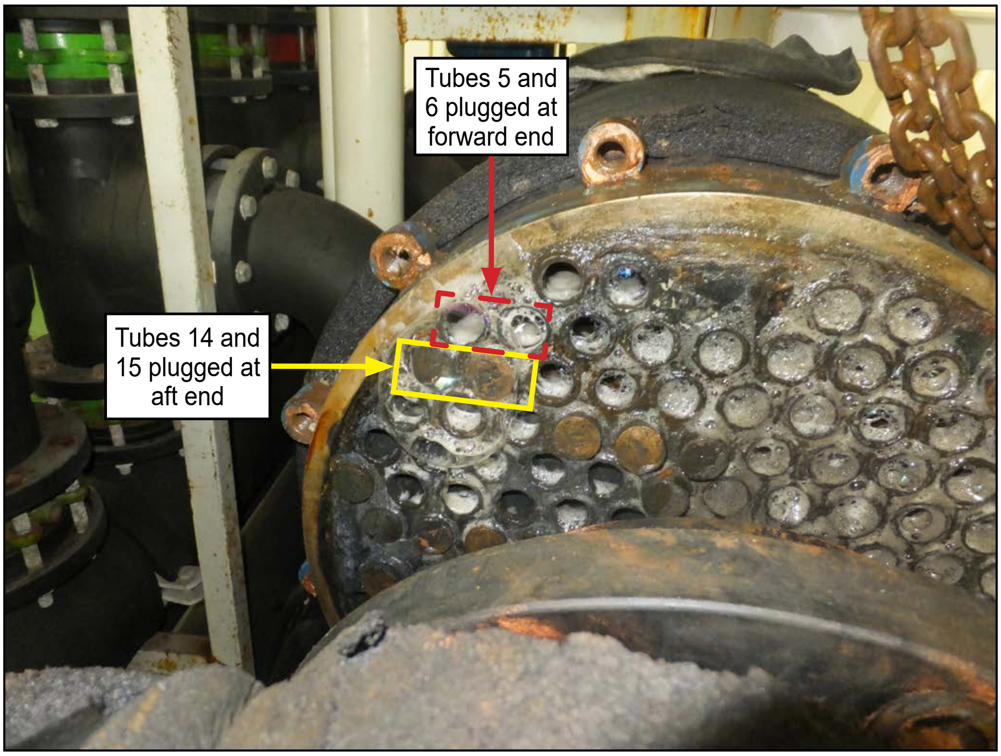

Figure 5b: *Sunbeam*'s starboard upper heat exchanger, aft end showing tubes 14 and 15 sealed with brass plugs (immediately below tubes 5 and 6)

9 Tubes 5, 6, 14 and 15 were plugged at only one end.

10 Tubes 5, 13, 60 and 71 were identified as leaking.

1.7.3 Offsite examination and testing

STS subcontracted Element Materials Technology (EMT) of Edinburgh to conduct metallurgical examination and test of tubes 5, 13, 60 and 71 that had failed leak tests on board and had been extracted from the starboard evaporator. These tests identified the presence of pinholes and cracks in the tubes **(Figure 6)** and EMT's report concluded that '*the failure of the tubes was attributable to pitting and cracking caused by intergranular corrosion which initiated in the tube bores*.'

Images courtesy of Element Materials Technology, Edinburgh

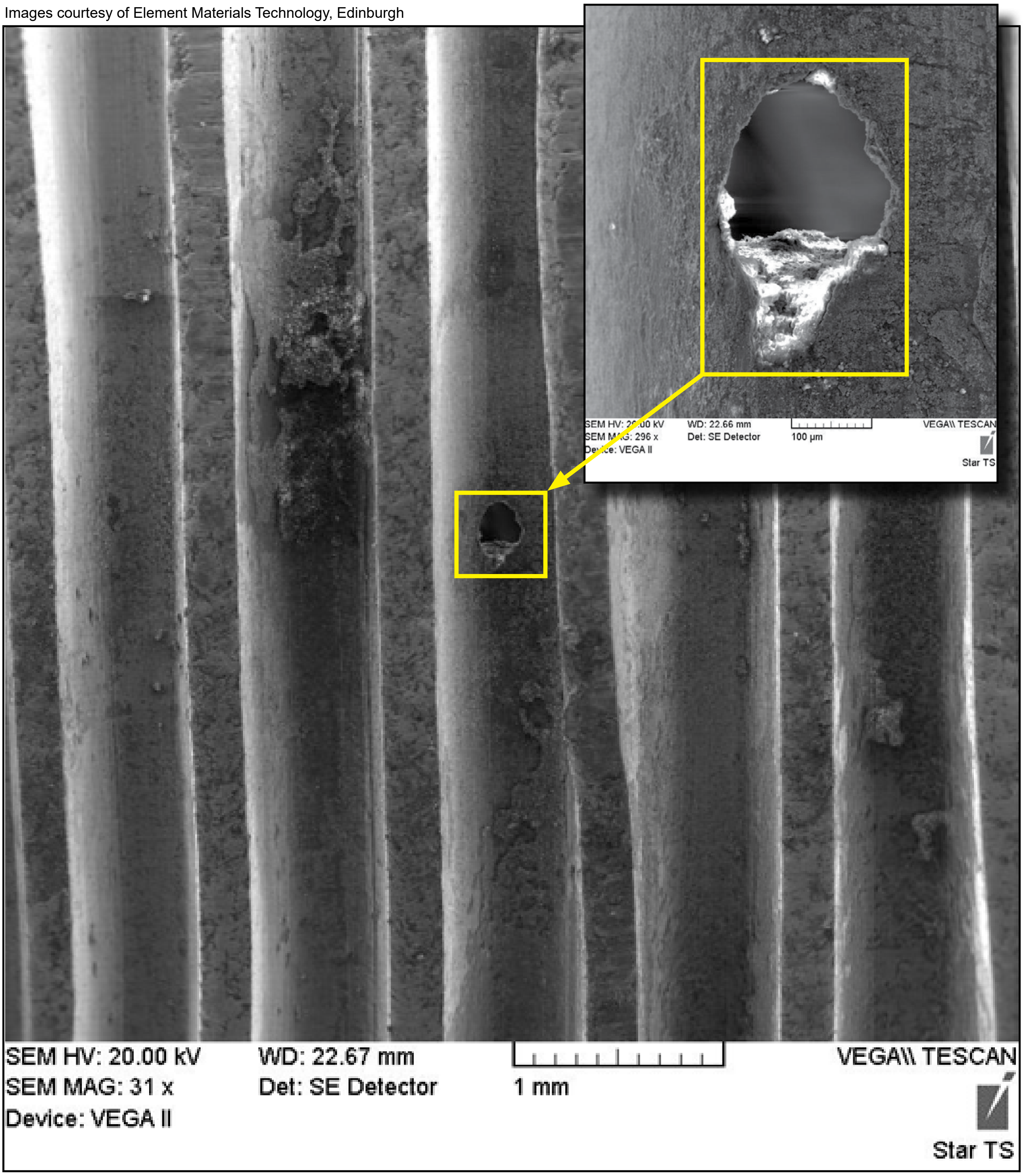

Figure 6: Microscopic examination of failed heat exchanger tubes with detail inset

STS also removed the aft centre RSW tank's seawater inlet and return isolation valves for inspection and testing. Visual inspection of the pump discharge isolating valve for the aft centre RSW tank identified that its disc was damaged by significant notches around the edge **(Figure 7a)**. Visual inspection of the pump suction valve for the aft centre RSW also showed a significant notch on the disc edge **(Figure 7b)**. Visual inspection of the isolating valves for the other RSW tanks did not reveal significant disc damage.

Sunbeam's seawater isolating valves were not designed to be gastight but were tested to identify whether Freon (in a gaseous form) could pass through them when in the shut position. The tests demonstrated that Freon gas would leak past both valves when in the shut position by gravity from the evaporators located above.

1.7.4 STS's key conclusions

The key conclusions extracted from STS's report were:

- *'Unattended manual operation of the compressors, which was the norm, anecdotally for periods ranging from >1/2 hour to up to 3 or 4 hours, significantly increases the risk of tube freezing.*

- *The method for sealing the leaking tubes by fitting brass plugs at both ends of a leaking tube was suitable… However, it is clear that a mistake was made in plugging Tube 5, when only its forward end was sealed. This was compounded by not having a post repair check process in place for the heat exchanger after the plugs were fitted. A post repair pressure test or pulling a vacuum and holding it for a period of time, prior to recharging the system with R22, would have clearly shown there were still leaks.*

- *While corrosion was the key factor in the failure…the EMT report provides further evidence that there was internal pressure applied …at the point of failure. The extent of corrosion at the point of failure was such that only a relatively small pressure difference would be needed to cause it.*

- *The leaks were significant in that they allowed R22 refrigerant gas to leak from the heat exchanger into the RSW System and into the aft middle RSW tank. This rate of leakage was high enough that over the period between midnight on the 9th of August 2018 and mid-day on the 14th of August 2018, after the R22 Refrigeration Systems had been shut down, sufficient R22 accumulated in the unventilated aft middle RSW tank to exceed all practical safety limits and was immediately dangerous to life & health. My assessment is that at the time the deceased and other personnel entered it, the concentration of R22 at the bottom of the tank was no less than 200,000 to 300,000 ppm*[11] *and was probably significantly higher.*

- *The most direct route for R22 gas from the top starboard evaporator to any of the RSW Tanks was via a common manifold line that also had other top (pump discharge) isolating valves connecting it to the other aft tanks* **(Figure 8)***. It is my opinion that R22 was only seen in the middle aft tank as, although closed at the time of the incident, the top (pump discharge) isolating valve provided the path of least resistance to the R22. This was probably due to the extent of damage seen on its disc edge compared to the other adjacent valves.*

[11] These values significantly exceed the potentially fatal oxygen deprivation limit of 140,000ppm [Section 1.6.3].

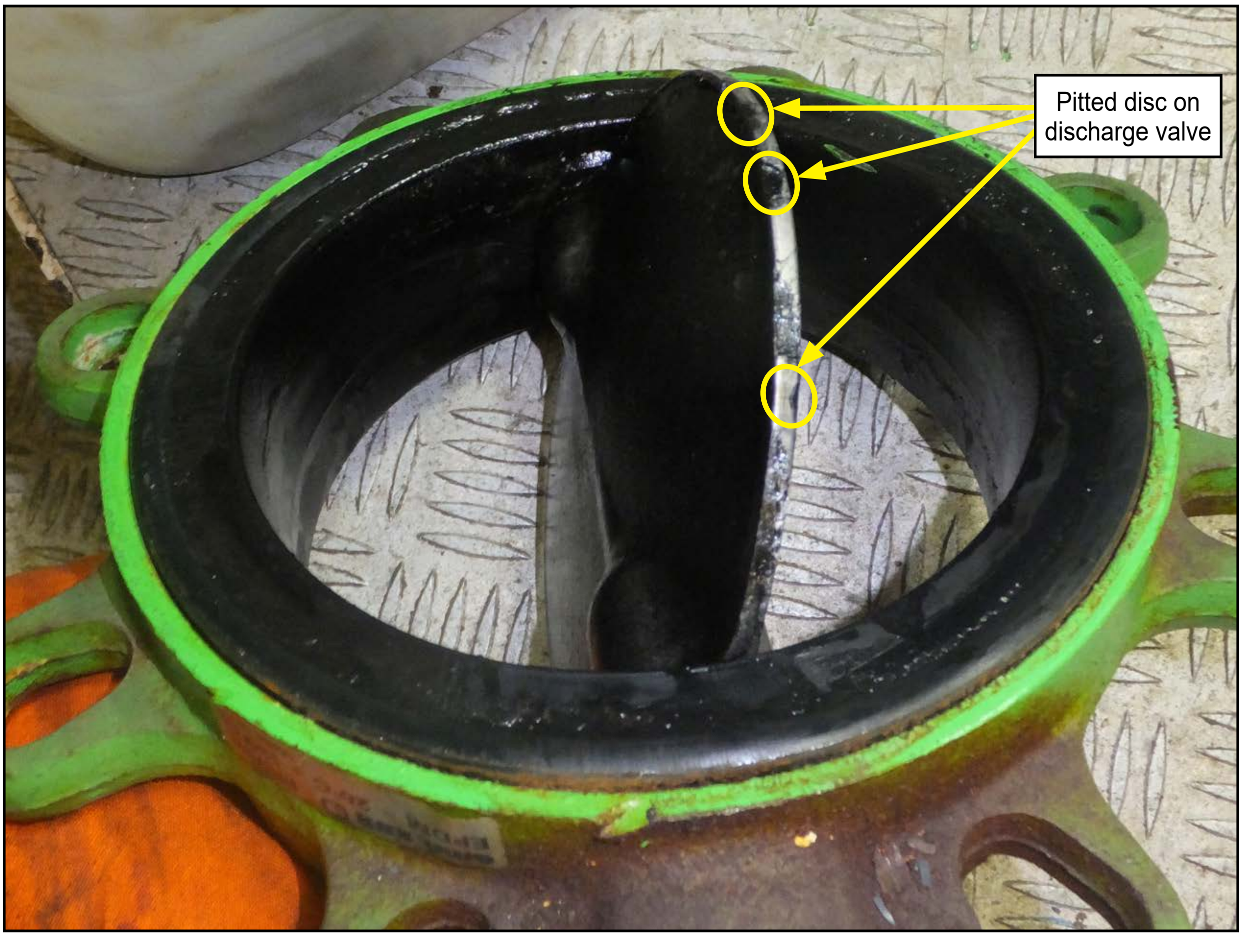

Figure 7a: Aft centre RSW pump discharge isolating valve showing significant notches on disc edge

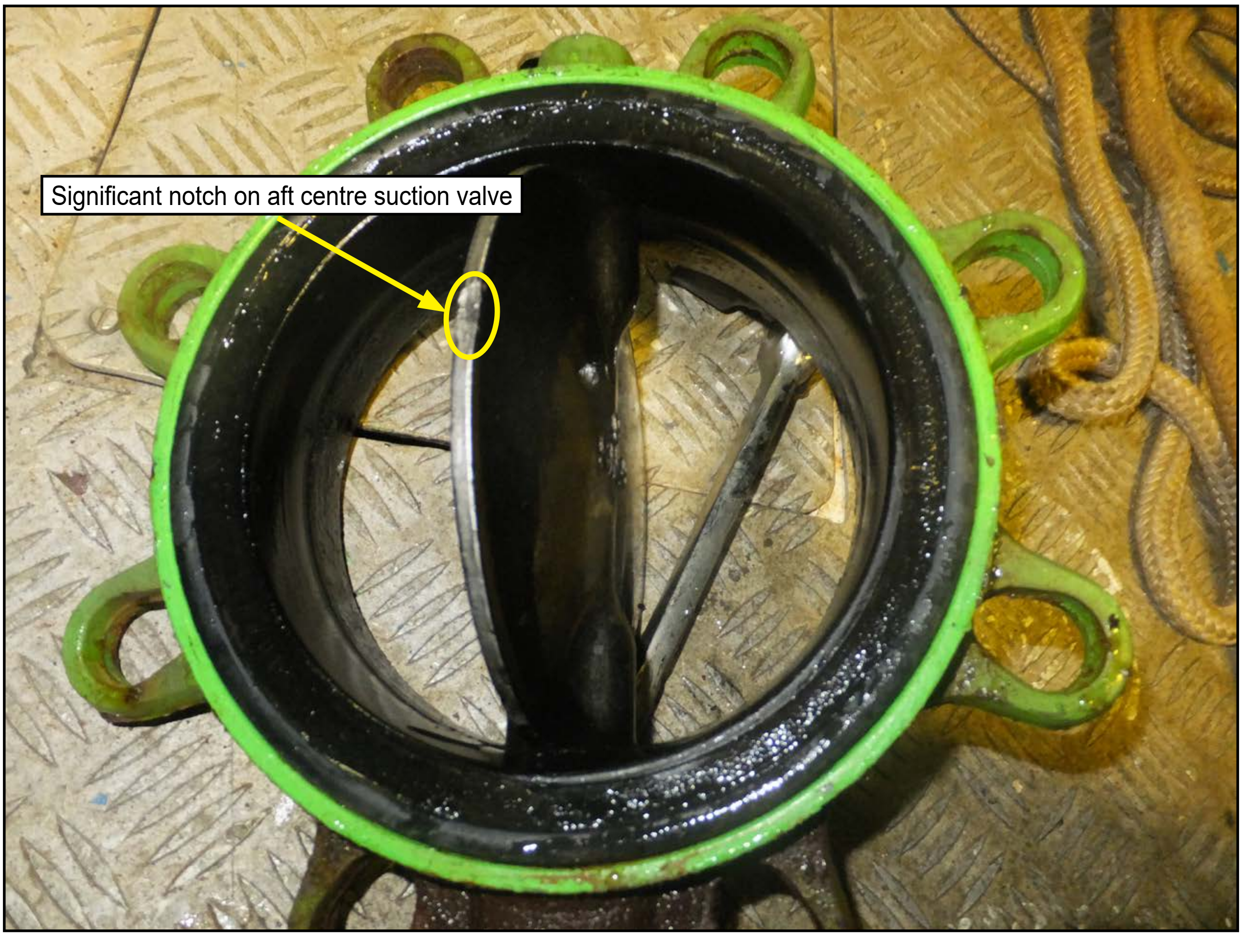

Figure 7b: Aft centre RSW pump suction isolating valve showing a single significant notch on disc edge

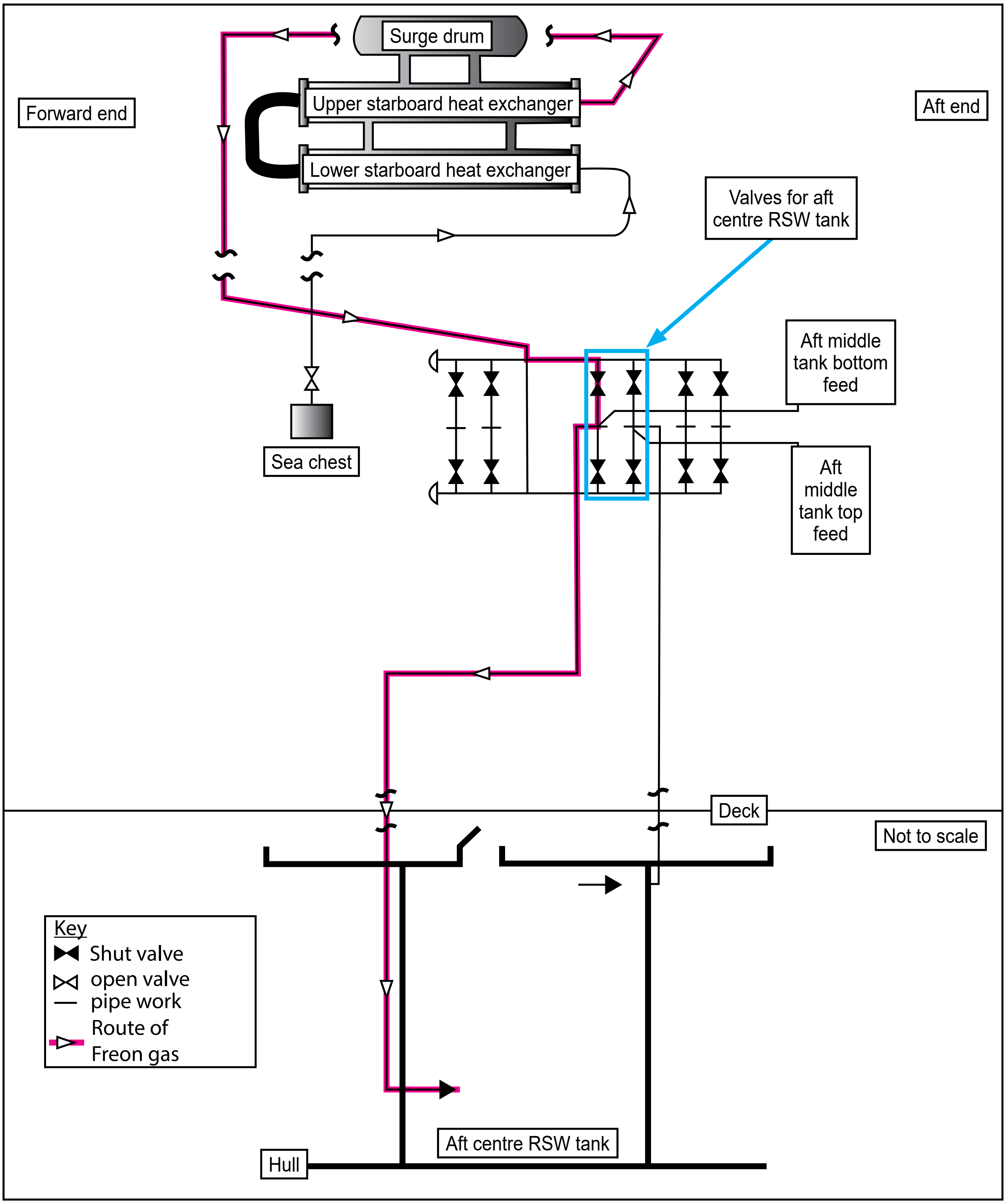

Figure 8: Schematic diagram of *Sunbeam*'s RSW system highlighting the freon gas' route through the RSW system into the aft centre RSW tank

- *As far as the R22 Refrigeration Systems on the MFV Sunbeam were concerned, my conclusion is that reactive maintenance, associated with components failing, was practiced, rather than any planned preventative maintenance. Reactive maintenance is not a wholly unknown way for refrigeration plant operators to run their systems, in fact it might be argued it is a valid approach, particularly given the low annual running hours, due to the operational pattern of the pelagic fishing season. However, it leaves plant* *operators open to higher risks associated with unplanned equipment outage and premature failure. In addition, certainly latterly, with the potential of a new RSW refrigeration system getting closer, the imperative to repair malfunctions, other than identified R22 leaks, were not prioritised, and a "make do and mend" approach was adopted.*

- *Sheet G012 of Standard Risk Assessment Forms…is inadequate for a number of reasons: it does not describe the work activity involved, it does not define who could be at risk, it does not mention all of the hazards associated with the anticipated work activity, and the proposed control measures statement is inadequate as it does not define the PPE requirements, or describe the work equipment to be used.'*

1.8 SAFETY MANAGEMENT

1.8.1 The Code of Practice

The Merchant Shipping and Fishing Vessels (Health and Safety at Work) Regulations 1997 required employers to make a suitable and sufficient assessment of the risks to the health and safety of fishermen. *Sunbeam* was operated in accordance with the MCA's *Code of Practice for the Construction and Safe Operation of Fishing Vessels of 24m Registered Length and Over* (The Code of Practice), that was promulgated in Merchant Shipping Notice (MSN) 1873(F) and came into force in October 2017.

Key aspects of the Code of Practice were:

- Section 4.1.17 stated that refrigerating plant '*shall be of a design and construction adequate for the service for which they are intended and shall be so installed and protected as to reduce to a minimum any danger to persons on board. Refrigerant detection sensors, compatible with the refrigerant being used, shall be fitted*.'

- Sections 4.1.17.5 to 4.1.17.9 provided guidance specifically for compartments containing refrigerating machinery. This included a requirement for gas leak detection, exit routes, alarms and provision of BA where refrigerant harmful to personnel was carried. Refrigerating plants were also required to be maintained '*in an efficient working condition and examined by the Classification Society, or as directed by MCA, at regular intervals*.'

- Sections 6.1.2.2 to 6.1.2.6 regarded crew safety and required risk assessments that were '*intended to be a careful examination of the vessel's procedures or operations which could cause harm, so that decisions can be made as to whether adequate control measures are in place to reduce those risks to an acceptable level or whether more shall be done*.' Risk assessments were required to be reviewed at least annually and the crew were required to be briefed on the onboard safety measures.

- Sections 6.1.7.1 to 6.1.7.4 provided guidance specific to the ventilation of enclosed workspaces. This required sufficient ventilation in workplaces taking into account '*the work methods used and the physical demands that are placed on the crew*.' Furthermore, it stated that '*effective means of ventilation shall be provided to all enclosed spaces that may be entered by persons on* *board*.' The Code of Practice also drew the attention of skippers and owners to the MCA's Marine Guidance Notice (MGN) 309(F) *Fishing Vessels – The Dangers of Enclosed Spaces*.' **(Annex A)**.

- Chapter 8 of the Code of Practice required that '*the Owner must establish plans and instructions, including checklists as appropriate, for key shipboard and fishing operations concerning the safety of the ship and crew and the prevention of pollution*.' The chapter included guidance and the requirement for crew training in abandon ship, fire, anchoring and man overboard. There was no specific obligation for training or drills in enclosed space rescue.

1.8.2 Enclosed space safety

Potential hazards associated with enclosed spaces include exposure to heat, flooding, flammable gases, toxic gases or oxygen deprivation. The International Maritime Organization's (IMO) definition[12] of an enclosed space was a compartment that had any of the following characteristics: '*limited openings for entry and exit; inadequate ventilation; and not designed for continuous worker occupancy*'.

The MCA's Merchant Shipping (Entry into Dangerous Spaces) Regulations[13], 1988 applied to all UK-registered vessels, excluding fishing vessels. These regulations required procedures for safe entry to potentially dangerous spaces, regular crew rescue drills and the carriage of suitable atmosphere testing equipment. Dangerous spaces in these Regulations were defined as '*any enclosed or confined space in which it is foreseeable that the atmosphere may at some stage contain toxic or flammable gasses or vapours, or be deficient in oxygen, to the extent that it might endanger the life or health of any person entering the space*.'

Guidance for enclosed spaces in the UK fishing industry was provided in MGN 309(F) **(Annex A)**. This MGN specifically warned of the unseen risks from the build-up of gases in enclosed spaces, including RSW tanks. The MGN also offered guidance that enclosed spaces should be entered only '*if absolutely necessary*'. If entering an enclosed space, the guidance stated that the compartment should be ventilated and, before entering, the atmosphere tested for oxygen and combustible or toxic gases. There was also guidance on preparations for dealing with an emergency, including communications with those in the enclosed space, and a rescue plan.

The MCA Fishermen's Safety Guide stated that '*it may be unsafe to enter an enclosed compartment or confined space either because the air in it has too little oxygen or because it has poisonous fumes in it, therefore there is a danger of suffocation. For example: fires, fumes from fuel or engines, escaped refrigerant gases, rotting fish in the refrigerated seawater tanks (RSW tanks) and rusting inside a space which is hardly ever entered. Do not go into an enclosed space to assist someone in difficulty without wearing the correct gear and having back up from other crew members*.'

[12] IMO Resolution A.1050(27), Recommendations for Entering Enclosed Spaces Aboard Ships, dated 20 December 2011.

[13] Statutory Instrument 1988 No. 1638.

1.8.3 *Sunbeam*'s safety folder

Sunbeam's safety folder (extract at **Annex B)** contained details of the onboard safety management arrangements. The safety policy statement stated that the vessel would be operated in accordance with Health and Safety Regulations in order to minimise the risks to the crew. The safety folder's signature sheet stated that the risk assessments had been reviewed in 2018; however, the amendment record sheet was blank and the individual risk assessment sheets had been assessed, authorised and signed by a previous mate, dated 11 September 2000. The safety folder included emergency procedures for: man overboard, fire, abandon ship, helicopter rescue and collision. The folder also listed all safety equipment on board. *Sunbeam*'s record of training and drills included regular checks of fire, man overboard and abandon ship procedures.

Risk Assessment Form G012 **(Annex B)** covered maintenance work on board. This form included the possible hazards of refrigerant gases and enclosed spaces. For refrigerant gases, the control measures stated that only trained and experienced crew were permitted to maintain the system. The risk assessment also stated that '*in enclosed spaces, such as tanks that have held fuel or oil, do not enter until checks have been made…*'

The folder did not contain safety or emergency procedures for enclosed spaces; there was no record of enclosed space training, and no atmosphere monitoring equipment on board.

1.8.4 Industry safety initiative

In order to assist fishing vessel owners and operators to comply with the International Labour Organization's Working in Fishing Convention 188 (ILO188) and the relevant Code of Practice, the MCA developed the Fishing Safety Management Code (FSM Code) with industry co-operation.

The FSM Code was introduced in October 2017 through the MCA's Marine Information Note (MIN) 558(F). In November 2018, MIN 558(F) was replaced by MGN 596(F) – *Fishing Safety Management Code*. The FSM Code included guidance on maintenance management, safety reviews, crew certification, incident reporting and environmental management. In establishing a safety management system (SMS) on board a fishing vessel, the FSM Code recommended that the SMS should include:

- *Company Safety and Environment Policies;*
- *All crew certification and training records;*
- *Planned maintenance system;*
- *Vessel Operation (operating procedures and the risk assessment);*
- *Testing/Certification relating to the lifesaving appliances and fire-fighting equipment;*
- *Accident and incident reports and any remedial actions taken thereof;*

- *Evidence of reviews of your safety management system, self-audit Reports and close outs thereof;*

- *Environmental management and pollution prevention; and,*

- *Records of drills and safety training.*

Annex 2 to the FSM Code was an aide-mémoire for fishing vessel owners and skippers to create an SMS. Section 8 listed the procedures necessary for potential onboard emergencies, including entry into enclosed spaces.

1.9 SURVEY AND OVERSIGHT

1.9.1 Overview

The MCA's survey policy for fishing vessels over 24m was published in MGN 439(F)[14], which explained that, in the absence of its own specific rules for design, construction and maintenance of over 24m fishing vessels, the MCA accepted classification society rules[15] instead. The MCA's MGN 322[16] stated that over 24m fishing vessels were required to be maintained in accordance with classification rules (referred to as 'in class'). Classification society rules for UK flagged vessels were provided by one of the MCA's Recognised Organisations (RO); LR's rules were acceptable to the MCA.

Survey items for over 24m fishing vessels delegated by the MCA to LR in its partial authorisation document were:

- *hull construction, strength and watertight integrity;*

- *scuppers, inlets, discharges and water freeing arrangements;*

- *main and auxiliary machinery for propulsion and safety;*

- *shafts, gearbox, propellers and steering;*

- *pressure vessels and systems;*

- *fuel, lubricating oil, seawater systems and hydraulics;*

- *fire safety;*

- *refrigeration plant;*

- *electrical systems;*

- *anchors, cables and windlasses;*

- *fishing gear and lifting equipment; and,*

- *stability.*

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[14] MGN 439(F): Survey Standards for 24m and over Registered Length Fishing Vessels.

[15] Referred to as 'class rules'.

[16] MGN 322 (M+F): Ship Survey Standards.

Survey items (in accordance with either the construction rules that were in force at the time of build and/or the Code of Practice) that were not delegated to a classification society, remained the responsibility of MCA surveyors to assess. For over 24m fishing vessels, the MCA would issue an International Fishing Vessel Certificate (IFVC).

Items surveyed under classification society rules were on a 5-year cycle; Flag State survey items were on a 4-year cycle, with intermediate reviews. The MCA maintained a regular dialogue with its ROs to review operational and policy matters.

1.9.2 MCA surveys of *Sunbeam*

Sunbeam was surveyed by the MCA and issued with a full-term IFVC, dated 12 April 2016 and valid until 10 July 2019, stating compliance with the EU Regulations[17] and the 1975 rules[18]. Intermediate surveys of *Sunbeam* were undertaken by MCA surveyors on 20 June 2017 and 20 June 2018. For both these surveys, the MCA surveyors used a survey items checklist[19] based on the Code of Practice. Under the heading '*Survey/Inspection*', the checklist included a line for '*Refrigeration Plant, condition and operation*'; under the heading '*Certificates and Records*', the checklist included the line item '*Risk Assessment – copies on board/available in risk assessment folder. Note: change of ownership or change of mode of fishing will require amendment/new Risk Assessments*.' The checklist did not include a requirement for an assessment of enclosed space operations. The completed checklist for the June 2017 survey showed that both the refrigeration and risk assessments boxes had been ticked; for the June 2018 survey, the refrigeration box had not been ticked but the risk assessments box had been.

Guidance for MCA surveyors when conducting surveys and inspections of fishing vessels[20] required the surveyor to establish that risk assessments existed, and specifically, that they had been kept up to date and contained '*adequate information to inform of the hazard associated with the risk*'. The MCA instructions also required surveyors to check that risk assessments referred to specific guidance in key areas, including enclosed space entry (MGN 309).

1.9.3 LR surveys of *Sunbeam*

Between 22 May 2014 and 13 August 2018 surveyors from LR attended *Sunbeam* on ten[21] occasions to survey items delegated under the class rules. LR had issued a Certificate of Class for *Sunbeam*, dated 1 July 2014 and valid until 10 July 2019. The Certificate of Class stated that *Sunbeam* had been surveyed by LR and found compliant with the classification rules and regulations for ships. LR had also issued *Sunbeam*'s International Air Pollution Prevention Certificate certifying compliance with the IMO MARPOL Annex VI[22] Regulations.

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[17] European Union Directive 97/70/EC of 11 December 1997 – a harmonised safety regime for fishing vessels of 24m in length and over.

[18] The Fishing Vessels (Safety Provisions) Rules 1975 (that applied to *Sunbeam* at build).

[19] MCA Form MSF 5551: over 24m Survey/inspection Aide-memoire, revision 10 October 2013.

[20] MSIS 27/CH1/Rev 0620, Article 1.11.

[21] LR Final Reports for surveys conducted on: 22 May 2014, 26 June 2014, 11 June 2015, 10 July 2015, 29 September 2015, 6 May 2016, 30 September 2016, 13 October 2017, 29 November 2017 and 13 August 2018 (the day prior to the accident).

[22] International Maritime Organization's MARPOL Regulations Annex VI: Prevention of Air Pollution from Ships.

LR's survey reports included details of the items assessed during the survey. Despite the delegation by the MCA to LR for the survey of refrigeration machinery [Section 1.9.1], there was no record of refrigeration machinery surveys on board *Sunbeam* between 2014 and 2018. However, LR's report of the survey conducted on the day prior to the accident did refer to refrigeration and ozone depleting substances, stating that the equipment was '*approaching its allowable date'* and that the vessel's ozone depleting record book was *'to be updated*'.

1.10 PREVIOUS SIMILAR ACCIDENTS

1.10.1 *Atlantic Princess* – MAIB report dated 24 July 1997[23]

On 25 July 1996, three crew members died and six were injured on board the UK registered fishing vessel *Atlantic Princess* while attempting to flush and clean an RSW tank. The vessel was fishing off the coast of Mauritania and the accident occurred when the third engineer opened the side door to an RSW tank. Shortly after opening the side door, the third engineer collapsed. Unaware of the reason for the collapse, several of the engineer's colleagues went to his assistance. By the time the crew realised that toxic gases had escaped from the RSW tank, several other crew members were overcome. The situation was eventually brought under control but not before three crewmen had suffered fatal effects and six others injured.

The investigation found that a toxic atmosphere, which included hydrogen cyanide and hydrogen sulphide, had built up in the sealed RSW tank due to the presence of rotting fish. The report recommended that all operators of fishing vessels equipped with RSW systems:

- *'Fully ventilate all fish storage tanks and areas with outside air where a mixture of fish and sea water, or sea water contaminated with fish waste, is likely to remain for more than a few hours.*

- *Ensure that all working areas, including ramp decks, are fully ventilated using a positive pressure system to remove dangerous concentrations of toxic gases from fish storage and processing areas and bilges.*

- *Provide rescue equipment such as self-contained BA for use in spaces likely to be subjected to the presence of toxic gases and ensure that the crew are properly trained in its use. It is also recommended that periodic emergency exercises are conducted.*

- *Ensure that crew members are trained to a defined level of competence in the use of RSW systems.*

- *Make suitable arrangements to ensure that when crew changes take place, safety precautions are continuously implemented.*

- *Ensure that precautions continue to be carried out and that adequate information is available for checking what is done in practice. A record should be kept showing specified information including when RSW tanks are cleaned.*

[23] https://www.gov.uk/maib-reports/toxic-fumes-from-refrigerated-sea-water-tank-on-pelagic-freezer-trawler-atlantic-princess-off-mauritania-west-africa-resulting-in-6-people-affected-by-fumes-and-loss-of-3-lives

- *Supply and maintain gas level and oxygen depletion monitoring equipment on board, and ensure that crew are trained and practised in its use.*

- *Assess the risk of toxic gases and oxygen depletion as a result of operation of RSW systems.'*

The MAIB's report into this accident made a recommendation to the Marine Safety Agency[24] to introduce a Code of Practice to address the risk of toxic gas production arising from the operation of RSW systems.

1.10.2 *Viking Islay* –MAIB Report 12/2008[25]

On 29 September 2007, three crewmen on board the emergency response rescue vessel *Viking Islay* lost their lives as a consequence of entering the vessel's chain locker. The MAIB's investigation identified that the fatalities were attributable to oxygen depletion in the compartment caused by corrosion. The crew had not recognised that the chain locker was a potentially hazardous enclosed space; as a result, appropriate and well-established safety procedures were not followed. Training and drills for the use of emergency equipment were also found to be insufficient.

The MAIB's report into this accident reproduced the text of an MAIB safety digest article published in 2002 that stated:

- *'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.*

- *Some spaces are evidently dangerous, and there are very sound rules in place to prevent accidents…other spaces are not necessarily quite so obvious. If in doubt, assume the space is potentially dangerous and take the necessary precautions.*

- *Never ever carry out an entry alone. A well-formulated plan should always be followed.'*

1.10.3 *Oileán an Óir* – MCIB Report 246/2016[26]

On 24 August 2015, two members of the crew from the fishing vessel *Oileán an Óir* were rescued from inside one of the vessel's RSW tanks, where they had been working to pump out water. Despite the attendance of the emergency services, neither of the crewmen survived.

The MCIB's report of the investigation into the accident concluded that both fatalities were attributed to the inhalation of lethal levels of hydrogen sulphide due to the presence of stagnant water and rotting fish. *Oileán an Óir*'s crew were not properly equipped for atmosphere monitoring in the RSW tanks, and the hazards associated with enclosed spaces were assessed to be less well understood in the fishing industry compared to the broader marine industry.

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[24] The Marine Safety Agency was subsumed when the MCA was formed.

[25] https://www.gov.uk/maib-reports/entry-to-an-enclosed-space-on-emergency-response-rescue-vessel-viking-islay-off-the-east-yorkshire-coast-england-with-loss-of-3-lives

[26] https://www.mcib.ie/reports.7.html?r=209

The report made a safety recommendation to the Irish Minister of Transport, Tourism and Sport to issue a Marine Notice highlighting the risk of the build-up of toxic gases in RSW systems, details of enclosed space entry and rescue techniques and the benefits of atmosphere monitoring systems.

SECTION 2 - ANALYSIS

2.1 AIM

The aim 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 SUMMARY

One of *Sunbeam*'s 2/Es was asphyxiated and died when working alone inside an enclosed space. He was unconscious when the crew found him and three of his rescuers were also nearly overcome. The accident happened due to a leak of Freon gas into *Sunbeam*'s aft centre RSW tank from the starboard refrigeration plant. The dense Freon gas displaced the air at the bottom of the unventilated tank and created an invisible, hazardous environment that could not support life. This section of the report will assess the causes of the accident including the nature of the hazard, onboard safety management and external oversight.

2.3 THE FATAL HAZARD

Post-accident readings and subsequent laboratory analysis of atmosphere samples revealed the absence of sufficient oxygen to support life in *Sunbeam*'s aft centre RSW tank. *Sunbeam*'s crew had historically decanted the Freon out of the refrigeration plants when in harbour; however, this practice had ceased in January 2018, leaving the Freon in the system and vulnerable to any loss of containment.

STS's technical analysis demonstrated that there was a credible pathway for the Freon gas to escape out of the refrigeration plant and into the aft centre RSW tank. First, the Freon leaked through the corroded and failed tubes of the starboard evaporator into the RSW system pipework. The denser than air Freon gas then descended down into the aft centre RSW tank via damaged non-gastight seawater isolation valves **(Figure 8)**. With the tank empty of water over the weekend, there was also sufficient time for the Freon gas to build up to a point where the displacement of oxygen meant that the atmosphere could not support life.

Although the aft centre RSW's tank hatch was open, there was no ventilation system inside, so the Freon settled in the lower part of the tank. Two of the crewmen at the bottom of the tank collapsed; however, the crewman who was on the ladder only reported throat tightening and light headedness, tending to confirm that higher concentrations of Freon were at the lower part of the tank, where Mr Ironside was found.

2.4 ENCLOSED SPACES

With no ventilation, limited openings and that they were designed for the storage of fish, *Sunbeam*'s RSW tanks met every criterion of the IMO definition of an enclosed space. Prior to entering an enclosed space, it should be suitably ventilated, preferably by forced draft fans. The atmosphere should be tested for oxygen and combustible or toxic gases, and a rescue plan in place that includes communications and safety equipment, including BA, at the entry point. If someone in the enclosed space gets into difficulty, the alarm should be raised and an established procedure followed, using BA, to deliver the rescue. Entering a compartment without BA to rescue a collapsed colleague, risks the rescuer becoming another casualty.

However, *Sunbeam*'s RSW tanks were not managed by the crew as enclosed spaces. This uncontrolled entry into the RSW tank happened because the absence of appropriate safety measures had become normalised on board. The vessel had operated for many years with regular crew who were experienced and familiar with the systems and operations, and uncontrolled entry into the RSW tanks had been routine work for them. Each cycle of fishing operations involved internal cleaning of RSW tanks and pumping out of residual water. Both these tasks required crew to enter the tanks, always previously completed without incident, normalising the exposure to enclosed space risk.

All the previous accidents included in this report [Section 1.10] highlight various hazards associated with enclosed spaces. The *Oileán an Óir* investigation report established that these risks were not as readily identified or managed on board pelagic trawlers with RSW tanks, compared with merchant vessels. Indeed, a small merchant vessel of a similar size to *Sunbeam* would almost certainly be properly equipped with atmosphere testing equipment and have approved procedures for enclosed space operations.

The hazards associated with enclosed spaces include exposure to heat, flooding, flammable gases, toxic gases or oxygen deprivation, and can be present in any fishing vessel other than perhaps the very smallest open-decked boats. Fishing vessels were exempt from the Merchant Shipping (Entry into Dangerous Spaces) Regulations. Given there is effectively no difference between an enclosed space on a merchant vessel or fishing vessel, it would be appropriate for such regulations to apply to any vessel, irrespective of its operational purpose.

Although different terminology and definitions exist in UK and IMO documentation for 'dangerous' or 'enclosed' spaces, these terms are, broadly, discussing the same thing – any space where life could be endangered. Nevertheless, clarity would be improved if the terminology and definitions in use were aligned.

2.5 ATMOSPHERE MONITORING

The Code of Practice mandated a gas leak detection capability only in dedicated refrigeration machinery spaces. However, MGN 309(F) **(Annex A)** recommended that the atmosphere of any enclosed space should be tested for oxygen and combustible or toxic gases. The MAIB's report into the *Atlantic Princess* accident in 1996 made a recommendation to all operators of fishing vessels with RSW tanks to supply and maintain atmosphere monitoring equipment and to train the crew in its use. There was no atmosphere monitoring equipment on board *Sunbeam*. Therefore, it is significant and disappointing that this long-standing and evident hazard has not led to a routine industry-wide practice of providing atmosphere monitoring equipment for use in any enclosed space.

2.6 LONE WORKING

RSW tank cleaning in Fraserburgh had been interrupted by the LR survey, the fishing net offload and a defect to the pressure washer. Tank cleaning was usually undertaken by the deck crew, but when they went aft to offload the nets, the two 2/Es took the initiative to progress the cleaning task instead.

Neither of the 2/Es had been directed to carry out the tank cleaning task. Furthermore, when the first of the 2/Es entered the port forward RSW tank, he had an expectation that his colleague would be waiting on the deck by the tank hatch. However, this was not the case and the other 2/E, Mr Ironside, decided to enter the aft centre RSW tank. The reason for this decision will never be exactly known; however, the presence of water, a shovel and the bilge system being configured to pump from this tank strongly indicated that he was intending to sweep away residual water. However, the 2/E's decision to enter the aft centre RSW tank led to the unsafe, lone working situation.

Although the two 2/Es had commenced working together, their activities quickly diverged, leaving both as lone workers in potentially hazardous environments. This happened because there was no safe system of work on board *Sunbeam* for controlling maintenance activities, or for identifying when a risk of lone working existed.

Lone working is completely unacceptable in enclosed spaces. In this case, two members of the crew were inadvertently exposed to lone working hazards due to the absence of a coherent plan for controlling hazardous work on board.

2.7 REFRIGERATION PLANT MAINTENANCE

Sunbeam's refrigeration plants and control system had suffered defects and been subjected to repairs by the crew and refrigeration specialist contractors. The most significant repair work prior to the accident was the crew's plugging of failed tubes in the starboard evaporator. Unfortunately, the plugs had not been applied uniformly, resulting in a situation where tubes that had been identified as leaking had not been plugged at both ends. **Figures 5a** and **5b** show the forward and aft ends of the starboard evaporator's upper heat exchanger illustrating the misalignment between the plugs at each end. This resulted in a significant leak remaining present, specifically in tube 5, after the repair. This leak went undetected by the crew as there was no effective post-repair pressure test.

Sunbeam's refrigeration plants had not been well maintained and were not being operated as designed. This might have been a consequence of the plants reaching the end of their working life, and the owners and crew taking a reactive maintenance approach to keep this machinery running ahead of its planned replacement. Nevertheless, the repairs to the starboard evaporator were inadequate and left failed tubes in place, facilitating the fatal leak of Freon.

2.8 SAFETY MANAGEMENT

Management of risk requires risk assessments, safe systems of work, the provision of safety equipment and crew training. A risk assessment should start with a careful examination of all aspects of the vessel's operations that could cause harm. Risk assessments should also be regularly reviewed and everyone on board should be aware of their contents. To ensure that procedures are effective, a vessel's crew should undertake regular, realistic emergency drills.

The risk of a fatal accident in one of *Sunbeam*'s RSW tanks caused by a Freon gas leak from a remote system might have been less foreseeable than oxygen depletion from corrosion or hydrogen sulphide from rotting fish. However, *Sunbeam*'s crew were aware of the change in the onboard procedure that had stopped the decanting Freon out of the system when alongside, and the risk of leaks through corrosion in the evaporator tubes, given the previous repairs. This serves to underpin the critical need for effective risk assessments and safe operations.

Given that *Sunbeam* was alongside at the time of the accident, it is reasonable that the risk assessment for maintenance work **(Annex B)** was applicable. Although this risk assessment did identify hazards associated with enclosed space working, including the potential for an unsafe atmosphere, RSW tanks were not specifically included as an area of potential hazard. Additionally, this risk assessment did not describe any detail of the appropriate precautions for enclosed spaces, specifically how the atmosphere was to be checked given there was no atmosphere monitoring equipment on board. The analysis is underpinned by STS's report [Section 1.7.4] that also identified *Sunbeam*'s risk assessment G012 being inadequate as it did not describe the work involved, identify who was at risk or set out the proposed control measures.

Although there was a covering sheet at the front of the safety folder stating that the procedures had been recently reviewed, no amendments had been made to the risk assessments since their original endorsement by a previous mate in 2000. Therefore, the safety folder was not providing a basis upon which safety could be proactively managed on board. This happened because many of those on board were long-standing crew members who were settled into the vessel's operational routines and who did not challenge or update risk assessments or onboard procedures.

Sunbeam's safety folder did not contain any tank rescue procedures, and enclosed space rescue had not been a training drill that was conducted on board. This meant that, when the casualty was found, there was no safe and coherent response to the emergency. Potentially, the most hazardous initial reaction to a collapsed crewman in an RSW tank is other crew members rushing to help. The rescuers needed to be rescued which, in turn, prolonged the 2/E's exposure to the atmosphere that could not support life. Helping a colleague who is experiencing difficulties is a compelling reaction; however, this instinct has to be resisted to prevent further potential fatalities, which could easily have been the case on board *Sunbeam*. Enclosed space working requires a sentry to be posted and a plan in place to react to any emergencies that may arise.

In summary, *Sunbeam*'s crew did not have safe systems of work for their operations. The introduction of a comprehensive SMS, in accordance with the FSM Code [Section 1.8.4], would provide a better structure for the safety management of the vessel.

2.9 EXTERNAL OVERSIGHT

The purpose of Flag State and classification surveys is to ensure that a vessel's structure and equipment complied with statutory safety standards and owners were providing a safe working environment. *Sunbeam* was subject to regular surveys by the MCA and LR, as an approved RO.

For classification surveys, items delegated by the MCA to LR under the class rules included the refrigeration plant. However, the reports of LR surveys between 2014 and the day before the accident contained no indication that *Sunbeam*'s refrigeration plant was ever assessed by an LR surveyor. The inclusion of refrigeration equipment on the MCA's checklist was, therefore, unhelpful as it might have resulted in a situation where LR thought the MCA was responsible for surveys in this area, and the MCA believed the opposite was the case. As this lack of clarity evolved, and notwithstanding the regular MCA / LR dialogue, both organisations potentially considered that the other was undertaking surveys of *Sunbeam*'s refrigeration plants. This meant that the refrigeration plants were subject to an inconsistent level of surveys.

The MCA's surveys primarily assessed compliance with the Code of Practice. Although the Code of Practice drew attention to the MCA's MGN guidance on enclosed space [Section 1.8.1] and required ventilation in any enclosed space, it contained insufficient guidance on the safe management of enclosed spaces. There was also no reference to enclosed space safety in the MCA surveyors' checklist. It is disappointing that a recommendation made in 1996 to introduce a Code of Practice [Section 1.10.1], has only resulted in a guidance notice (MGN 309) and not incorporation into the Code of Practice.

Specific guidance for MCA surveyors included a requirement to ensure that risk assessments contained adequate information [Section 1.9.2]. Although *Sunbeam*'s crew maintained a safety folder and risk assessments existed, this report has highlighted weaknesses with the onboard safety management system that were not detected by the MCA's survey regime [Section 2.8].

The absence of enclosed space safety and management on the surveyors' checklist meant that it was unlikely to be something that the MCA was supervising effectively. Given that many of the UK-registered over 24m fishing vessels are fitted with RSW tanks, the Code of Practice and surveyors' checklist would benefit from inclusion of detailed guidance on the safe conduct of entry into enclosed spaces.

SECTION 3 - CONCLUSIONS

3.1 SAFETY ISSUES DIRECTLY CONTRIBUTING TO THE ACCIDENT THAT HAVE BEEN ADDRESSED OR RESULTED IN RECOMMENDATIONS

1. *Sunbeam*'s 2/E died because he entered an RSW tank, which was an enclosed space, where the presence of Freon gas meant that the atmosphere could not support life. [2.3]

2. The fatal hazard was present and went undetected due to the absence of safety precautions normally associated with enclosed spaces, specifically ventilation and atmosphere monitoring. [2.4, 2.5]

3. Entry into enclosed spaces on board *Sunbeam*, without safety precautions, had been normalised by the crew through many years' operations, and without previous consequence. [2.4]

4. *Sunbeam*'s risk assessment for maintenance operations did not specifically address the potential hazards associated with RSW tank entry. There was also no safe system of work in place for the maintenance being undertaken. [2.8]

5. The 2/E had entered the tank alone; as a result, other members of the crew were unaware where he was or when he collapsed. The 2/E's decision to enter the tank resulted in the unsafe situation of lone working. [2.6]

6. *Sunbeam*'s crew was not properly prepared for dealing with the emergency because there were no emergency procedures for tank rescue and no drills had been conducted to test the arrangements in the event of a casualty. [2.8]

3.2 SAFETY ISSUES NOT DIRECTLY CONTRIBUTING TO THE ACCIDENT THAT HAVE BEEN ADDRESSED OR RESULTED IN RECOMMENDATIONS

1. The exclusion of fishing vessels from the UK's regulations for potentially dangerous spaces, meant that there was no underpinning regulation requiring safety precautions where any such hazard could exist. [2.4]

2. *Sunbeam*'s refrigeration plants had not been well maintained and were not being operated as designed. Evaporator tube corrosion had been managed onboard through previous repairs; however, these repairs were ineffective resulting in the leak of Freon. [2.7]

3. External oversight of the refrigeration plants was hampered by a lack of clarity between the Flag State and the recognised organisation regarding responsibility for survey. [2.9]

4. MCA surveys of *Sunbeam* were unlikely to have assessed the safety of enclosed space operations as this did not form part of the surveyors' checklist and was not embodied in the Code of Practice. [2.9]

SECTION 4 - ACTIONS TAKEN

The **MAIB** has:

- Published a Safety Bulletin 4/2018 **(Annex C)**. This explained the initial findings and safety lessons of the investigation. It also recommended[27] that the owner of *Sunbeam* conduct risk assessments specifically for entering and working in RSW tanks, and provide safe operating procedures for its crew to follow and appropriate levels of safety equipment to use.

- Issued a Safety Flyer to the Fishing Industry **(Annex D)**.

The **owners of *Sunbeam*** have:

- In response to the MAIB's safety recommendation, completed a risk assessment and introduced a safety procedure for enclosed space working, including atmosphere monitoring equipment.

Lloyds Register has:

- Issued a Technical Performance Circular notice to all surveyors. This notice was intended to promote effective communication between LR and the MCA; it also drew surveyors' attention to their specific responsibilities regarding fishing vessel surveys.

[27] MAIB safety recommendation S2018/129.

SECTION 5 - RECOMMENDATIONS

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

2020/137 Implement measures for the safe conduct of enclosed space operations on board fishing vessels, specifically:

- Amend the Merchant Shipping (Entry into Dangerous Spaces) Regulations, 1988, or any subsequent regulations for potentially hazardous spaces, to include fishing vessels. Consideration should also be given to aligning UK regulations and guidance with the IMO terminology for enclosed spaces.
- Update fishing vessel codes of practice and surveyor's checklists to reflect enclosed space safety and operations, specifically including atmosphere monitoring and crew preparation for emergencies.

2020/138 Review Letters of Delegation to its Recognised Organisations in order to ensure clarity of understanding with regard to responsibility for survey of machinery items.

The **owners of *Sunbeam*** are recommended to:

2020/139 Implement an onboard safety management system in accordance with the MCA's Fishing Safety Management Code, specifically ensuring that safe systems of work are in place for all operations.

The **Scottish Pelagic Fishermen's Association** is recommended to:

2020/140 Encourage its members to maintain onboard safety management systems in accordance with the MCA's Fishing Safety Management Code.

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

Marine Accident Report