HELLENIC REPUBLIC
HELLENIC BUREAU FOR MARINE CASUALTIES INVESTIGATION

MARINE CASUALTY SAFETY INVESTIGATION REPORT 14/2013

Death of 3rd Engineer of M/V CAPTAIN PETROS H.

July 2017

Contents

GLOSSARY OF ABBREVIATIONS AND ACRONYMS		
1.	IMO	International Maritime Organization
2.	Bf	Beaufort (wind force measuring unit of Beaufort Scale)
3.	SOLAS	Convention for the Safety of Life at Sea 1974, as amended
4.	m	meters
5.	kW	kilo Watt (power measuring unit)
6.	ltrs	liters
7.	ISM	International Management Code for the safe operation of ships and for pollution prevention
8.	SMS	Safety Management System
9.	SMSM	Safety Management System Manual
10.	PMS	Planned Maintenance System
11.	LT	Local time
12.	F.O.	Fuel Oil
13.	B.S.O. Tank	Bilge Separator Oil Tank
14.	W.O.S. Tank	Waste Oil Settling Tank
15.	ICU	Intensive Care Unit
16.	PPE	Personal Protective Equipment
17.	˚C	Degrees Celcius
18.	ISO	International Organization for Standardization

Foreword

The Hellenic Bureau for Marine Casualties Investigations was established by Law 4033/2011 (Government Gazette 264/12.22.2011), in the context of implementing EU Directive 2009/18/EC.

HBMCI conducts technical investigations into marine casualties or marine incidents with the sole objective to identify and ascertain the circumstances and contributing factors that caused it through analysis and to draw useful conclusions and lessons learned that may lead, if necessary, to safety recommendations addressed to parties involved or stakeholders interested in the marine casualty, aiming to prevent or avoid similar future marine accidents.

The conduct of Safety Investigations into marine casualties or incidents is independent from criminal, discipline, administrative or civil proceedings whose purpose is to apportion blame or determine liability.

This investigation report has been produced without taking under consideration any administrative, disciplinary, judicial (civil or criminal) proceedings and with no litigation in mind. It does not constitute legal advice in any way and should not be construed as such. It seeks to understand the sequence of the events that occurred on March 08, 2013 and resulted in the examined very serious marine casualty and aims to prevent and deter repetition.

Fragmentary or partial disposal of the contents of this report, for other purposes than those produced may lead to misleading conclusions.

The investigation report has been prepared in accordance with the format of Annex I of respective Law (Directive 2009/18/EC) and all times quoted are local times unless otherwise stated.

Under the above framework HBMCI has been examining the fatal injury of the 3rd Engineer of Bulk Carrier CAPTAIN PETROS H. following severe burns caused by the splashing of hot sludges onto his body, occurred on the 23 of August 2013.

1. Executive summary

On 21 August 2013 the Greek flagged M/V CAPTAIN PETROS H, IMO No 9426415 arrived at Ponta Da Madeira anchorage, Brazil and by 22:15 she had dropped her anchor waiting to enter the port for loading operations.

The following day, afternoon hours, while the vessel was still at the anchorage, the 2nd Engineer transferred a quantity of 1.8 m^3 of sludge from the “Bilge Separator Oil Tank” to No 2 “Waste Oil Settling Tank” by means of the sludge pump. After the completion of said transfer, it was observed that the level gauge of No 2 Waste Oil Settling Tank malfunctioned because the level indication of the tank did not alter.

On 23 August 2013 at 08:00 the crew of the engine department started a periodic inspection on the bearing of the intermediate propeller shaft. The task was completed approximately at 08.45 and the Chief Engineer assigned to the 2nd Engineer the draining of No2 Waste Oil Settling Tank in order to clean the tank from the sludge residues and repair the mechanism of the level gauge. The 2nd Engineer undertook the assignment with the assistance of the 3rd Engineer.

They opened the drain valves and when they presumed that the tank had emptied the 3rd Engineer begun to slack the nuts of the tank’s manhole cover located at the mid-height of aft side of the tank. Having in mind that the tank had been emptied, the 3rd Engineer slacked all the nuts of the manhole cover except 4 nuts at the upper part of the cover which were slacked by half a turn. Then he pulled the manhole cover to open it; however when the cover detached from the cover seat hot sludges from the tank at a temperature of approximately 85°C splashed on to his body.

The Chief Mate was informed about the incident as well as the Master who notified the vessel’s local agent as well as the managing company. By 1150 a helicopter approached the vessel, retrieved the casualty and transferred him to a hospital in Sao Luis where he was diagnosed with 2nd degree burns to a large part of his body. He remained hospitalized until 04 September 2013 when he passed away due to septic shock. CAPTAIN PETROS H sailed from Ponta da Madeira on 26 August 2013 for China.

2. Factual information

2.1 Vessel´s details

Figures 1,2: B/C CAPTAIN PETROS H.

Name of Vessel	**CAPTAIN PETROS H.**
Call Sign	SVB17
Managing Company	Marmaras Navigation Ltd.
Ownership	AVISA HOLDINGS INC.
Flag State	Greece
Port & No of Registry	Piraeus 12059
IMO Number	9426415
Type of Vessel	Bulk Carrier
Classification Society	Lloyd’s Register
Year built	2009
Ship Yard	Namura Shipbuilding Co., Ltd, Imari japan
Loa (Length over all)	289,98 m
Boa (Breadth over all)	45 m
Gross Tonnage	91499
Main Engine	MITSUI B&W 6S70MC-C Mk7 – 16860 KW
Safety Management Cert	Hellenic Republic

2.2 Voyage details

Vessel´s name	**CAPTAIN PETROS H**
Port of departure	Singapore
Port of arrival	Ponta Da Madeira, Brazil
Type of voyage	International
Crew on board	24
Minimum safe manning	12

2.3 Marine casualty information

Vessel´s name	CAPTAIN PETROS H
Type of casualty	Very serious marine casualty
Date and time	23 August, 2013 at approximately 0945
Position – location	lat: 02° 30´ 66´´ S - long: 44° 21´ 60´´ W Anchorage of Ponta Da Madeira, Brazil
External environment	Wind force 5 Bf - good visibility - day time
Ship operation	Awaiting port entry
Voyage segment	Anchorage
Consequences (to individuals, environment , property)	Fatal injury of 3rd Engineer

2.4 Transfer of casualty to shore

The master of CAPTAIN PETROS H. informed the local agent and requested the immediate transfer of the casualty ashore for medical treatment as he suffered burns at most of his body. The local agent arranged for a private helicopter which arrived at the vessel at 1150 almost two hours after the occurrence. In the meantime first aid treatment was provided to the casualty by the vessel’s crew.

The 3rd Engineer boarded on to the helicopter and was transferred to a hospital in Sao Luis. By the time he left the vessel his condition was considered to be relatively good and he managed to walk by himself in order to get on the helicopter.

3. Narrative

3.1 Level gauge malfunction

On the 22nd August 2013 the 2nd Engineer drained a quantity of 4,5m^3 of oil from the F.O. Settling Tank to the Bilge Separator Oil Tank. The operation was recorded to the vessel’s Oil Record Book Part 1 and was signed by the 2nd Engineer, as appropriate. Before the transfer operation the quantity of the Bilge Separator Oil Tank was recorded to be 2,5m^3 and after the transfer the total remaining quantity of the tank was recorded to be 7m^3.

Afternoon hours on the same day the 2nd Engineer transferred a quantity of 1,8m^3 from the Bilge Separator Oil Tank to No 2 Waste Oil Settling Tank. The operation was properly recorded and signed by said Officer at the Oil record Book. The remaining quantities of the tanks after the transfer were recorded to be 5,2m^3 for the B.S.O. Tank and 1,9m^3 for the No 2 W.O.S. Tank.

However after the transfer it was observed that the local level gauge of the No 2 W.O.S. tank was not indicating the correct quantity. The 2nd Engineer confirmed the transferred quantity by sounding the B.S.O. tank and it was concluded that the level gauge was not working properly.

The Chief Engineer who was at the Engine Control Room was informed and it was decided to clean the tank on the following day and repair the level indicator.

For this purpose, the Chief Engineer prepared a "Job Hazard Analysis" for the tank cleaning operation, according to the vessel's Safety Management System Manual – SMSM.

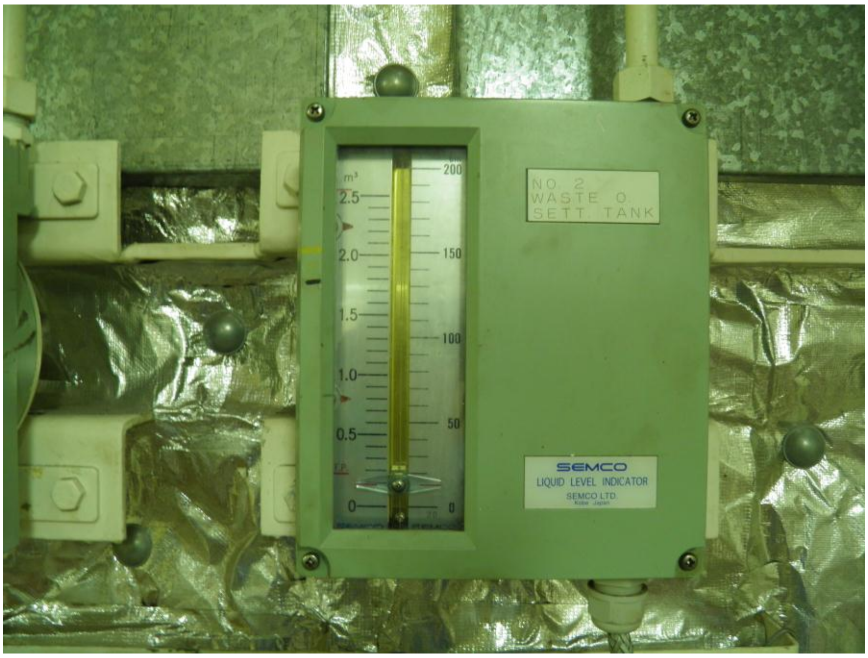


Figure 3: The level gauge of No 2 Waste Oil Settling tank.

3.2 Manhole opening

The following day, at 0800 all personnel of the engine department gathered in the engine room and were engaged to a routine inspection of the bearing of the propeller shaft's intermediate section.

The inspection lasted almost 45 minutes and when completed the Chief Engineer assigned to the 2nd Engineer the repairing of the No 2 Waste Oil Settling Tank level gauge.

The 2nd Engineer informed the 3rd Engineer and together they went to the No 2 W.O.S. Tank to open the manhole of the tank and let it vent before any other operation.

It was reported that when they got at the tank the 3rd Engineer climbed on the top of the tank to check manually the mechanism of the level gauge and reported to the 2nd

Engineer that it was working. The exact indication of the level gauge at that time could not be established however it was reported to be more than 300 ltrs.

Figure 4: The mechanism of the level gauge on top of No 2 Waste Oil Settling tank.

To empty the tank, the 2nd Engineer opened the tank's drain valve by which the sludge quantity would drain by gravity directly back to the Bilge Separator Oil Tank. He left the drain valve open for approximately 10 minutes until the level gauge indicated 300 ltrs.

In order to confirm that the tank was empty, the 2nd Engineer opened also the self-closing drain valve that is being used for draining the water quantity that settles and accumulates at the low levels of the tank. A small quantity of water flowed through the self-closing drain valve and when it stopped the 2nd Engineer was convinced that the tank was empty and told the 3rd Engineer to proceed with the manhole opening.

The manhole was situated almost two meters higher from the floor on the aft side of the tank which was close to a bulkhead. The distance of the tank from the bulkhead was approximately one meter. The 3rd Engineer used a small aluminum folding ladder to reach to the manhole height and started loosening the manhole cover nuts using an air impact wrench.

Figure 5: The manhole at the aft side of the tank almost one meter from the bulkhead and two meters from the floor.

The 3rd Engineer removed most of the nuts of the manhole and left four of them. He then loosened the four nuts by half turn. As the 3rd Engineer didn't observe any oil leakage from the manhole's seat he started loosening the nuts more rounds. Then, without removing the nuts he pulled the manhole cover which detached from the tank and hot oil started splashing from the manhole's bottom side onto the 3rd Engineer who was standing on the folding ladder.

The 2nd Engineer who was watching from a distance of almost one meter when he saw the oil splashing heavily onto the 3rd Engineer pulled him out and took off his coverall which was soaked with the hot oil. At that time the engine cadet came and assisted the 2nd Engineer to pull out the 3rd Engineer and remove his coverall. He then called the Chief Engineer who was at his office and reported the incident. The Chief Engineer went in to the Engine room and together with the other engine crew members moved the 3rd

Engineer to the vessel's hospital. In the meantime the incident was reported to the Chief Officer and the Master.

3.3 Emergency response actions

When the 3rd Engineer was transferred to the hospital it was observed that he had sustained serious burns to various areas of his body. The Master immediately reported the incident to the company and called the local agent to request assistance for the immediate transfer of the 3rd Engineer to a hospital by helicopter. In the meantime the Chief Officer provided first aid and applied special ointment for burn treatment and paraffin gauzes to the injuries.

At 1150, almost two hours after the casualty a helicopter approached the vessel and received the 3rd Engineer and transferred him to the local hospital in Sao Luis where he was diagnosed with "2nd degree burns on right and left superior limbs, inferior limbs and right and left portions of the trunk". He was submitted to "surgical wound dressing" and admitted to ICU.

The 3rd Engineer remained hospitalized until the 4th of September 2013 when he died from a septic shock.

CAPTAIN PETROS H remained at the anchorage until 25 August 2013 when she berthed at the port of Ponta de Madeira for loading. The cargo operations were completed night hours of 26 August 2013 and the following day she sailed for China.

4. Analysis

The analysis of the examined marine casualty aims to identify and determine the factors and causes which contributed to the occurrence, taking into account the sequence of events and the collection of the investigation information and data focusing both on specific points of the temporal evolution of them, as well as on the root causes in order to draw useful conclusions leading to safety recommendations.

4.1 Waste Oil Settling Tank

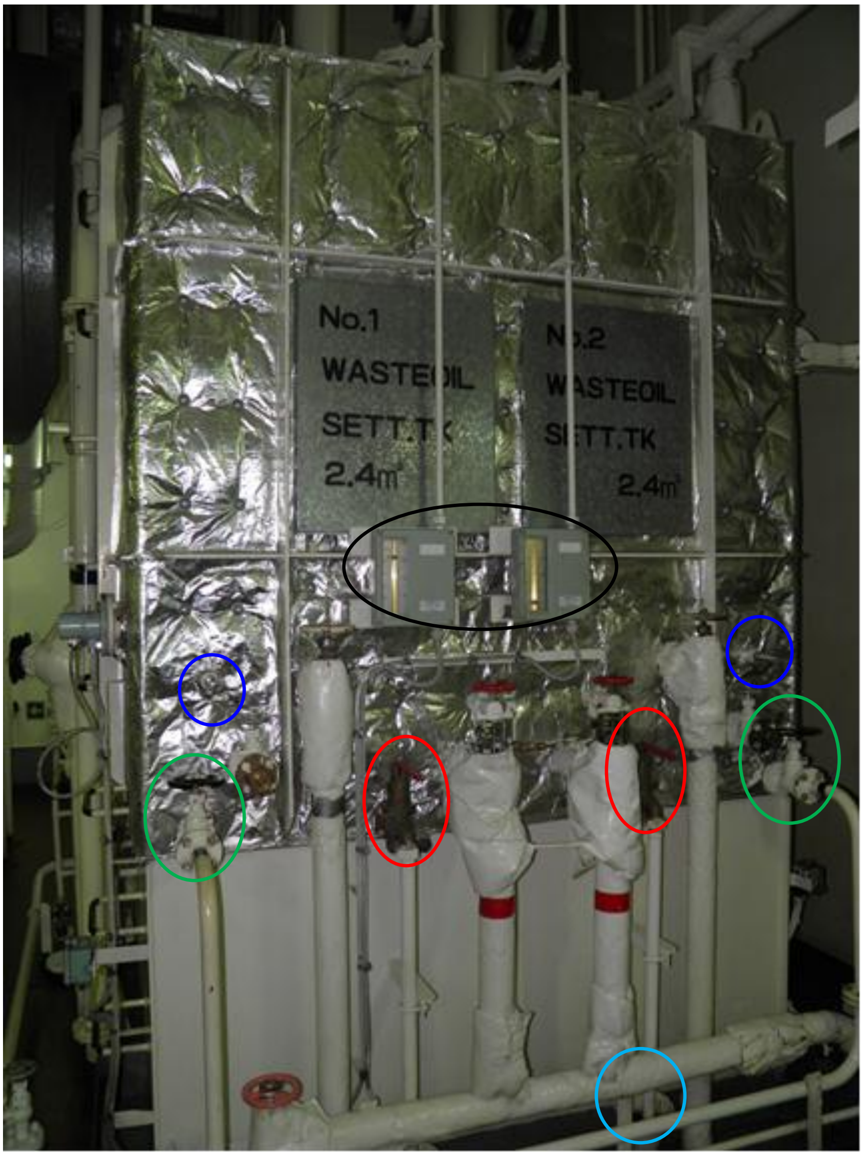
4.1.1 Tank description

CAPTAIN PETROS H had two Waste Oil Settling Tanks, both located at the second floor in the engine room. The capacity of each tank was 2,4m^3 and they were situated adjacently almost one meter from the floor.

The W.O.S. tanks were used to store the produced waste oil and sludge quantities before they were incinerated at the vessel's incinerator. They were also used for the evaporation of the water that was mixed with the sludge quantities and they were fitted with suitable steam heating coils.

Each tank was fitted with a floating type level gauge, a thermometer and a manhole the center of which was approximately 2m above the floor. In addition they were fitted with a drain pipe that was draining the tank to the Bilge Separator Oil Tank through a manually operated valve as well as with a self-closing valve for draining the water quantities that accumulated at the tank lower levels. The piping of the self-closing valves was leading to an open scupper fitted at the tank floor for the visual check of the water drainage (Figures 6,7).

It is noted that the level gauge was the only available means for perceiving the remaining quantity in the tanks as they were not fitted with sounding pipes at the top of the tanks.



Thermometer

Drain to B.S.O. tank

Self-closing valves

Scupper

Level Gauges

Figure 6: Depiction of the two Waste Oil Settling Tanks.

Figure 7: The manhole of No 1 W.O.S. Tank fitted at the fore side of the tank.

4.1.2 Level gauge

The level gauge system of the Waste Oil Settling Tanks was float type, operating with a floating device on the liquid surface. The float was fitted inside a guide pipe and it was connected to the level indicator by wire which was passing through an intermediate device for the scale reduction. The lower part of the float guide pipe was almost at the bottom of the tank.

Figure 8: The device for the wire scale reduction fitted on top of the tank.

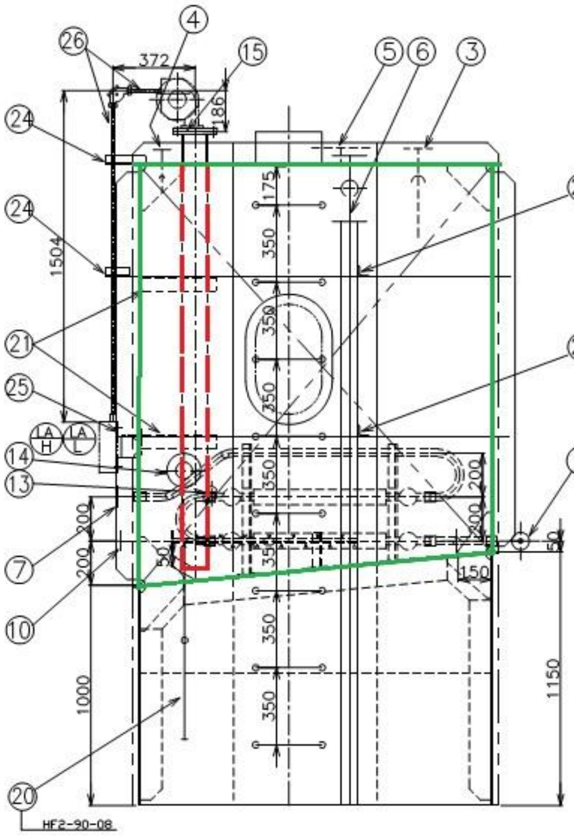


Figure 9: Drawing and photos of the float guide pipe fitted inside the tank.

4.2 Ascertaining the remaining quantity of No 2 Waste Oil Settling Tank

4.2.1 Technical requirements

The provision for means to ascertain the remaining quantities in oil tanks, lubricating oil tank or tanks with other flammable oils is generally regulated by SOLAS 74, Ch. II-2, Reg. 4.2, which states: *"2.2.3.5 Safe and efficient means of ascertaining the amount of oil fuel contained in any oil fuel tank shall be provided".*

Moreover said Regulation states:

"2.2.3.5.2 Other oil-level gauges may be used in place of sounding pipes subject to the following conditions:

. 1 in passenger ships, such gauges shall not require penetration below the top of the tank and their failure or overfilling of the tanks shall not permit release of fuel; and

. 2 in cargo ships, the failure of such gauges or overfilling of the tank shall not permit release of fuel into the space. The use of cylindrical gauge glasses is prohibited. The Administration may permit the use of oil-level gauges with flat glasses and self-closing valves between the gauges and fuel tanks."

Apart from the above, the tank measurement means are being regulated by the vessel's Classification Society's Rules. More specifically, at the Section 12 of the Rules, *"Air, overflow and sounding pipes"* it is stated:

"12.11 Sounding arrangements

12.11.1 Provisions is to made for sounding all tanks and the bilges of those compartments which are not at all times readily accessible. The soundings are to be taken as near the suction pipes as practicable.

……..

12.11.4 Sounding devices of approved type may be used in lieu of sounding pipes for sounding tanks. These devices are to be tested, after fitting on board, to the satisfaction of the Surveyors.

…….

12.11.6 If means of sounding. Other than a sounding pipe, is fitted in any ship for indicating the level of liquid in tanks containing oil fuel, lubricating oil or other flammable *liquid, failure of such means or over filling of the tank should not result in the release of tank contents."*

Considering the above it is inferred that there was no requirement for the Waste Oil Settling tanks to be fitted with a sounding pipe as alternative means of sounding in cases when the level gauge would malfunctioned and would not indicate the actual quantity of the tank.

4.2.2 Crew's estimation of the remaining quantity

As stated above, No 2 W.O.S Tank was fitted with one float type level gauge and was not provided with a sounding pipe. When the two engineers went to open the manhole of the tank they were aware of the level gauge malfunction which was stuck close to 300 liters indication. Before they proceeded to any other action the 3rd Engineer got on top of the tank and turned the wire wheel of the scale reduction device and reported to the 2nd Engineer that it was working. The actual operation of the 3rd Engineer could not be established however it is suggested that he opened the cover of the device and attempted to turn manually the wire wheel to check if it would return to the former position.

Then the 2nd Engineer opened the drain valve of the tank which drained the tank to the Bilge Separator Oil Tank. He left the valve open for almost ten minutes and noticed that the level indicator had slightly moved downwards indicating a remaining quantity of 300 liters. Then he opened the self-closing drain valve and noticed a small quantity of sludge mixed with water to drain at the scupper. When the flow had stopped he assumed that the tank had emptied and proceeded to open the manhole.

Considering the actual remaining quantity of the tank which splashed onto the 3rd Engineer's body when he pulled the manhole cover, it derives that both drains of the tank were clogged which is attributed to the oil sludge mud that had accumulated at the bottom of the tank.

In light of the above it is inferred that the two Engineers had falsely assumed that the tank was empty. They were misguided by the small downward movement of the level indicator, the movement of the wire wheel on the scale reduction device and the non-flow of oil sludge to the scupper from the drain pipe with the self-closing valve.

Nonetheless, at the time of the casualty these parameters could not be considered credible as the level gauge mechanism was evidently malfunctioning while the drain valves of oil tanks are known to be susceptible to clogging by the oil sludge mud. In addition it was reported that the tank was expected to have oil sludge mud accumulation at the bottom as one month after the last cleaning operation had passed.

It is suggested that the wrong perception of the two Engineers that the tank had emptied is related to "confirmation bias[1]" based on the above mentioned three parameters which as explained could not be considered credible.

As an additional means to confirm the draining of the tank, the two Engineers could have measured the quantity of the Bilge Separator Oil Tank to ascertain if it had increased as expected; however this was not performed as it required going to the lower level of the engine room and sound the tank.

On the above grounds it is suggested that had the Waste Oil Settling Tank had a sounding pipe, the two Engineers would have sounded the tank and have ascertained the actual remaining quantity and have not proceeded with the manhole opening.

The lack of a sounding pipe for the sounding of the tank in cases when the level gauge would not be working properly is considered a contributing factor to the examined casualty.

4.3 Cleaning of Waste Oil Settling Tanks

The Waste Oil Settling Tanks were used for storage of oil residues and they were opened occasionally for cleaning and removing the oil sludge mud which accumulated at the bottom of the tank. The time between two consecutive cleaning operations was not provided by the vessel's Planned Maintenance System and it was decided by the crew based on how each tank was operated.

According to vessel's records the cleaning operations of the Waste Oil Settling Tanks before the casualty are projected to the following table by which it derives that the No 2 Waste Oil Settling Tank had been opened and cleaned almost one month before the casualty.

Date	Tank cleaning
30 May 2013	No 1 – No 2 W.O.S. Tanks
24 July 2013	No 2 W.O.S. Tank
14 August 2013	No 1 W.O.S. Tank

[1] Personal factor of human performance when the search for data or information is restricted to that which will confirm current assumptions or expectations.

It was reported that in some occasions the mud quantity that accumulated in the Waste Oil Settling tank bottom was affecting the normal operation of the incinerator by clogging the filters and on some occasions it was jamming the level gauges as the float device was stuck in the sludge mud and provided wrong indication of the tank quantity.

According to data collected through the interview process, the quantity of oil sludge mud that was removed from the tank bottom was a little less than the quantities that were removed during routine cleaning operations. Moreover no other evidence was observed that could have caused the malfunction of the level gauge.

On the above grounds it derives that the jamming of the level gauge float and the clogging of the drain valves was caused by the accumulated oil sludge mud to the bottom of the No 2 W.O.S. tank.

The respective regulation of SOLAS 74 as described in par. 4.2.1 states in par. 2.2.3.5.3 *“The means prescribed in paragraph 2.2.3.5.2 which are acceptable to the Administration shall be maintained in the proper condition to ensure their continued accurate functioning in service.”*

This indicates that the level gauges that are being fitted in place of sounding pipes shall be maintained accordingly in order to provide an accurate indication of the remaining quantity in the tank at all times. On this ground it derives that an effective periodic maintenance should be included to a vessel’s Planned Maintenance System for the continuous operation of the level gauges.

Considering that the operation of Waste Oil Settling Tank level gauges were affected by the heavy oil residues that accumulated at the bottom, as stated above, it is suggested that a routine cleaning operation of the Waste Oil Settling Tanks should be provided by the vessel’s maintenance system, in order to remove the heavy oil residues and ensure the proper operation of the level indicators.

In light of the above, the lack of specific instructions to the vessel’s PMS for the periodic cleaning of the Waste Oil Settling Tanks in order to avoid the jamming of the level gauges is considered as a contributing factor to the examined marine casualty.

4.4 Manhole opening

The manhole of the No 2 Waste Oil Settling Tank was oval shaped with 16 bolts. The manhole cover had two jackscrews on the top and on the bottom side and a handle at the middle.

As described above the 3rd Engineer used an air impact wrench to loosen the manhole cover nuts. He removed all the nuts of the manhole except four of them. He then loosened the four nuts by half turn and as there was no oil leakage he started loosening the nuts more rounds. Then he pulled the manhole cover which detached from the tank and the hot oil started splashing from the manhole's bottom side onto his body.

The common practice to safely remove this type of manhole cover comprises the following steps.

- remove all nuts except four crosswise (top-bottom, left-right),
- slightly loosen the four nuts not more than half a turn,
- tighten the jackscrews to detach the cover from the manhole seat. If leakage is observed the cover may easily be secured back to the manhole by loosening the jackscrews and tightening the four nuts,
- if no leakage is observed, loosen another half round the four nuts,
- tighten again the jackscrews and
- if no leakage is observed continue to loosen the four nuts and remove the cover.

Considering the above in conjunction to the massive leakage and the splashing of oil onto the 3rd Engineer's body, it derives that the 3rd Engineer did not use the jackscrews to detach the cover from the manhole seat while the nuts were loosened by half a round. Instead he loosened the nuts more while the cover was still attached to the manhole seat and when he pulled the manhole cover the oil started splashing heavily from the bottom side of the manhole.

It is suggested that the false perception of the two Engineers that the tank had been drained and it was empty had contributed to the decision to skip the necessary step for the safe opening of the manhole, by using the jackscrews while four crosswise nuts were slightly loosened.

Figure 10: The manhole cover of No 2 Waste Oil Settling Tank and the two jackscrews fitted on the top and bottom side.

4.5 Job Hazard Analysis

The vessel's Safety Management System Manual was incorporating instructions and procedures for the vessel's safe operation and working environment which were included to Part VI of the SMSM under the title "Risk Assessment and Risk Management". According to said instructions Risk Assessments were to be conducted for ongoing operations (routine and non routine) in order to identify and address potential hazards to personnel, property, the environment, Company's reputation as well as for the following cases:

- temporary or permanent changes to procedures or equipment on board the vessel as part of the SMS process,
- Accidents, incidents, serious near misses,
- Before the introduction of new critical equipment or procedure,
- Preparation of complex or high risk jobs,
- New operations or activities.

The Risk Assessment was performed by the shore personnel following a request of the Master and after conducting a "Job Hazard Analysis" which would identify high risks. The "Job Hazard Analysis" should be conducted for every job or task on board that could result to personnel injury or other job hazards. Said analysis was recorded to the dedicated "JHA 01" form.

Following the aforementioned provisions of the SMSM the previous day of the casualty the Chief Engineer had conducted a Job Hazard Analysis for the inspection and maintenance of No 2 Waste Oil Settling Tank which was recorded to the respective form. According to said analysis mechanical injury/burns and eye injuries or other health risks had been recorded amongst the identified hazards. The recorded preventive measures for these hazards were to exercise caution when working and the correct use of PPE. Moreover the evaluation matrix of the existing control measures provided a medium risk factor for serious injury to personnel. On this ground the operation could be performed without any additional procedure for requesting a Risk Assessment by the shore personnel.

Considering the above it is noted that the Job Hazard Analysis had not included potential risks related to the malfunctioned level gauge. The opening of the tank required the engine personnel to ascertain that the tank was empty before removing the manhole cover and as the level gauge was not working this had to be confirmed by other means. The evaluation of a procedure to confirm the draining of the tank could have alerted the two Engineers concerning the involved factors such as the not fitted sounding pipe, the susceptible drain pipes of the tank to clogging by the oil sludge mud and the need to confirm that the oil quantity in the tank had drained by measuring the Bilge Separator Oil Tank. Furthermore the identification of the aforementioned risks could have increased the awareness of the two Engineers and prevented them from skipping critical steps of the proper procedure for safely opening the manhole as described in the previous paragraph.

The lack of identifying during the Job Hazard Analysis the potential hazards related to the remaining quantity in the tank due to the faulty level gauge is considered as a contributing factor to the examined marine casualty. Nonetheless, as reported during the interview process, it was expected that the two Engineers would have applied their professional knowledge and expertise and would have measured the Bilge Separator Oil Tank to confirm the draining of the W.O.S. Tank and would have opened the manhole following the proper procedure.

4.6 Supervision

According to the recorded Job Hazard Analysis for the inspection and maintenance of No 2 Waste Oil Settling Tank the 2nd Engineer was assigned with supervision duties. As already stated the 2nd Engineer opened the drains of the tank and having in mind that the tank had emptied he allowed the 3rd Engineer to proceed with the opening the manhole.

At the time of the casualty he was standing almost at one meter distance from the 3rd Engineer watching him as he was removing the manhole cover. However as described in par. 4.2.2 the 2nd Engineer had falsely perceived that the tank was empty therefore he didn't urge the 3rd Engineer to apply the common practice for opening the manhole as described in par. 4.4.

4.7 Oil temperature

The two Waste Oil Settling Tanks were fitted with steam heating coils for heating the oil sludge quantity to a temperature up to 100˚C in order to evaporate the water of the mixture and to decrease the flow resistance.

The previous day of the casualty the heating valves of No 2 Waste Oil Tank were closed. However the heating of the adjacently No 1 Waste Oil Settling tank was open for evaporation purposes. As a result the quantity of No 2 Waste Oil Settling Tank was indirectly heated. It was reported that the temperature of the oil sludge of No 2 W.O.S. Tank was 86˚C and therefore it caused 2nd degree burns to the 3rd Engineer's body.

The heating of No 1 W.O.S. Tank that through conduction heated the oil sludge of No 2 W.O.S. Tank is considered as a contributing factor to the examined marine casualty.

4.8 Personal Protective Equipment[2]

4.8.1 Burn injuries

It is known that extended burns can cause local or systematic complications to the human organs that may lead to incapacitation or even life threatening injuries. If the injury is serious it cannot be treated on site using the vessel's medical first aid supplies and equipment and immediate medical assistance and hospitalization is required. The situation becomes more difficult directly threatening a crew member's life if a vessel is far away from shore assistance and any Medevac operation is not feasible, as severe burns are not to be self-treated on board and require medical attendance and hospitalization.

For this reason it is considered vital to implement proactive measures and mitigate the risk of burn injuries to the crew. The most commonly applied approach targets to safety measures to prevent or avoid the direct cause of serious burn injuries such as fire, hot surfaces, hot liquids etc. Nonetheless, as many deaths of crew members are caused by serious burn injuries it is considered highly significant to implement safety measures to mitigate the consequences of an accidental event that could cause serious burns to

[2] Reference: Protective Clothing: Managing Thermal Stress by Faming Wang and Chuansi Gao.

personnel. To this direction it is considered compelling to use effective PPE that can provide the maximum protection to the crew.

According to a *"Laboratory Evaluation of Thermal Protective Clothing Performance Upon Hot Liquid Splash"*[3] conducted by Farzan Gholamreza and Gwoen Suong (Human Ecology Department, University of Alberta) hot liquid that flows on the surface of the fabric creates external convection, which delivers heat to the surface of the fabric. This amount of heat delivers results in heat conduction through the fabric. The liquid may also penetrate through the porous structure of the fabrics and be stored in the fabric. The penetration of hot liquid through the fabric delivers heat closer to the skin and causes increased injuries. The hot liquid may also be transferred to the inside surface of the fabric and contact the skin. This skin contact with hot liquid is even more damaging. Moreover among the physical properties of the fabric, air permeability is a dominant factor in protection performance against hot liquid since resistance to mass transfer is shown to be the key factor for reducing the amount of transmitted heat to the skin.

4.8.2 Crew's PPE

According to the safety policy of CAPTAIN PETROS H managing company, each crew member was provided with a list of PPE when they signed on the vessel which they were obliged to use during the performance of their duties. The PPE list included amongst others:

- one safety helmet,
- one protective mask,
- one set of protective goggles,
- one pair of safety shoes,
- one pair of gloves,
- two overalls.

At the time of the casualty the 3rd Engineer was wearing a common type cotton coverall which was provided to him when he signed on. This type of clothing is commonly used by vessels' engine crews mostly for their cooling and sweat absorbing features taking into account the high temperatures of their working environment. However it provides limited protection from heat, whereas the weave structure allows the penetration of the hot liquid and the transfer of heat to the skin causing the burn injuries.

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[3] https://academic.oup.com/annweh/article/57/6/805/149038/Laboratory-Evaluation-of-Thermal-Protective

In the examined marine casualty the hot oil that was leaking from the manhole was splashing onto the 3rd Engineer's coverall. As it was constructed with cotton and a plain weave structure the fabric got soaked and it allowed the penetration of the hot oil into the casualty's body causing the 2nd degree burns. His injuries were serious and the crew could not cope with the situation as the vessel's medical supplies and equipment and the crew medical training were not sufficient for a complete medical treatment.

In light of the above it derives that the clothing of the 3rd Engineer did not protect his body from the splashing hot oil which caused the serious burn injuries that required medical support from shore.

4.8.3 Protective clothing standards

Certain Organizations have developed respective standards for the protective clothing against several hazards including the heat and flame. However, the maritime sector has not yet adopted the use of this type of clothing when the crews perform tasks with hazards related with burn injuries. The issue has been highlighted in the 03/2014 HBMCI safety investigation report concerning the death of a crew member due to severe burn injuries after an explosion[4].

A general description of the aforestated standards are presented below:

ISO 11612:2015[5]

This standard specifies performance requirements for protective clothing made from flexible materials, which are designed to protect the wearer's body, except the hands, from heat and/or flame. The performance requirements set out in this standard are applicable to protective clothing which could be worn for a wide range of end uses, where there is a need for clothing with limited flame spread properties and where the user can be exposed to radiant or convective or contact heat or to molten metal splashes.

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[4] HBMCI Safety Investigation Report 03/2014 published on 13-09-2016 which can be downloaded at the link: http://hbmci.gov.gr/js/investigation%20report/final/03-2014%20NAKHODKA.pdf

[5] http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=57457

EN ISO 11612

- **Code A:** Limited flame spread
- **Code B:** Protection against Convective Heat-3 levels
- **Code C:** Protection against Radiant Heat - 4 levels
- **Code D:** Protection against Molten Aluminium Splash - 3 levels
- **Code E:** Protection against Molten Iron Splash - 3 levels
- **Code F:** Protection against Contact Heat Â· 3 levels

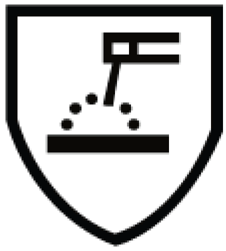
Figure 23: Indicative protective overall against heat and flame ISO 11612:2015 (source web)

ISO 11611:2015[6]

This standard specifies the minimum basic safety requirements and test methods for protective clothing including hoods, aprons, sleeves, and gaiters that are designed to protect the wearer's body including head (hoods) and feet (gaiters) and that are to be worn during welding and allied processes with comparable risks. For the protection of the wearer's head and feet, this International Standard is only applicable to hoods and gaiters. This International Standard does not cover requirements for feet, hand, face, and/or eye protectors. This type of protective clothing is intended to protect the wearer against spatter (small splashes of molten metal), short contact time with flame, radiant heat from an electric arc used for welding and allied processes, and minimizes the possibility of electrical shock by short-term, accidental contact with live electrical conductors at voltages up to approximately 100 V d. c. in normal conditions of welding. Sweat, soiling, or other contaminants can affect the level of protection provided against short-term accidental contact with live electric conductors at these voltages.

[6] http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=57455

FLAME RETARDANT COVERALL



EN ISO 11611

- Limited Flame Spread (A 1 + A2)
- Molten Droplets
- Heat Transfer (radiation)
- Electrical resistance

Class1:protection against less hazardous welding techniques and situations, causing lower levels of spatter and radiant heat

Class2:protection against more hazardous welding techniques and situations, causing higher levels of spatter and radiant heat

Figure 24: Indicative flame retardant overall ISO 11611:2015 (source web)

BS EN ISO 14116

This standard specifies the performance requirements for the limited flame spread properties of materials, material assemblies and protective clothing in order to reduce the possibility of the clothing burning and therefore avoiding a hazard. Additional requirements for clothing are also specified. Protective clothing complying with this standard is intended to protect workers against occasional and brief contact with small igniting flames, in circumstances where there is no significant heat hazard and without the presence of another type of heat. When protection against heat hazards is necessary in addition to protection against limited spread flammability, then standards, such as BS EN ISO 11612, are more appropriate.

According to the research stated in par. 4.8.1 the hot liquid hazard is considered relatively unexplored and has generated interest in the safety clothing industry. In earlier studies, most of the research has been done on the thermal performance of textiles under convective and radiant heat exposure, researchers have identified considerable findings about the fiber, yarn, and fabric characteristics that affect the thermal performance of the protective clothing. Although a considerable amount of attention has been paid to the thermal performance of fabric systems exposed to convective and radiant exposures, few studies have been done on other thermal hazards such as direct exposure to steam and hot liquids. Moreover, traditional clothing materials used for protection against a flash fire provide little protection against hot liquid hazard, and the routine flame-retardant protective gear, commonly worn by workers, is not fully engineered against steam and hot water.

In light of the above it is suggested that existing protective clothing do not provide full protection against steam and hot liquid. However the use of a heat/flame protective clothing complying with ISO 11612 could have provided better protection to the 3rd Engineer's body than the common cotton type overall he was wearing at the time of the casualty.

4.9 The involved crew

The Master

The Master of the vessel was 51 years of age. He had been serving on vessels as a Master from 2002 and had been contracting with the managing company of CAPTAIN PETROS H for almost eight years. He had joined the vessel on 13 January 2013. At the time of the casualty he was in his office and when he got informed by the Chief Officer he went to the vessel's hospital to assess the seriousness of the injuries. He instructed the Chief Officer for the medical treatment and reported the accident to the vessel's managers. He then contacted the local agent and requested a helicopter to transfer the 3rd Engineer to a hospital.

The Chief Officer

The Chief Officer was 27 years of age and this was his first contract as a Chief Officer. He had been serving to vessels of CAPTAIN PETROS H managing company for almost 7 years. He had joined the vessel on 22 February 2013. At the time of the casualty he was at the Ship's Office and was informed by an engine rating. He gave the order to muster the medical team which transferred the 3rd Engineer to the vessel's hospital and treated his burn injuries.

The Chief Engineer

The Chief Engineer was 52 years of age and had joined the vessel on 30 August 2012. He was serving on vessels as a Chief Engineer from 1997 and from 2004 he was contracting with the managing company of CAPTAIN PETROS H. He assigned to the 2nd Engineer the opening of the No 2 Waste oil Settling Tank and performed the Job Hazard

Analysis the previous day. At the time of the casualty he was in his office and he was informed by the engine cadet.

The 2nd Engineer

The 2nd Engineer was 51 years of age and he had joined the vessel on 09 July 2013. He was serving on vessels of the managing company of CAPTAIN PETROS H since 1993 with an intermediate break on 2000 when he had one contract with another company. It was his second time serving on a vessel with the Chief Engineer of CAPTAIN PETROS H. When he joined the vessel he completed the orientation and familiarization training program provided by the Chief Officer and the Chief Engineer.

The 3rd Engineer

The 3rd Engineer was 42 years of age and he had joined the vessel on 28 June 2013. Before taking over his duties he completed the orientation and familiarization program provided by the Chief Officer and the Chief Engineer according to the respective Check List of the SMSM which was duly signed.

4.10 Fatigue

The examination of the working and resting hours records for the key personnel involved in the marine casualty as well as the interview process did not provide evidence that fatigue was a contributing factor to the marine accident. The previous day the two Engineers were involved with the replacement of the anodes of the Main Engine Air Cooler. They completed their work at 1700 and went to rest until 0800 of the day of the casualty when they started their daily work.

The following conclusions, safety measures and safety recommendations should not under any circumstances be taken as a presumption of blame or liability. The juxtaposition of these should not be considered as an order of priority or importance.

5. Conclusions

1. The Waste Oil Settling tanks were not fitted with sounding pipes and the level gauge was the only available means for perceiving the remaining quantity in the tanks (§ 4.1.1).
2. There was no requirement for the Waste Oil Settling tanks to be fitted with a sounding pipe as alternative means of sounding in cases when the level gauge malfunctioned and did not indicate the actual quantity of the tank (§ 4.2.1).
3. The accumulation of oil sludge mud to the bottom of the tank caused the jamming of the level gauge float and the clogging of the drain valves (§ 4.2.2, § 4.3).
4. The two Engineers had falsely assumed that the tank was empty. They were misguided by the small downward movement of the level indicator, the movement of the wire wheel on the scale reduction device and the non-flow of oil sludge to the scupper from the drain pipe with the self-closing valve (§ 4.2.2).
5. It is suggested that the wrong perception of the two Engineers that the tank had emptied is related to confirmation bias (§ 4.2.2).
6. Had the Waste Oil Settling Tank be fitted with a sounding pipe, the two Engineers would have sounded the tank and have ascertained the actual remaining quantity and have not proceeded with the manhole opening (§ 4.2.2).
7. No 2 Waste Oil Settling Tank had been opened and cleaned almost one month before the casualty (§ 4.3).
8. The jamming of the level gauge float and the clogging of the drain valves was caused by the accumulated oil sludge mud to the bottom of the No 2 W.O.S. tank (§ 4.3).
9. The vessel's PMS did not provide guidelines for periodic routine maintenance/cleaning of the Waste oil Settling Tanks in order to remove the heavy oil residues and avoid the jamming of the level gauges (§ 4.3).
10. The 3rd Engineer did not apply the common practice for the safe opening of the manhole. It is suggested that the false perception that the tank had been drained and it was empty had contributed to skip the necessary steps (§ 4.4).
11. The Chief Engineer conducted a Job Hazard Analysis for the inspection and maintenance of No 2 Waste Oil Settling Tank the previous day of the casualty which

was recorded to the respective form. However potential hazards related to the remaining quantity in the tank and the faulty level gauge were not identified as it was expected that the two Engineers would have applied their professional knowledge and expertise to verify that the tank was empty (§ 4.5).

12. The 2nd Engineer who was supervising the operation allowed the 3rd Engineer to open the manhole without applying the common practice and use the jackscrews because he had falsely perceived that the tank was empty (§ 4.6).
13. The No 2 W.O.S. Tank heating valves were closed. However the remaining oil quantity was indirectly heated up to 86˚C by the adjacently heated No 1 W.O.S.Tank (§ 4.7).
14. The overalls of the 3rd Engineer was the common type made of cotton fiber and did not protect his body from the splashing hot oil which caused serious burn injuries (§ 4.8.2).
15. Existing protective clothing do not provide full protection against steam and hot liquid. However the use of a heat/flame protective clothing complying with ISO 11612 could have provided better protection to the 3rd Engineer's body than his common cotton type overall that he was wearing at the time of the casualty (§ 4.8.3).

6. Actions taken

No information was provided about actions taken following the examined marine accident.

7. Safety recommendations

Taking into consideration the analysis and the conclusions derived from the safety investigation conducted the following recommendations are issued:

The managing company of the vessel is recommended to:

83/2013 Amend the vessel's PMS with provisions for routine maintenance/cleaning operations of Waste Oil Tanks to prevent the malfunction of the level gauges due to the accumulation of oil sludge mud.

84/2013 Consider providing the crew with heat/flame protective clothing (overalls) complying with the respective standards, for use at works or operations with burn injury hazards.

85/2013 Highlight to the crews of their managed vessels the importance of applying precautionary measures during the opening of a tank when the remaining quantity is not provided by direct and credible means.

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Accident Investigation Report 14/2013
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