



Marine Safety Investigation Unit



MARINE SAFETY INVESTIGATION REPORT

**Safety investigation into the fatality of two crew members
on board the Maltese registered chemical tanker**

KEY FIGHTER

**in position 62° 20.70' N 004° 39.40' E
on 01 September 2018**

201809/001

MARINE SAFETY INVESTIGATION REPORT NO. 15/2019

FINAL

Investigations into marine casualties are conducted under the provisions of the Merchant Shipping (Accident and Incident Safety Investigation) Regulations, 2011 and therefore in accordance with Regulation XI-I/6 of the International Convention for the Safety of Life at Sea (SOLAS), and Directive 2009/18/EC of the European Parliament and of the Council of 23 April 2009, establishing the fundamental principles governing the investigation of accidents in the maritime transport sector and amending Council Directive 1999/35/EC and Directive 2002/59/EC of the European Parliament and of the Council.

This safety investigation report is not written, in terms of content and style, with litigation in mind and pursuant to Regulation 13(7) of the Merchant Shipping (Accident and Incident Safety Investigation) Regulations, 2011, shall be inadmissible in any judicial proceedings whose purpose or one of whose purposes is to attribute or apportion liability or blame, unless, under prescribed conditions, a Court determines otherwise.

The objective of this safety investigation report is precautionary and seeks to avoid a repeat occurrence through an understanding of the events of 01 September 2018. Its sole purpose is confined to the promulgation of safety lessons and therefore may be misleading if used for other purposes.

The findings of the safety investigation are not binding on any party and the conclusions reached and recommendations made shall in no case create a presumption of liability (criminal and/or civil) or blame. It should be therefore noted that the content of this safety investigation report does not constitute legal advice in any way and should not be construed as such.

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LIST OF REFERENCES AND SOURCES OF INFORMATION

Crew members *MT Key Fighter*;

IMO Resolution A.1050(27) – Revised Recommendations for Entering Enclosed Spaces Aboard Ships, adopted 30 November 2011;

ISM Managers *MT Key Fighter*;

Managers internal investigation report;

Procedures and Arrangement Manual *MT Key Fighter*;

Safety Management System Procedures – *MT Key Fighter*.

GLOSSARY OF TERMS AND ABBREVIATIONS

°C	Degrees Celsius
AB	Able bodied seafarer
CCR	Cargo control room
CO	Carbon monoxide
COLREGs	International Regulations for Preventing Collisions at Sea, 1972
DNV GL	Det Norske Veritas Germanischer Lloyd
DOC	Document of Compliance
DWT	Deadweight tonne
FW	Freshwater
GT	Gross Tonnage
H ₂ S	Hydrogen Sulphide
IBC	International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk
ICS	International Chamber of Shipping
IMO	International Maritime Organization
ISGOTT	International Safety Guide for Oil Tankers & Terminals
ISM	International Safety Management
kW	Kilowatt
LEL	Lower explosive limit
m	Metres
m ³	Cubic metres
MARPOL	The International Convention for the Prevention of Pollution from Ships, 1973, as amended by the Protocol of 1978
MLC	Maritime Labour Convention
mm	Millimetre
m ³ hr ⁻¹	Cubic metres per hour
MSDS	Material Safety Data Sheet
MSIU	Marine Safety Investigation Unit
MT	Motor tanker
NLS	Noxious Liquid Substances
O ₂	Oxygen
P&A	Procedures and Arrangement Manual
PEC	Pilotage Exemption Certificate
PEL	Permissible explosive limit
PPE	Personal protective equipment
ppm	Parts per million
RINA	Registro Italiano Navale
RPM	Revolutions per minute
SMC	Safety Management Certificate

SMS	Safety Management System
STCW	The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, as amended
SW	Seawater
TWA	Time weighted average
UKOG	Oil and Gas UK Guidelines

SUMMARY

On 31 August 2018, *Key Fighter* berthed alongside *Crude Passion* at Averøy, Norway, where she discharged her remaining cargo of Rapeseed oil. Before sailing for Erith, UK, 58 m³ of slops, reported to contain a mixture of tank wash water and vegetable oils, were transferred from *Crude Passion* to *Key Fighter*. The slops, which were being loaded in cargo tank no. 5 port, were noted by the crew members to have a pungent odour of ‘rotten egg’. Following departure and while on passage, the slops were pumped out at sea and the crew started cleaning the cargo tanks.

The following morning, at about 0405¹, two crew members involved in the cleaning and washing of cargo tanks were found lying motionless inside cargo tank no. 5 port. The crew members were rescued and airlifted to a hospital in Norway.

A summary of the autopsy report submitted by the Accident Investigation Board of Norway concluded that the injuries sustained by the crew members were compatible with a fall from a considerable height. The injuries may have been fatal, but based on the circumstances of the accident, the autopsy report indicated that it was possible that the cause of death was either intoxication by Hydrogen Sulphide (H₂S), or suffocation due to lack of oxygen.

As a result of the safety actions already taken by the Company, no recommendations have been made.

¹ Unless otherwise stated, all times quoted in the report are local time (UTC+2).

1 FACTUAL INFORMATION

1.1 Vessel, Voyage and Marine Casualty Particulars

Name	<i>Key Fighter</i>
Flag	Malta
Classification Society	RINA
IMO Number	8712166
Type	Oil / Chemical Tanker – Type 2
Registered Owner	Key Shipping AS
Managers	Fjord Shipping AS, Norway
Construction	Steel (Double bottom)
Length overall	104.25 m
Registered Length	98.10 m
Gross Tonnage	3,693
Minimum Safe Manning	11
Authorised Cargo	Vegetable oil
Port of Departure	Averøy, Norway
Port of Arrival	Erith, UK
Type of Voyage	International
Cargo Information	Rapseed Oil,
Manning	14
Date and Time	01 September 2018 at 04:05 (LT)
Type of Marine Casualty	Very Serious Marine Casualty
Place on Board	Cargo hold
Injuries/Fatalities	Two fatalities
Damage/Environmental Impact	None
Ship Operation	Normal Service – On passage
Voyage Segment	Transit
External & Internal Environment	Gentle to moderate breeze, sea state was recorded as moderate – night time. Air temperature was 14 °C
Persons on Board	14

1.2 Description of Vessel

Key Fighter was a 3,693 gt, Type 2 Maltese registered oil / chemical tanker. She was owned by Key Shipping A.S. and managed by Fjord Shipping AS, Norway. The vessel was built by Verolme Scheepswerf Heusden BV in The Netherlands in 1989 and was classed by RINA. *Key Fighter* had a length overall of 104.25 m, a moulded breadth of 17.0 m and a moulded depth of 8.70 m. The vessel had a summer draught of 6.14 m and a summer deadweight of 4,999 tonnes. Propulsive power was provided by a Wärtsilä, 9-cylinder, four-stroke diesel engine producing 3,375 kW at 750 RPM. This drove a single, four bladed, controllable pitch propeller through a reduction gearbox, giving an estimated speed of 15.0 knots.

Key Fighter was issued with a Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk. A list of products that the vessel was authorised to carry was attached to the certificate, provided operational provisions of the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code) and Annex II of MARPOL 73/78 are observed. The vessel also carried on board a Class approved Procedures and Arrangements (P&A) Manual, issued in accordance with MARPOL 73/78 –Annex II, Appendix 4. The Manual described the ship's equipment and operational procedures on unloading of cargo, and discharge of cargo residues and tank washings.

1.3 Safety Management Certification

Key Fighter's Safety Management System (SMS) complied with the requirements of the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code). The vessel's Safety Management Certificate (SMC) and Fjord Shipping's Document of Compliance (DOC) was issued by DNV GL, under the authority of the Government of the Republic of Malta.

1.4 Cargo Tanks

Key Fighter had 14 stainless steel cargo tanks of 5,202 m³ at 98% capacity. The tanks were arranged on the port and starboard side in seven pairs. Two slop tanks, each of 104.6 m³ capacity were fitted between cargo tanks nos.4 and 5. A layout of cargo tanks is shown in Figure 1.

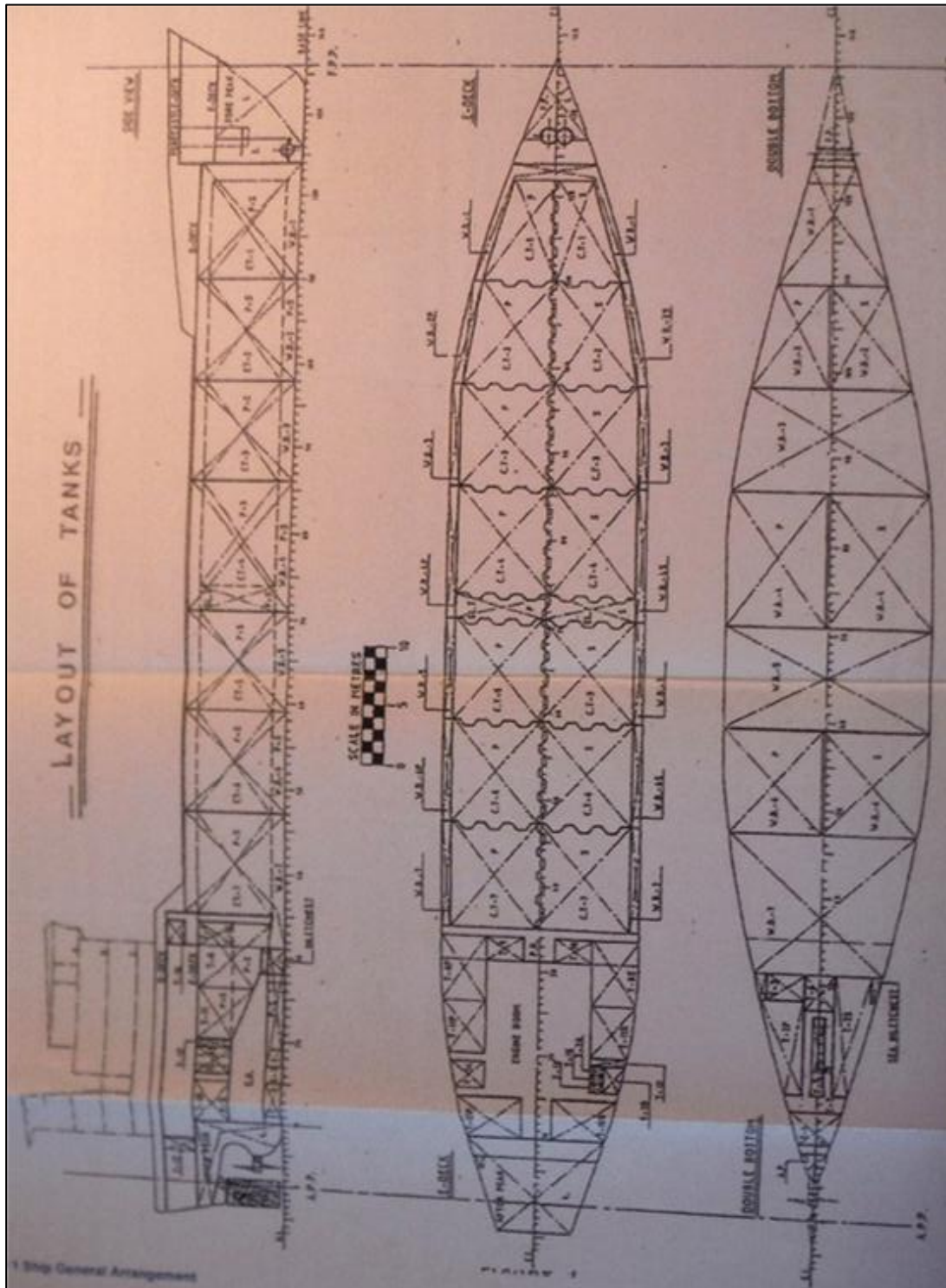


Figure 1: *Key Fighter* tank plan

The cargo tanks were surrounded at the bottom, sides and partly the top with dedicated ballast tanks. A cross section of vessel showing ballast tanks, cargo tanks is shown in Figure 2. A heating system for cargo and slop tanks was provided by external hot water ducts which ran through the double bottom underneath the tanks.

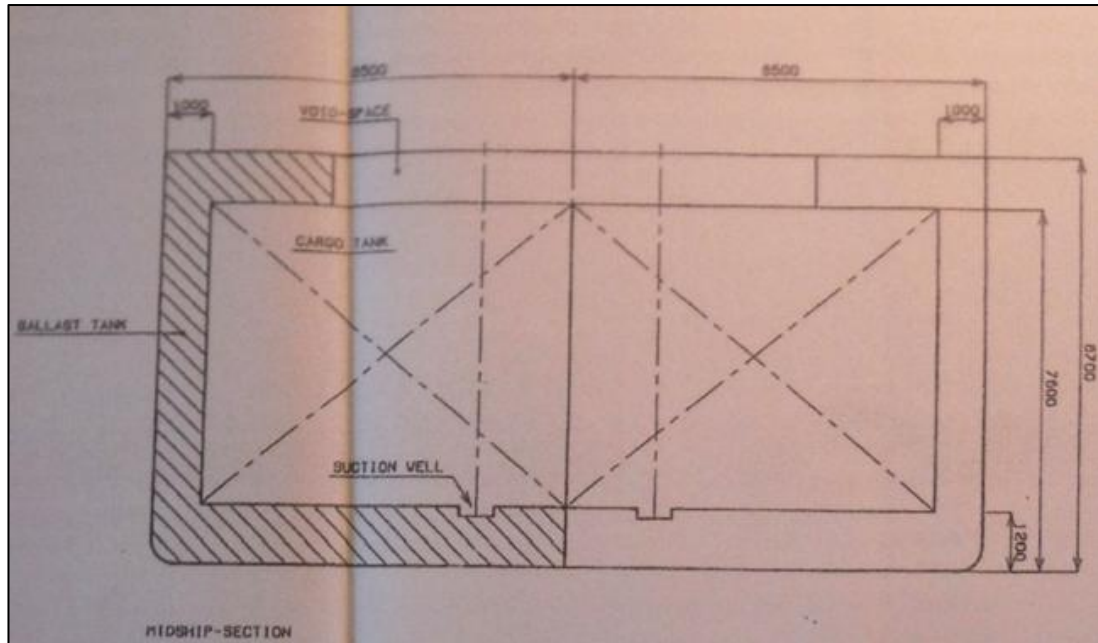


Figure 2: Cross-section showing the ballast and cargo tanks

1.5 Cargo Pumps and Pipelines

Each cargo tank was fitted with an electrically driven Svanehoj H100-3-k deep well pump with a capacity of $100 \text{ m}^3\text{hr}^{-1}$. The pumps were situated in suction wells and included a double shaft sealing system consisting of gas and liquid seals, which allowed for different cargoes to be processed fully segregated. The loading and discharge cargo valves were operated remotely from the cargo control panel located in the cargo control room (CCR). Each slop tank was fitted with an electrically driven Svanehoj H80-3-k deep well pump with a capacity of $50 \text{ m}^3 \text{ hr}^{-1}$.

A portable Framo TK4 submersible pump was also available on board. This pump had a capacity of $70 \text{ m}^3\text{hr}^{-1}$ and was operated by the vessel's hydraulic system, with the discharge line being connected to the fixed vessel lines by flexible hose.

All cargo pipelines were located on the main deck where the valves for the pumps and drop lines were remotely controlled from the CCR. A butterfly valve and blind flange

were provided at the connection of each cargo pipeline to the crossover manifold. Each deep well pump was also provided with a stripping line fitted with a lower valve which was connected on deck to a stainless steel line leading to the manifold.

The cargo system was controlled from the CCR by means of a cargo monitoring system, and a remote pump and valve control system.

1.6 Tank Washing Equipment

Each cargo and slop tank was fitted with two fixed washing machines of Toftejorg SSt40T type. These had a nozzle diameter of 7 mm and a capacity of about $12.5 \text{ m}^3\text{hr}^{-1}$. The tank cleaning main was connected to the general service pump of $85 \text{ m}^3\text{hr}^{-1}$ output. Each cleaning machine was connected to the main line by a flexible hose. The fixed tank washing system was operated from the CCR. A Bloksma tank wash heater was fitted in the pump room. This machine had a capacity of 3,720 kW and at a throughput of $85 \text{ m}^3 \text{ hr}^{-1}$, and operates at water temperatures from $10 \text{ }^\circ\text{C}$ to $48 \text{ }^\circ\text{C}$. This throughput was sufficient for the operation of six tank washing machines simultaneously. The Bloksma heater had the capacity to increase wash temperature to $60 \text{ }^\circ\text{C}$. Throughput was restricted to $60 \text{ m}^3\text{hr}^{-1}$ and the number of tank machines in use to four. The position of the tank washing machines, and the obstruction free construction of the tanks, was such that all areas of the cargo tanks were reachable during the cleaning process.

1.7 Tank Ventilation System

A Novenco type centrifugal fan model CPC 900/100 POS LG 270 was fitted on the starboard aft of the main deck. The fan was connected to a 14 inch pipe toward the manifold. From the manifold, eight connections of 4 inch and 8 inch were available for flexible hoses. The ventilation system had the capacity to deliver air through the loading line and / or through the pump stack.

Two portable gas freeing fans (Figure 3) were also carried on board. These did not have any specific marks or maker information on their structure; nor did they list capacity or airflow rate. The portable gas freeing fans were powered by compressed

air and consisted of a metal fan enclosure with a plastic extension hose which was placed into the tank through the tank-hatch.



Figure 3: Portable ventilation fans

1.8 Gas Measuring Equipment

Key Fighter was provided with four GMI type PS241 (Figure 4) portable gas detectors designed for measurements of cargo and slop tank atmospheres for oxygen (O₂), carbon monoxide (CO), H₂S gas and lowest explosion limits (LEL). The detectors could be used prior to entering and while working inside the cargo tank, where it monitored the atmosphere continuously.

The measuring equipment conformed to standard EN 50104 and complied with:

- EN 60079-29-1 (Flammable);
- IEC 60079-29-1 (Flammable);
- EN 50104: 2002 including amendment No.1 2004 (Oxygen);

- ANSI / ISA S12.13.01 - 2000 (Combustible); and
- C22.2 No.152 - M1984 (Combustible)

Typical operating parameters of the equipment are tabulated in Table 1.

Table 1: Operating parameters

<i>Gas</i>	<i>Range</i>
LEL	0 to 100%
Oxygen	0 to 25%
Carbon monoxide	0 to 1000 ppm
Hydrogen Sulphide	0 to 100 ppm

The PS241 portable gas detector, was also designed for measurements inside confined spaces, both prior to entering and while working inside the confined space. The gas detector could be worn as a personal device for the entire duration when a confined space was entered, thereby continuously monitoring the atmosphere. The detector alerted the wearer with audible, vibration and visual alarms in the event of exposure to flammable or toxic gases.

The gas detector alarms for H₂S were set at 5 ppm for high alert and 10 ppm for high-high alert.



Figure 4: GMI type PS241 gas detector

The remote measurement of an atmosphere was possible by means of the internal electric pump, fitted to the detectors. A remote sampling hose was fitted to the sample connector at the bottom of the instrument and lowered into the tank to be sampled. The vessel carried a length of remote sampling hose (15 m) which had a bulb fitted at the end, to be lowered into a tank. Once the gas detector airflow pump was operated, the equipment indicated the atmospheric conditions once sufficient air would have been drawn up the hose and through the unit. This took around two minutes, depending on the length of the hose.

In addition to the gas detectors, Dräger tubes were used to measure atmospheric chemical composition². A selection of different chemical tube types were carried, however, the PS241 gas detectors were sufficient for the rapeseed oil cargo on this occasion, without the need for Dräger tube sampling.

1.9 Cargo Tank Cleaning

Cleaning and washing of cargo tanks after discharge is an important part of the cargo operation in order to remove minute residues of the previous cargo which can lead to contamination of subsequent cargoes. Several sources of information and guidance on tank washing and cleaning were available on board the vessel, all written in English, the common working language on board. The Vessel Operator's Tanker Safety Manual (SMS), Section 03-04-01-05 (Tank Cleaning and Ventilation, last reviewed 31 August 2017), provided clear instructions on how tank cleaning and ventilation was to be carried out. The section discussed cargo tank cleaning in both general and specific terms, also referring to several publications, as follows:

- The vessel specific Procedures and Arrangement (P&A) Manual;
- The ICS Tanker Safety Guide (Chemical);
- MARPOL; and
- Cargo MSDS.

² Dräger tubes are glass tubes filled with a chemical substance that reacts with a specific chemical or group of chemical substances.

The SMS made reference to risk mitigation measures to ensure that hazards were identified, and safety precautions were put in place, for the specific cargo residue to be cleaned. These included, at Section 2, a pre-cleaning meeting, PPE requirements, tank entry requirements, monitoring tank atmospheres, references to the specific cargo MSDS and awareness of conflicting operations. At section 3.8.1, it is stated that a tank entry permit is required before entry, and further, that any change in circumstances should see the tank vacated and a new entry permit process undertaken.

The SMS also contained a section on toxic cargo specific precautions (03-04-04-13, last reviewed 05 July 2018), which included requirements for gas protective suits and self-contained breathing apparatus where contact with the cargo may occur.

1.10 Pre-Cleaning Meeting

The vessel's SMS required that a pre-cleaning meeting is conducted by the chief officer prior to all tank cleaning and ventilation operations (03-04-01-05). All persons involved in the operation had to participate to ensure that all hazards and precautions related to operation are known to all. The cleaning and ventilation plans, and risk assessment documents are to be prepared in advance, along with a tank cleaning summary, with all persons involved in the operation to sign off the documentation as being understood, including duty officers.

There did not appear to be a record of sign-off on a dedicated pre-cleaning meeting pro-forma, however, the risk assessment mentioned above would be included in the pre-cleaning meeting and it was expected that the sign-off sheet for the risk assessment would evidence the pre-cleaning meeting participants.

1.11 Cargo Tank Cleaning and Ventilation Plan

The cargo tank cleaning and ventilation plan had to be in place and discussed at the pre-cleaning meeting. The plan was to include step-by-step detail of the cleaning sequence, tanks involved, duration of cleaning, cleaning media (SW / FW / temperature), minimum ventilation duration and gas measurement. The pro-forma checklist also required a double sign-off for certain tank cleaning checks and had a dedicated page for gas measurement recording. The gas measurement section was for

toxic or flammable gas only, with lack of oxygen being addressed in a Tank Entry Permit, which had to be used in conjunction with the tank cleaning plan.

1.12 Entry into Enclosed Spaces Procedure

The vessel's SMS contained an entry into enclosed space procedure (03-02-01-07, last reviewed on 08 May 2018). The SMS stipulated that the procedure was in accordance with the guidance in ISGOTT, chapter 10 and defined the roles of those involved along with the specific entry permit type to be used. Cargo tank entry permits referred to specific points that had to be verified prior entry approval.

These verifications included initial and repetitive atmosphere checks and a requirement for a watchman to be in the vicinity of each tank at the time of entry. The specific entry permit required in this case is referred to as the 'Cargo Tank Entry Permit'. The procedure continued to detail both the hazards and the precautions and conditions, which had to be in place prior to entry. Specific requirements included:

- At 4.1 (General precautions) - "The following must be checked physically and verified as under control prior to any entry:
 - Gas measurement must be carried out prior to entry with devices capable of indicating level of...Hydrogen Sulphide...";
 - Personal gas alarm devices capable of indicating O₂, HC, H₂S and CO must be carried by all personnel entering the enclosed space for the duration of the entry."
- At 4.3 - "The initial gas measurement is carried out at entry:
 - Gas measurement shall be carried out on three levels for cargo tanks...;
 - Oxygen level percentage (O₂ %), shall be measured in all circumstances and the minimum acceptable level for entry is 20.8%;
 - Hydrogen Sulphide (H₂S) is a colourless gas with the characteristic foul odour of rotten eggs. H₂S is toxic in small concentrations, and may be present in any space where any form of organic decomposition or corrosion may have occurred, or in spaces previously containing fuel oil. The presence in parts per million (ppm) shall be measured in all circumstances and the maximum acceptable level for entry is 0 ppm."

A mandatory requirement to carry a personal gas detector was in place, along with repetitive atmosphere checks and communication with the watchman. The duties of the watchman were detailed and included the need to raise the alarm without delay for emergency and evacuation. An entry log was to be delivered to the duty officer in advance of anyone entering a tank. Every person entering the space had to report to the duty officer for log entry before entering. It was also clearly stated that no entry was allowed without informing the duty officer.

1.13 Cargo Tank Entry Permit

The Tank Entry Permit was a four page document. The first two pages contained the identification of the cargo tanks, general precautions, space specific precautions, initial gas measurement, approval to enter and securing on completion sections, all of which had to be completed by a responsible officer, the master and the persons involved in the operation prior to entry. The last two pages allowed recording of regular atmosphere testing, at a frequency which had to be previously agreed when taking the cargo into consideration. An entry log had to be delivered to, and completed by the duty officer whenever a person entered a cargo tank listed in the Permit. The Permit had to be completed by hand in close proximity to the entry area.

The Permit also contained brief guidance including a statement under the watchman's duties and sign off section in bold type, "**The Watchman may NEVER enter the cargo tank.**" The Cargo Tank Entry Permit appeared to be in line with the IMO Recommendations for Entering Enclosed Spaces aboard Ships and ISGOTT, Chapter 10.

1.14 Risk Assessment

A standard general risk assessment and corrective actions were signed off by the crew involved in the cargo tank cleaning operations. The following task areas were covered in the assessment:

- Planning;
- Hot water handling;

- Pollution;
- Fatigue;
- Climbing up and down stairways / ladders, mopping and drying; and
- Hose connect and disconnect.

1.15 Vessel Manning

Key Fighter's Minimum Safe Manning Certificate required 11 crew members. The vessel sailed from the port of Averøy with 14 crew members on board and satisfied the manning requirements of the relevant Statutory certification.

The master was 48 years old from Iceland. He had about 30 years of service at sea, with around half of that time as master on vessels managed by Fjord Shipping. At the time of the accident, he had been master of *Key Fighter* for about four years.

The Filipino chief officer was 42 years old. He had been at sea for 17 years, five years of which in the capacity of chief officer with Fjord Shipping. The second officer was also from the Philippines. He had spent about 10 years at sea with the last three years in the current rank with Fjord Shipping on *Key Fighter* and similar vessels. At the time of the accident, he was in charge of the navigational watch.

All the deck officers were familiar and experienced with this particular vessel and her recent trading pattern. They had been using Fjord Shipping's SMS for several years prior to the accident. The fatality injured crew members were an AB (who was a team leader and appeared to have been undertaking the actual cargo tank entry), and one painter, who had been assigned as the watchman³ for the cargo tank cleaning operation.

The AB was a 42 year old Filipino national. He held a certificate for Ratings Forming Part of a Navigational Watch and had successfully completed both Basic and Advanced Training for Oil and Chemical Tanker Cargo Operations (IMO Model Course 1.01, 1.02 and 1.04). He had undergone a familiarisation programme upon

³ The watchman is stationed at the cargo tank hatch opening and is responsible for maintaining communication with the team leader during his entry into the cargo tank(s).

joining the vessel on 29 August 2018. The AB had been working on this vessel for some time⁴. The AB was assigned the 12 to 4 bridge watch as a look-out. However, it was the custom for the AB to undertake cargo tank cleaning while the vessel was at sea, along with the vessel's pumpman.

The painter was a 76 year old Spanish national. He was qualified in accordance with the provisions of Regulation II/4 (support level-navigation) of the STCW Convention and trained for Oil, Chemical and Liquefied Gas Tanker Cargo Operations. He had undergone familiarisation training on 19 June 2018 and, similarly to the AB, had served on this vessel before and also with Fjord Shipping, for several years. The master stated that the painter had served in the position of a pumpman on the vessel in the preceding years. There was no specific job description for painter but he variously carried out duties of AB, bosun and also as a pumpman.

1.16 Weather Conditions

The wind on 31 August 2018 was Southwest Beaufort Force 4, backing to South Force 6. The sea state was moderate. The air temperature was 14° C.

1.17 Narrative

Key Fighter sailed for Stavanger, Norway from Kaliningrad, Russia on 27 August 2018, with 4,378 m³ of Rapeseed oil in cargo tanks nos. 2, 3, 4, 5, 6 and 7 (port and starboard).

She arrived at Stavanger on 29 August, and started discharging cargo from cargo tanks nos. 2 and 7 port and starboard. The following morning, a cargo tank entry permit was completed and cargo tanks nos. 2 and 7 (port and starboard) were swept clean by the crew. *Key Fighter* departed for Averøy, Norway at 1015 on 30 August. While at sea, cargo tanks nos. 2 and 7 port and starboard, were cleaned, drained and dry. The cleaning and discharge into the sea of tank washings were recorded in the Cargo Record Book.

⁴ The master stated that regardless of their length of service, every time a returning seafarer joined the vessel they repeated the familiarisation program.

At 0945, on 31 August, *Key Fighter* arrived at Averøy and moored alongside the chemical / oil tanker *Crude Passion*⁵ (Figure 5). *Key Fighter* commenced discharge of the remaining Rapeseed oil from cargo tanks nos. 3, 4, 5 and 6 port and starboard. The cargo discharge was completed at 1945.



Figure 5: *Crude Passion* moored at Averøy

Information made available to the safety investigations indicated that while berthed alongside, 58 m³ of slops⁶ were transferred from *Crude Passion* to *Key Fighter*. The slops were pumped into 5 port cargo tank from the top⁷. The chief officer stated that he had been advised by the master of *Crude Passion* that the slops contained mixed wash water of vegetable oils. *Key Fighter* neither received documentary information on the slops nor did the vessel record any details of the transfer of this slop in the deck logbook and / or Cargo Record Book. During loading of the slops, several of the crew members stated that they noticed a ‘rotten egg’ smell coming from the slops. In fact, it was mentioned that on this occasion, the smell was awful and he had attributed it to H₂S gas.

While the vessel was in port, cargo tanks nos. 4 and 6 port and starboard were swept clean by the crew. A cargo tank entry permit was put in place with the record of entry, indicating that there were persons inside these cargo tanks between 1619 and

⁵ *Crude Passion* (IMO 9010917) is an 8,000 DWT, Norwegian flag vessel, used as an additional cargo storage unit for the cargo terminal.

⁶ Slops refers to a mixture of water and cargo residue, which remains on board after tank cleaning.

⁷ Loading through the deck openings by means of portable hose.

1935. However, part 5 of the permit neither had the completion of operation closed nor was it signed by a responsible officer.

At 2000, *Key Fighter* departed Averøy for Erith, UK.

Cargo tank cleaning commenced at 2248 while the vessel was on passage. The cleaning operation was undertaken by one AB and the painter. The chief officer, who was responsible for cargo tank cleaning operations, handed over the navigational watch to the second officer at midnight and proceeded to the CCR to enquire on the progress made. The AB also handed over the watch, with the 2000 to 2400 AB being relieved by the oncoming 0000 to 0400 watch AB.

The chief officer stated that on arrival in the CCR, he noticed that the washing and cleaning of cargo tanks nos. 3 port and starboard had been completed and that washing of cargo tank no. 5 port had already started at 2340. He stated that he had advised the AB and the painter to be very careful with the entry into cargo tank no. 5 port, due to the 'rotten egg' smell reported earlier. He recalled that he had also requested that the cargo tank is well ventilated, to keep the bridge informed and use personal gas detectors. He wrote down these instructions on a sheet of paper, which was left in the CCR, and then went to bed.

In the meantime, the second officer remained alone on the bridge. He confirmed that from the bridge, he could see the floodlit deck area and the cargo tank entry lids, including those fitted on cargo tank no. 5 port. However, he neither saw the watch changeover nor any crew member on deck; he actually assumed that if there was no one to be seen on deck, then everyone must be in the CCR. During the duration of his watch, there were no communication checks between the bridge and the cargo tank cleaning team. Moreover, the section in the cargo tank entry permit was filled neither with cargo tank entry nor exit details for the remaining time of the navigational watch.

At about 0405, the 0400 to 0800 AB arrived on deck at the changeover of watch. Upon looking into cargo tank no. 5 port, he found the AB and the painter lying inside. He alerted the second officer on the bridge, who raised the alarm. By 0409, the master and the chief officer were in attendance and a rescue operation was commenced, using self-contained breathing apparatus, a tripod and the harnesses. The chief officer and the pumpman eventually entered inside the cargo tank and, after

a rapid examination, elected to rescue the AB first who appeared to have clear signs of life.

By 0431, the AB was recovered to deck, followed by the painter at about 0444. Both crew members were administered first aid. By this time, the vessel had altered course toward Måløy, Norway. The Norwegian authorities were contacted by the vessel at 0439. A helicopter was dispatched to airlift the two casualties from the vessel. The helicopter arrived on scene at 0529, picked up both casualties and departed for a Norwegian hospital at 0539.

At 0550, the cargo tank no.5 port atmosphere was tested by the chief officer. The readings obtained were:

LEL: 0%;

O₂: 20.9%;

CO: 0 ppm; and

H₂S: 4 ppm.

The vessel proceeded to Måløy, where she was alongside at 0705 on the same day. The master was later informed that both crew members had succumbed to their injuries.

1.18 Hazards of H₂S

H₂S is a flammable, poisonous gas with a characteristic odour of rotten eggs. It can be generated in nature whenever organic material containing sulphur is present and oxygen is depleted, although it is difficult to predict the rate of gas emission from biological process although it can rapidly reach dangerous levels. The gas is heavier than air and tends to accumulate at the bottom of poorly ventilated spaces. The pungent nature of the gas can be sensed at low concentrations in air. However, at low continuous exposure or at high concentrations, a person loses his ability to smell the gas and one cannot rely on it to indicate the continuing presence of H₂S. The health effects of gas vary, depending on the level and duration of exposure. A level of H₂S at or above 100 ppm is immediately dangerous to life and health.

This gas is well described in ISGOTT Chapter 2, which contains extensive guidance on H₂S, including the hazards and mitigations. Additionally, the vessel's SMS procedure for entry into enclosed spaces contains warnings and guidance, including a requirement for the atmospheric level of H₂S to be zero ppm before tank entry is permitted.

The Permissible Exposure Limit (PEL) of H₂S expressed as a Time Weighted Average (TWA) is 10 ppm. The effects of the gas at concentrations in air in excess of the TWA is shown in Table 1, which is re-produced from the ISGOTT Manual.

Table 1: Typical effects of exposure to hydrogen sulphide (H₂S)

H ₂ S Concentration (ppm by volume in air)	Effects
50 - 100	Eye and respiratory tract irritation after exposure of one hour.
200 – 300	Marked eye and respiratory tract irritation after exposure of one hour
500 - 700	Dizziness, headache, nausea etc. within 15 minutes, loss of consciousness and possible death after 30-60 minutes exposure
700 - 900	Rapid unconsciousness, death occurring a few minutes later.
1,000 – 2,000	Instantaneous collapse and cessation of breathing.

Note: Persons over exposed to H₂S vapour should be removed to clean air as soon as possible. The adverse effects of H₂S can be reversed and the probability of saving the person's life improved if prompt action is taken.

1.19 Cause of Death

The autopsy results confirmed that neither drugs nor alcohol were contributing factors to the accident.

Both the deceased seafarers had serious injuries compatible with a fall from a considerable height. The distance from the access hatch to the cargo tank top inside no. 5 port was 10.0 m. It was considered unlikely that both crew members would have fallen in a similar manner without the presence of additional factors. The MSIU was informed that *post mortem* tests could not confirm the presence of H₂S gas. The injuries may have been fatal, but taking into consideration the circumstances of the accident, the autopsy report did not exclude that the cause of death could have been either H₂S gas intoxication or suffocation due to lack of O₂.

2 ANALYSIS

2.1 Purpose

The purpose of a marine safety investigation is to determine the circumstances and safety factors of the accident as a basis for making recommendations, to prevent further marine casualties or incidents from occurring in the future.

2.2 Fatigue

According to the ship's Watch Arrangement Schedule, both the chief officer and the second officer worked within their 12-hour watch (6 on / 6 off) system. The deceased AB kept a four hour watch (4-on / 8-off) and attended mooring operations outside his assigned watch hours. The master worked between 0800 and 1800, and as a PEC holder, he piloted the vessel within the Norwegian waters. The painter worked during the day, seldom exceeding 11 hours in any 24 hour period. Analysis of the record of rest hours of the crew members involved in the cargo tank cleaning operations indicated that the documents were in compliance with the MLC and STCW Convention requirements⁸.

2.3 Medical Fitness

Maltese Legislation⁹ requires "...a medical certificate issued in accordance with the medical standards of the STCW Convention, or a medical certificate meeting in substance the same requirements for seafarers not covered by the STCW Convention...". The fatally injured AB held a valid STCW medical certificate issued in the Philippines. The painter was medically examined in accordance with Oil and Gas UK Guidelines (UKOG) and was declared fit for unrestricted offshore work.

⁸ The master stated that *Key Fighter* carried a deck officer (a third officer) less than other vessels in the fleet. He claimed that this did not allow the crew members to keep an eye on the crew engaged in the cargo tank cleaning operations.

⁹ Subsidiary Legislation 234.51 - Merchant Shipping (Maritime Labour Convention) Rules, regulation 16.2.

2.4 Loading of Slops

Interviews on board established that loading of slops was a regular event at Averøy, having taken place many times previously. However, no evidence was found on board, to confirm authorisation to Key Fighter to transport slops. There were no management guidelines and its carriage were not authorised in the vessel's Certificate of Fitness. The Company also advised that it was not aware of this practice. There were no slop specific MSDS¹⁰ and noxious liquid substances (NLS) in the slop were no available to the vessel.

Moreover, the loading of slop and its discharge at sea was not recorded in the Cargo Record Book. No reasonable explanation was provided by the master and it would appear that the pungent smell was an accepted element of these slops¹¹. Indeed, the MSIU was informed that on this occasion, it was noticed that the smell was strong and this was attributed to H₂S gas. Nonetheless, the operations had not been terminated and the alert on the gas detector did not alarm the crew members; the reading on the gas detector had not been recorded in the logbook.

2.5 Internal Audit

On 01 June 2018, Fjord Shipping conducted an internal ISM audit in Skagen, Denmark under ship operating conditions. The audit started with a physical inspection of the vessel and the crew working practices to assess the effectiveness of the SMS. Audit records indicated that the loading of slop was neither raised by the master nor identified during the audit.

2.6 Cargo Tank Cleaning Practices on Board

2.6.1 Vessel SMS procedures

The Company's SMS contained appropriate and extensive guidance in several areas of tank washing operations to ensure cargo tanks are made safe for entry. Each stage

¹⁰ *Key Fighter's* P&A Manual required that if any of the noxious liquid substances (NLS) were not categorized as X, Y, Z or OS (other substance), no transport was allowed.

¹¹ During the safety investigation, *Key Fighter's* managers provided MSDS of Cameline Seed Oil, Rapeseed Oil and Fish Oil acquired from *Crude Passion*.

of the SMS procedures for washing, ventilation, and cargo tank entry allowed for reinforcement of the hazards and mitigation measures. The tank entry procedure and the tank entry permit were in line with IMO recommendations and the guidance offered in ISGOTT Chapter 10.

There were several points in the SMS and tank entry permit where specific requirements were highlighted, including mandatory use of personal gas detectors, the regular verification of tank atmosphere, and the reporting of entry and exit times to the duty officer. It was a requirement for persons to verify that all parts of the permit were completed to his satisfaction before entering the tank. A watchman had to be present at the entry point of the cargo tank and regular communication with the person inside the cargo tank had to be maintained.

In order to provide the crew with clear instructions on cargo tank cleaning and ventilation, a cargo tank cleaning plan had to be prepared by the chief officer. The plan, outlining method of washing and ventilation for each cargo tank, had to be prepared in advance and distributed to the crew during a pre-cleaning meeting to ensure that duty officers and crew members were aware of all hazards and safety precautions.

2.6.2 Tank cleaning and ventilation plan

On 30 August, a day before her arrival at Averøy, the chief officer prepared a Tank Cleaning and Ventilation Plan. On page 1 of the Plan, cargo tanks nos. 3, 4, 5 and 6 were identified free of flammable, toxic or corrosive hazard with 'N/A'¹² being entered against these tanks. This was in line with the Rapeseed oil cargo MSDS, which specified that the product had a flashpoint above 225 °C and was not toxic. On page 3 (gas measurement), cargo tank no. 5 port, which was classified with cargo residues of Rapeseed oil and vegetable oil slop water, the entry under flammable or toxic gas was left blank (unqualified), indicating atmosphere measurements during tank washing of cargo tank no. 5 port. However, during the course of this safety investigation, no record of pre-cleaning meetings were found on board, and it could not be established whether the atmosphere testing of cargo tank no. 5 port was discussed during toolbox talks, given that no readings were taken by the crew during cargo tank washing.

¹² Not applicable.

2.6.3 Risk assessment

The general risk assessment and mitigating measures for the cargo tank cleaning operation attached to the cargo tank and ventilation plan were in line with the practice maintained on board during previous occasions. However, this document did not list any precautionary measures for H₂S gas. Moreover, it was noticed that the risk assessment document was dated 01 September 2018 (a day after the cargo tank washing operations had started), and was signed neither by the AB nor the painter. The safety investigation could not determine whether the risk assessment document was actually sighted by the two crew members involved, given that their signature was missing.

2.6.4 Tank washing

Key Fighter was provided with the MSDS for Rapeseed oil at Kaliningrad. This document did not contain details on the washing procedures for this specific cargo. However, the Tank Cleaning and Ventilation Plan provided step-by-step details of the cleaning operation:

- One hour hot sea water at 70 °C;
- 15 minutes fresh water rinse at ambient temperature; and
- Six hours fixed ventilation for gas freeing.

Accordingly, the plan would require a total washing time of one hour 15 minutes, followed by six hours of fixed ventilation giving seven hours 15 minutes total time.

After leaving Averøy, *Key Fighter* commenced washing cargo tanks nos. 3 port and starboard at 2248, and had completed the cleaning some 52 minutes later, at 2340. It was evident that the washing plan for these cargo tanks had not been strictly followed. The fact that the cargo tank entry permit for mopping and drying was not available on board suggested that the crew members either had not entered the cargo tank or if they did, this may have been done without the entry permit in place.

The MSIU was informed that since the vessel had been carrying mainly vegetable oil cargoes for some months, cargo tank cleaning was not required to be extensive due to the compatibility of the grades being carried. This was also extended to the verification of cleanliness by cargo tank entry, which had been achieved with only a

very brief check of the cargo tank condition, once washing had been carried out. This practice was further assisted by the non-toxic and non-flammable nature of these cargoes, allowing a 'quick' access to the cargo tanks.

Moreover, the completed records that were found on board, contained several inconsistencies. The chief officer reported that washing of cargo tank no. 5 port was underway at midnight when he made his way to the CCR. However, it was not possible for the MSIU to determine the duration of the washing of cargo tank no. 5 port and whether any toxic or flammable gas was measured during the washing. During crew interviews, it was stated that on discovery of the casualties, at about 0400, the washing of cargo tank no. 4 port had been left running. This cargo tank was already recorded as being cleaned and completed prior to departing Averøy. Hence, it was not clear as to why this cargo tank was being washed and cleaned again. Entries made in the Cargo Record Book, between hours of 2300 and 0400, also did not tally with the actual work that was done during this period.

2.6.5 Ventilation

According to the Tank Cleaning and Ventilation Plan, each cargo tank required six hours of ventilation by fixed fans. On discovery of the AB and painter inside cargo tank no. 5 port, a single portable fan was found running on the deck. The plastic fan's extension hose, which would have been placed inside the cargo tank through the access hatch, was entirely on deck. This must have been withdrawn from the access hatch to allow entry inside the cargo tank. It was clear that fixed ventilation had not been in used for cargo tank no. 5 port.

Given that the crew members involved had not signed the plan as prepared by the chief officer, the safety investigation did not exclude the possibility that the fixed ventilation had not been used for other cargo tanks as well. Data collected from the ship revealed that the fixed ventilation system on the vessel had not been in use for some time. Because of the non-toxic and non-flammable nature of the cargoes, which the vessel had been carrying for some time, the portable fan was considered sufficient by the crew. At the time, the crew had little concern on oxygen depletion inside the cargo tanks, due to the nature of the vegetable oils cargo and given that the cargo tank full to empty discharge a few hour previously. Rather than for oxygen enrichment,

the portable fan was primarily being used to lower the excessive air temperature, following the hot water wash and therefore to allow entry.

2.6.6 Tank entry permit

Caro tank entry permits for the sweeping of Rapeseed oil in cargo tanks nos. 3 and 5 (after discharge at Averøy), were not available on board. Similarly, no permits were available for the mopping and drying of cargo tanks after washing and ventilation operations had been completed. One permit, dated 01 September 2018, was submitted to the safety investigation with respect to the inspection of cargo tank no. 5 port.

For the measurement of tank atmosphere, *Key Fighter* carried four portable gas detectors, three for personal use when in an enclosed space. The fourth one was used with an extension hose for initial gas measurement. These were functional and mandatory for use by any person entering a cargo tank. The chief officer stated that he instructed both the AB and the painter verbally and in writing, to use personal gas detector and ventilate cargo tank no. 5 port until safe for entry. However, both the AB and the painter were not wearing their personal gas detectors when they were found inside the cargo tank.

The cargo tank entry permit, which was valid for entry between 0000 and 0400 (01 September) had been approved by the master for entry without the initial readings of oxygen or toxic gas being recorded. The chief officer was available neither on deck nor in the CCR. Moreover, this permit was not signed by the AB and the painter, actually suggesting that they may have not been aware of this document before they entered the tank.

2.6.7 Cargo tank entry log

It was a requirement in the cargo tank entry permit that the entry log section was to be placed with the duty officer on the bridge and completed by him on each entry and exit of the crew members. The information available to the safety investigation did not indicate that this had occurred. The entry log was retained in the CCR and for the duration of the 0000 to 0400 watch, no communication was established (or at least apparently attempted) between the crew members washing the cargo tank and the second officer on the bridge. No entries were made in the cargo tank entry log, which remained attached to the cargo tank entry permit.

2.6.8 Cargo tank lighting

In addition to the personal headlight, the SMS recommended pneumatically powered lights for a satisfactory level of illumination inside the cargo tank. At the time of the accident, pneumatically powered lights were not available on board. Although, the deck lights had been switched on, it was unlikely that they provided adequate lighting inside the cargo tank and may have even created a shadow to the person entering the cargo tank. Considering the circumstances and events, it was possible that the personal headlight may have not provided sufficient illumination to detect the slippery nature of clingage¹³ from Rapeseed oil and / or slop, set on the cargo tank access ladder, the likelihood of which, was not excluded by the MSIU.

2.7 Crew Members' Entry into Cargo Tank No. 5 Port

Contemporary academic research in safety science suggest possible reasons for crew members not following established safety management procedures. Although the research setting is not necessarily the maritime domain, the findings may be nonetheless transposed to this domain.

The reasons are several and go beyond (and discredit) mere negligence, recklessness or cutting of safety corners. One main reason is the different perceptions of workplace safety, which managers ashore and crew members on board may have. Such discrepancies may actually lead to a gap between actions which are perceived to be needed and the actual actions taken on board.

The practice of loading slops from one vessel to another was a process which did not happen once. The 'routine' *per se*, and the related success (in terms of achievable goals) may have led to informal ways on how to complete the job – thereby becoming a routine 'non-conformity' over time. This would have equated to a drift into failure and the 'problem' *versus* 'normal work' actually becomes blurred.

Although there were no other crew members on the main deck, it was not excluded that before accessing the cargo tank, the crew members would have carried out some assessment – even if in the form of an informal discussion between the two and without any written documentation whatsoever.

¹³ Oil remaining on the internal surfaces of cargo tanks.

Given that:

1. this was not the first instance where crew members accessed cargo tanks;
2. past events / occasions were successfully completed by the crew members with a positive outcome;
3. the crew members involved could relate the characteristics of this entry with the characteristics of previous entries; and
4. no disconfirming cues were being received by the crew members which would have suggested not to access the cargo tank,

the decision to access the cargo tank was not rejected.

2.8 Bridge Manning

Rule 5 of the COLREGs states that:

Every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision.

Section A-VIII/2 part 4-1 of STCW 2010 (as amended) describes the principles to be observed in keeping a navigational watch. It further emphasises the requirements of Rule 5, and explains that look-out shall serve the purpose of maintaining a continuous state of vigilance by sight and hearing by all available means. A look-out person forming part of a navigational watch must also satisfy the mandatory minimum qualifications of the STCW Code. During the course of this safety investigation, it was found that in practice, a crew member designated for look-out duties was routinely sent on deck for cargo tank cleaning operations, even during hours of darkness.

**THE FOLLOWING CONCLUSIONS AND SAFETY
ACTIONS SHALL IN NO CASE CREATE A
PRESUMPTION OF BLAME OR LIABILITY.
NEITHER ARE THEY LISTED IN ANY ORDER OF
PRIORITY.**

3 CONCLUSIONS

Findings and safety factors are not listed in any order of priority.

3.1 Immediate Safety Factor

- .1 The immediate cause of the accident was a fall from a height which led to fatal injuries.

3.2 Latent Conditions and other Safety Factors

- .1 There were neither management directions nor guidelines available for the loading of slops;
- .2 *Key Fighter* undertook to receive a considerable amount of slop from *Crude Passion* without slop specific MSDS and without management directions or guidelines;
- .3 Audit records indicated that the loading of slop was neither raised by the master nor identified during the audit;
- .4 There were no records of pre-cleaning meeting and it is likely that the atmosphere monitoring of cargo tank no. 5 port during the cleaning process was not addressed in the toolbox talk;
- .5 There was no effective supervision of the cargo tank cleaning and ventilation operations / on-going atmosphere monitoring for toxic gas were not carried out;
- .6 The general risk assessment document was not signed by the deceased crew members;
- .7 Personal gas detectors were not worn by the crew members who accessed the cargo tank;
- .8 Ventilation of cargo tank no. 5 port was carried out using portable gas freeing fans rather than the fixed Novenco type centrifugal fan;
- .9 The officer responsible for ensuring that all parts of the entry permit were properly completed, was available neither on deck nor in the CCR during the cargo tank cleaning operations;

- .10 The cargo tank entry permit was approved without all parts of the permit completed;
- .11 The loading of slops 'routine' *per se*, and the related success (in terms of achievable goals) may have led to informal ways on how to complete the job;
- .12 Given the success of past procedures and given that there were no disconfirming cues where being received by the crew members which would have suggested not to access the cargo tank, the decision to access the cargo tank was not rejected.

3.3 Other Findings

- .1 Analysis of the record of rest hours of the crew members involved in the cargo tank cleaning operations indicated that the documents were in compliance with the MLC and STCW Convention requirements;
- .2 The tank entry procedure and the tank entry permit were in line with IMO recommendations and the guidance offered in ISGOTT Chapter 10;
- .3 Although the SMS recommended pneumatically powered lights for a satisfactory level of illumination inside the cargo tank, these were not available on board;
- .4 There was no dedicated look-out on the bridge during the hours of darkness;
- .5 The pungent odour of H₂S gas coming from the slops did not trigger a realisation of the potential hazard to the crew and the loading of slop was not terminated;
- .6 The loading of slops and its discharging at sea, was not recorded in the vessel's Cargo Record Book;
- .7 There were no management guideline and the carriage of slops was not authorised in the vessel's Certificate of Fitness.

4 ACTIONS TAKEN

4.1 Safety Actions Taken During the Course of the Safety Investigation

During the course of the safety investigation, the Company adopted the following safety actions:

- Frequent visits on board by Company representatives to observe and discuss shipboard operations;
- Additional training offered to crew members;
- Analysis of all Company procedures; and
- Crew conferences on board, aiming to improve on safety.

5 RECOMMENDATIONS

Considering the safety actions taken by the Company, no recommendations have been made.