Bundesstelle für Seeunfalluntersuchung
Federal Bureau of Maritime Casualty Investigation
Federal Higher Authority subordinated to the Federal Ministry
of Transport and Digital Infrastructure

Draft

Investigation Report 338/19

Very Serious Marine Casualty

Fire in the engine room on board the multi-purpose carrier KELLY with one deceased and two injured crew members on the River Elbe on 6 September 2019

Information as of 27 July 2021

This investigation was conducted in conformity with the Law to improve safety of shipping by investigating marine casualties and other incidents (Maritime Safety Investigation Law – SUG). According to said Law, the sole objective of this investigation is to prevent future accidents. This investigation does not serve to ascertain fault, liability or claims (Article 9(2) SUG).

This report should not be used in court proceedings or proceedings of the Maritime Board. Reference is made to Article 34(4) SUG.

The German text shall prevail in the interpretation of this investigation report.

Issued by:
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1 SUMMARY

The Malta-flagged multi-purpose carrier KELLY was en route from Rotterdam in the Netherlands to Kaliningrad in Russia on 6 September 2019. The ship was unladen at the time and appropriately manned for pilotage from the sea to Brunsbüttel toward the NOK[1]. A fire in the separator room triggered the fire alarm at 1335. The pilot on board notified the Brunsbüttel regional control centre, requesting assistance at the same time. In the meantime, the KELLY's crew was involved in fighting the fire and recovering two crew members. A third seriously injured crew member was able to leave the burning engine room unassisted. The fire was extinguished rapidly as a result of the firefighting measures initiated by the crew and thus confined to the engine room.

The ship's propulsion and power supply systems failed at the same time. The pilot on board consulted with the master with regard to anchoring the ship safely so as to prevent her from grounding or drifting out of control. At the same time, shore-based emergency services and the fire brigade were alerted and directed by the German Central Command for Maritime Emergencies (CCME), which had assumed overall control of the operation in the meantime.

The VIKING ENERGY collected and transferred the first casualty to the crew tender MASTER P, which then took him to Brunsbüttel where he was collected by a rescue helicopter and flown to a special clinic for burn injuries in Hamburg. A Federal Police helicopter winched the second casualty directly from the KELLY and also flew him to the clinic in Hamburg. An emergency doctor who had arrived on the ship could only record the third crew member's time of death.

The investigation revealed areas open to improvement when the crew is preparing risk and hazard assessments so as to identify potential hazards when working on heat transfer systems. In addition, a recommendation that the classification society amend its rules for surveying thermal oil systems after repairs and extended periods out of service was issued.

[1] NOK: Kiel Canal. Federal waterway linking the North Sea with the Baltic Sea.
Starts: Brunsbüttel, River Elbe (North Sea).
Finishes: Kiel-Holtenau, Kiel Firth (Baltic Sea).

2 FACTUAL INFORMATION

2.1 Photograph of the ship

Source: Hansa Shipping

Figure 1: MV KELLY

2.2 Ship particulars

Name of ship:	KELLY
Type of ship:	Multi-purpose carrier
Flag:	Malta
Port of registry:	Valetta
IMO number:	9255622
Call sign:	9HA4962
Owner (according to Equasis):	HS KELLY OU
Shipping company:	Hansa Ship Management OU
Year built:	2004
Shipyard:	Hull: Daewoo-Mangalia Heavy Industries S.A. (hull number: 1042) Bodewes Scheepswerf “Volharding” Foxhol B.V. (hull number: 515)
Classification society:	Registro Italiano Navale (RINA)
Length overall:	132.20 m
Breadth overall:	15.87 m
Draught:	7.75 m
Gross tonnage:	6,361
Deadweight:	9,857 t
Engine rating:	3,840 kW

Main engine:	MAK 8M32C; Caterpillar Motoren GmbH & Co. KG
(Service) Speed:	15 kts (empty); 13.5 kts (laden)
Hull material:	Steel
Hull design:	Double hull (Ice Class 1A)

2.3 Voyage particulars

Port of departure:	Rotterdam, the Netherlands
Port of call:	Kaliningrad, Russia
Type of voyage:	Merchant shipping/international
Cargo information:	Ballast
Manning:	13
Draught at time of accident:	Df= 4.20 m, Da= 4.60 m
Pilot on board:	Yes
Canal helmsman:	No
Number of passengers:	0

2.4 Marine casualty or incident information

Type of marine casualty:	Very serious marine casualty; fire in the engine room with one deceased and two injured crew members
Date, time:	06/09/2019, 1330[2]
Location:	River Elbe, buoy 51,
Latitude/Longitude:	φ 53°51.5'N λ 009°02.1'E
Ship operation and voyage segment:	River Elbe Fairway mode Approaching the NOK off Brunsbüttel
Place on board:	Separator room inside the engine room
Human factors:	Yes
Consequences:	One deceased and two injured crew members; fire damage in engine room

[2] All times shown in this report are local (UTC + 2 hours).

Extract from Navigational Chart 46 (INT 1453),
Federal Maritime and Hydrographic Agency (BSH)

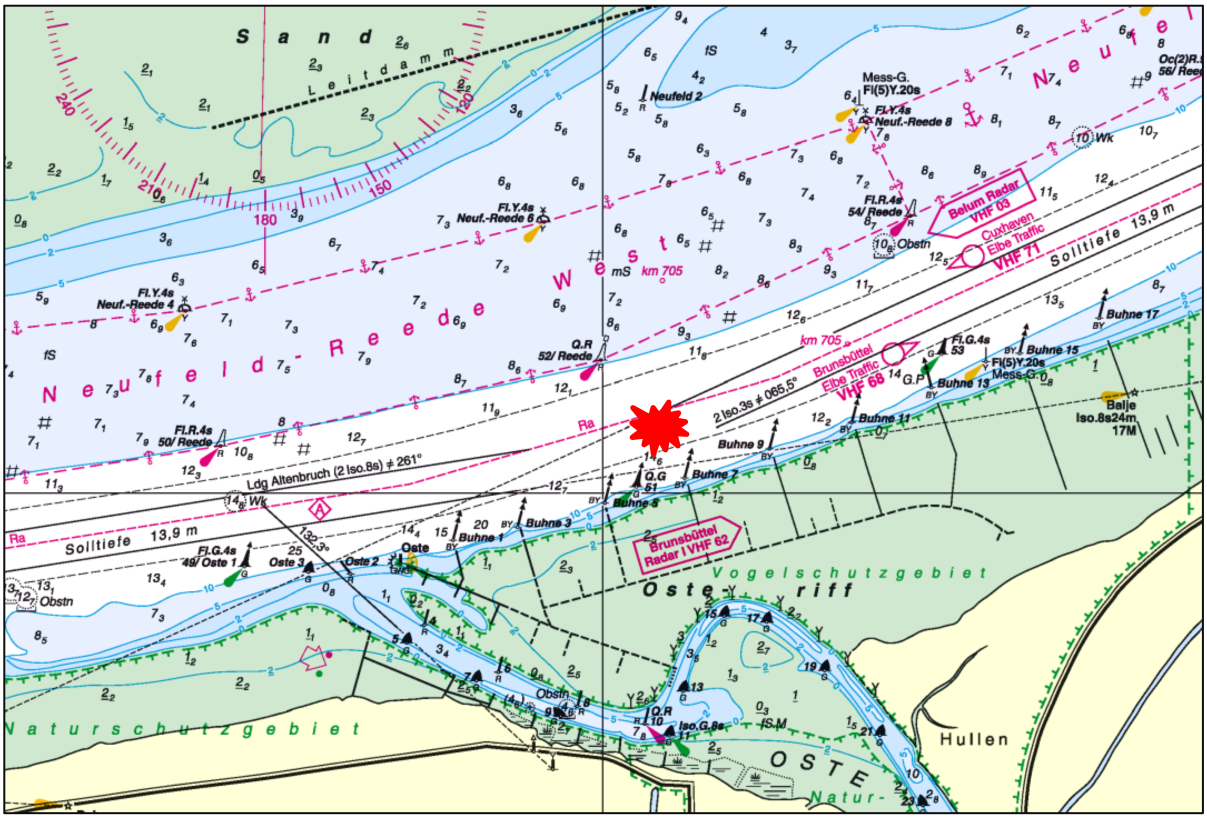


Figure 2: Scene of the accident

2.5 Shore authority involvement and emergency response

Agencies involved:	Vessel Traffic Service (VTS) Brunsbüttel, Waterway Police (WSP) Hamburg, Cuxhaven Criminal Investigation Department, CCME, Brunsbüttel, Stade and Cuxhaven fire brigades, Rescue control center West, Stade and Hamburg
Resources used:	Firefighting unit (FFU) from Brunsbüttel and Cuxhaven, Stade Fire Brigade, tug PARAT, rescue cruiser ANNELIESE KRAMER, customs vessel GLÜCKSTADT, tug FAIRPLAY XV, German Life Saving Association (DLRG) Brunsbüttel rescue boat, Federal Police helicopter PIROL 806, tug MULTRA SALVOR 3, crew transfer boat MASTER P, tug LUCHS, rescue helicopter CHRISTOPH 29, tug HELMUT, police boat VOßBROOK, workboat VIKING ENERGY, On-Scene-Coordinator (OSC) of the CCME, rescue helicopter CHRISTOPH HANSA
Actions taken:	Brunsbüttle Fire Brigade brought on board using the tug PARAT; in the further course implementation of the orders of the HK via the OSC on site;

casualty transported ashore by the MASTER P and then to a hospital,
other casualty transported to a hospital by helicopter,
firefighters and emergency doctors transported to the KELLY by rescue cruiser and rescue helicopter,
tugs shifted ship to Brunsbüttel’s south pier - WSP commences investigation there

3 COURSE OF THE ACCIDENT AND INVESTIGATION

3.1 Course of the accident

The account of the course of the accident is based on interviews with the ship's crew (with the exception of the chief engineer officer and one of the two surviving burns victims). The second engineer officer was visited in hospital and questioned about the accident with the assistance of an interpreter. The second severely injured motorman was not fit for questioning due to his life-threatening injuries and ensuing state of shock and submitted his recollections of the accident in the form of a written statement at a later date. The shipping company provided copies of the deck log book and bell book. A statement of facts and a record of events were also submitted. In addition, a copy of the printout of the alarm event log, which logs special events in the engine room and other technical installations, was also submitted. The BSU was also provided with the mission reports of all agencies involved. Moreover, the written statement of the pilot on board made a significant contribution to the clarification of the chronology of events and the measures taken by the ship's crew and the rescue agencies ordered. Accordingly, the following account of the accident shall be based mainly on the pilot's progress report. Submissions from the crew are in italics for easier distinction.

The Malta-flagged multi-purpose carrier KELLY was sailing in ballast from Rotterdam (NL) to Kaliningrad (RUS) via the NOK. The pilot entered her bridge at 1100 on 6 September 2020 and notified Scharhörn Radar that he had embarked. After the usual exchange of information and the master's verbal confirmation that all systems are currently operational and there are no faults, he also reported in to VTS Cuxhaven, which advised that the KELLY could expect the lock to be clear for entering the NOK at 1430. The master then left the bridge after handing over the responsibility to the officer on watch, requesting that he be informed 30 minutes before arrival at the Nordwest-Reede roadstead. The ship passed the radar tower at Cuxhaven at 1230. As agreed, the master returned to the bridge at 1320. On passing buoy 51 at 1331, they reported to VTS Brunsbüttel that the ship was inbound and approaching the canal.

The engine room's crew, comprising two motormen, the second engineer and the chief engineer, went on duty as usual at 0800 on the day in question. Works on the thermal oil system were planned for that morning. Since the available heating capacity was no longer sufficient due to the outside temperatures getting colder, a presumably blocked pipe section from said system in the separator room had to be inspected and cleaned. The second engineer and the two motormen were assigned this task. To that end, a pipe valve and one of the two control valves were closed but they were not disconnected from the power supply. Since neither of the valves closed completely, a cleaning rag had been put into the horizontal valve and a bucket was suspended from the vertical one. The second engineer stated that he had emptied it several times in the course of the morning.

The leakage oil was disposed of in the sludge tank[3] outside the separator room.

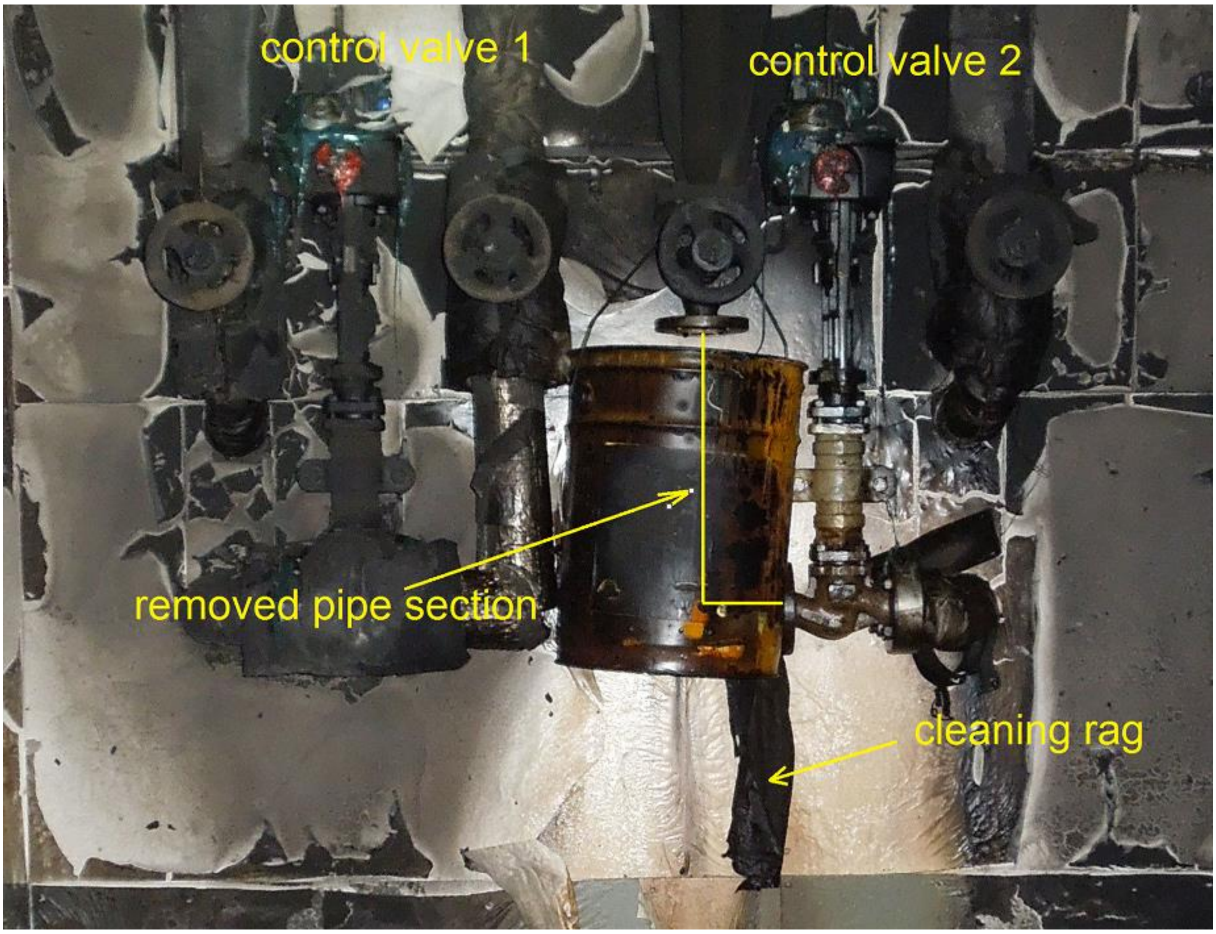


Figure 3: Removed pipe section/working area in the thermal oil system

Deposits found in the dismantled pipe section (or in this case assumed fuel residues leftover from an earlier fuel ingress in the thermal oil system) were removed mechanically and the pipe section was then cleared with compressed air. The second engineer stated that this work had been completed and they then discussed reassembling the pipe section so that it was available for the forthcoming canal passage. Immediately after, he noticed a hissing or rather whistling noise followed by an explosion[4] in the front of the separator room.

The fire alarm on the ship triggered automatically at 1335. The smoke coming out of the engine room was already so heavy at this point that it was also noticeable directly on the bridge. The master sent crew members to clarify the situation. At the same time, vessel lost propulsion. However, at this point it was still possible to steer the ship. The pilot reported the incident to VTS Brunsbüttel immediately, requesting that the fire and rescue services be alerted and that information be passed on to shipping near the casualty. After the pilot's urgent recommendation to the master that a crew member be sent to the forecastle to operate the windlass, the power supply system on board

[3] Sludge tank: Tank for oil residues (sludge). Every ship with a gross tonnage of 400 and above must be fitted with at least one tank of sufficient capacity to contain oil residues (sludge) from the cleaning of fuel and lubricating oils, as well as from oil spills in the machinery spaces.
[4] Event with subsequent fire as described by the second engineer.

the ship, including battery backup for navigation equipment, failed at 1337. This made it impossible for the ship to communicate on VHF. The pilot then switched on his own hand-held radio set. VTS Brunsbüttel’s response, informing them that the rescue chain was alerted and help is on the way, was received at 1340. Tug support was also confirmed.

The second engineer stated that the separator room suddenly filled with dense acrid smoke accompanied by fire. Figure 4 shows the position of the three casualties at the time of the explosion. He yelled at his two colleagues, who were apparently in shock, to follow him. He reportedly slipped on the oily floor and fell several times when leaving the separator room. Parts of his overalls that were soaked with oil, mainly on his arms and legs, were on fire.

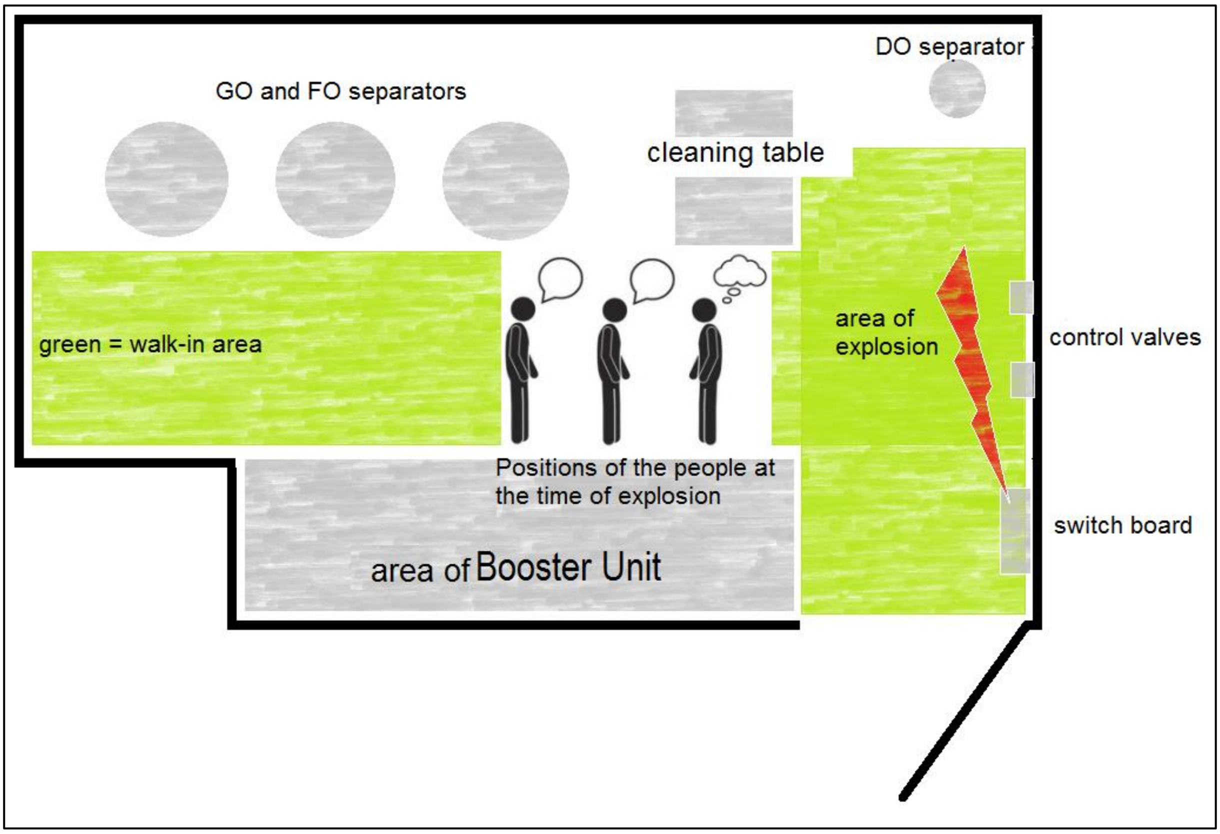


Figure 4: Schematic representation of the room immediately before the explosion

Deceased motorman, seriously injured motorman, seriously injured second engineer (from left).

In front of the separator room, lying on the floor in the engine room, he reportedly called for his two colleagues repeatedly. At that point there was zero visibility. Since he neither saw nor heard anything from them, he was hoping for physical contact. This failed to materialise, however. Suffering from shock and now barely able to breathe, he assumed both crew members had lost their lives and left the engine room. However, he still tried to turn off the fuel pumps and fans in the process.

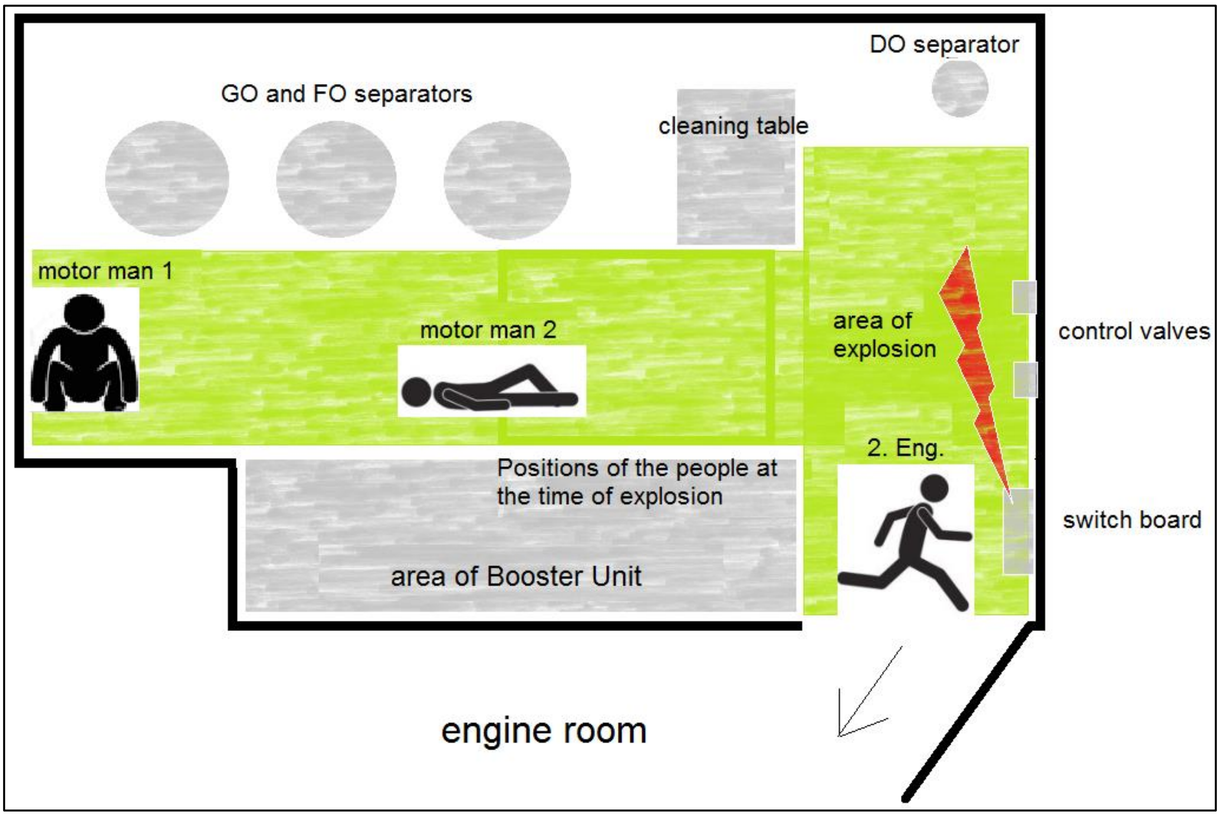


Figure 5: Schematic representation of the separator room shortly after the explosion

The ship was now no longer under command and began to drift in a south-westerly direction. To compensate for this, the KELLY executed an emergency anchor manoeuvre outside the green buoy line just after buoy 53. Several vessels in the immediate vicinity offered their assistance within minutes. The pilot asked if medically trained personnel were on board. The skipper of the VIKING ENERGY confirmed this request, assured full assistance and agreed to take the casualties on board.

At 1350, the master confirmed that firefighting was ongoing and that the first casualty from the engine room was being attended to. The latter could be seen on the main deck from the bridge[5]. He had severe burns but was apparently responsive when spoken to. This was the second engineer, who was able to leave the scene of the fire unassisted.

[5] The floor-to-ceiling windows on the starboard and port side of the bridge made it possible to see the main deck in front of the superstructures.

Once on deck, the second engineer met the chief engineer. He yelled loudly and repeated: "Fire, fire!" He then rather formally asked his superior to trigger the CO2 system. He could no longer recall whether it was he himself or the chief engineer who had flooded the engine room with CO2 via the release station on the deck. The chief engineer was also unable to provide any further information. He stated that the main motivation for his actions was protecting the remaining crew and the ship from further harm. The master was neither involved in this decision nor informed about it. He only became aware of the situation due to the CO2 alarm.

For a better understanding, and relevant from the investigator's point of view, it should be noted that the engine room and the separator room have two separate CO_2 systems that can be triggered independently of one another. Nevertheless, it is an indispensable measure to evacuate closed rooms, such as the engine room, before flooding with CO_2 and to ensure that the crew is complete in a designated place. The BSU investigators are unable to judge to what extent it would have been possible to evacuate the two crew members still remaining in the separator room. It can be assumed that the additional time required to fight the fire elsewhere would also have cost the second motorman his life.

In connection with the failure of the on-board power supply, it should be mentioned that fire fighting by means of water was no longer possible, as the fire pumps could also no longer be put into operation. The automatic starting of the emergency diesel also failed and prevented the possibility of pressurising the fire extinguishing system. Why no immediate attempt was made to start the emergency diesel manually could not be answered by any of the persons involved.

Translated with www.DeepL.com/Translator (free version)
Meanwhile, the skipper of the crew tender MASTER P offered to take the casualty to Brunsbüttel at maximum speed after the VIKING ENERGY had taken him on board.

At the same time, the pilot requested a status report from VTS Brunsbüttel on the deployment of auxiliary personnel. The latter advised that the tug PARAT was about to pick up firefighters in the outer port and would then proceed directly to the casualty. At 1357, the pilot called the German Maritime Search and Rescue Association's coordination centre in Bremen to request the status of the rescue cruiser ANNELIESE KRAMER from Cuxhaven and that it relay information about at least one seriously injured casualty on board. He also once more pointed out that assistance was urgently needed immediately.

At 1409, the second engineer was taken on board the VIKING ENERGY with the help of her shipboard crane.

The ship's firefighting team, consisting of two deckhands, entered the engine room wearing full respiratory protection. The team was accompanied by the second officer, also wearing full respiratory protection. They did not encounter any open flames after entering. Due to the dense black smoke, visibility was almost zero even under the light of torches. After they entered the separator room, they found one of the two motormen lying on the floor (Figure 5).

At 1412, the master of the KELLY reported that another casualty had been recovered, who could also be seen from the bridge. The crew attempted to resuscitate immediately. The crew member was entered on the crew list as a motorman.

A few minutes later, the master of the ship reported that the fire had been extinguished. The pilot relayed this information to VTS Brunsbüttel, requesting helicopter support at the same time. Furthermore, he once more pointed out that an emergency doctor was urgently needed in Brunsbüttel, as the evacuation of the first severely injured casualty (second engineer) was imminent.

Shortly after the motorman was recovered, the firefighting team returned to the separator room. The last casualty was found there, squatting with his back to the wall in the rear of the room (Figures 5 and 6). As far as could be seen, the supply of oxygen via a mask did not prompt any response. Due to his size and weight of about 130 kg, as well as his squatting position, it was not possible for the two rescuers to pull the motorman out of the corner of the room. Consequently, the chief mate, the second officer and the chief engineer were asked to provide assistance. It took an enormous effort for them to move the casualty to the deck, where they immediately tried to resuscitate but were unsuccessful.

Figure 6: Rear part of the separator room

According to the pilot's progress report, the second engineer was transferred from the VIKING ENERGY to the deck of the MASTER P at 1435 and taken by the latter to Brunsbüttel. It was then agreed with the skipper of the VIKING ENERGY that his vessel should form a platform on the port side of the KELLY for arriving emergency services. On the starboard side, the tug MULTRA SALVOR 3 was tasked with securing the position. The tug FAIRPLAY XV was moored as an assistant tug.

The CCME contacted the pilot at 1439. After verifying the status, the CCME asked if helicopter support was needed. The pilot confirmed this and a helicopter was immediately dispatched to collect the casualty. The CCME formally notified that it was assuming overall control of the operation at 1445. Immediately after the takeover, the CCME staff met in Cuxhaven.

At 1450, shortly after the arrival of the tug FAIRPLAY XV, the rescue cruiser ANNELIESE KRAMER also reached the casualty together with the FFU from Cuxhaven Fire Brigade and an emergency doctor. The fire brigade's operational commander forwarded the information to the CCME that one casualty had already been taken off the ship and the fire was extinguished. The status of the ship's engine and power supply was still unclear. At 1506, the CCME was informed that the emergency doctor had confirmed the death of one crew member. A few minutes later, the rescue helicopter CHRISTOPH HANSA dropped the emergency doctor on board and then went to Brunsbüttel in standby.
The tug PARAT arrived at the casualty immediately afterwards and went alongside the VIKING ENERGY to transfer firefighters from Brunsbüttel Fire Brigade on board. In the meantime, the unit from Stade Fire Brigade had also boarded the KELLY.

At 1510, the casualty's master advised that the fire had been in the separator room. At the same time, the MASTER P reported her return from Brunsbüttel and the transfer of the injured second engineer to the emergency services there. The MASTER P remained with the ship for the time being to provide assistance.

In the meantime, the remaining members of the engine room's crew had managed to restore the emergency power supply on board the KELLY. After a blackout, the emergency generator should start automatically within a few minutes, supply the auxiliary units with power via the emergency busbar, and then ensure the normal power supply operation of all units via the main busbar. It was not possible to clarify retrospectively why this did not happen in the case of the KELLY.

The Federal Police helicopter reported in at 1518, stating it would be arriving imminently. Since it was not possible to establish the hatch cover's load-bearing capacity with certainty, the fire brigade's operational commander decided to have the casualty winched up. This and onward transport to a special clinic in Hamburg took place at 1544.

The CCME's on-scene coordinator (OSC) reached the casualty prior to this happening. However, he remained on the tug TOW 8 and maintained contact with the pilot and the fire brigade's operational commander, who was on board, from there. An emergency doctor attended to the chief engineer, who was suffering from shock, at the request of the pilot.

Two officers from WSP Cuxhaven who arrived on the KELLY at 1615 took the body into custody and cordoned off the separator room. The decision of the average staff that the Brunsbüttel Fire Brigade should remain on board until arrival at the emergency berth was communicated to all those involved via the OSC on site. The chief engineer requested permission to inspect the engine room to close valves if necessary. He did this wearing respiratory protection and in the presence of firefighters.

An investigative team from WSP Hamburg arrived at 1825 and relieved the officers from WSP Cuxhaven. After consultation with the average staff the OSC reduced the number of emergency services personnel gradually.

At 1838, the chief engineer, an officer from WSP Hamburg and a team from the fire brigade re-entered the engine room to restore power to the ship via the generators. The emergency generator had been responsible for this up until that point. In the meantime, the pilot had consulted the NOK traffic control and the nautical supervisor on duty to establish whether a free lock would be available when the ship arrived.

At 1900, the master of the KELLY notified that power had been restored, which also made it possible to haul in the starboard anchor. Based on this report, VTS Brunsbüttel dispatched the second tug (LUCHS). The pilot reported to VTS Brunsbüttel 40 minutes later that the towing connection with the tugs FAIRPLAY XV (aft) and LUCHS (fore) was in place and the ship was ready to hoist anchor. The CCME's OSC then passed overall control of the operation to the responsible VTS Brunsbüttel.

A canal pilot relieved the marine pilot at 2030 and the KELLY proceeded to the emergency berth she had been allocated at the south quay in Brunsbüttel, where she made fast at 2200.

3.1.1 Other measures

After she had made fast, a team from Brunsbüttel Fire Brigade entered the engine room to re-inspect it. The temperature remained unchanged at 50 °C and fire pockets were not detected or could be excluded. After the inspection was completed, the KELLY's crew took charge of the fire watch until the following morning. The fire brigade's operation ended at 2300.

3.2 Investigation

The CCME notified the Federal Bureau of Maritime Casualty Investigation about the incident on the afternoon of the day of the accident.

3.2.1 Crew

There were 13 crew members (the two Ukrainian motormen and 11 people from Russia) on board the KELLY at the time of the accident. The description of qualifications is limited to the ship's command and the people directly involved in the accident or fighting the fire.

The 54-year-old Russian master has been working for the shipping company, Hansa Shipping, since December 2018. He has been employed in seagoing service since 1981 (as master for 25 years). According to the watchkeeping schedule, he was on navigational watch from 0800 to 1200 and 2000 to 2400.

The 49-year-old Russian chief mate has been employed in seagoing service since 1999. He has held a chief mate's licence since 2013 and serves as one for the shipping company, Hansa Shipping. He is the master's deputy and the ship's safety officer and as such crew members from the deck department report to him. According to the schedule, he kept navigational watch on the bridge from 0400 to 0800 and 1600 to 2000.

The 26-year-old Russian second officer has been employed in seagoing service for seven years, including four as second officer. He has been working for the shipping company, Hansa Shipping, for two years. According to the watchkeeping schedule, he is on watch at sea and in port from 0000 to 0400 and 1200 to 1600.

The 26-year-old Russian AB[6], who is part of the firefighting team, has held this rank since 2017. He has served on the KELLY since August 2019. It is his first contract with this shipping company. His daily hours of work at sea were set at 0800 to 1700. He was one of the gangway watchmen in ports (from 0000 to 0400 and 1200 to 1600).

The 63-year-old Russian AB, who is also part of the firefighting team, has been employed in seagoing service since 1977 and started his first contract with the shipping company, Hansa Shipping, and thus also his first assignment on the KELLY in September 2019. His hours of work begin at 0800 (1200 to 1300 lunch break) and end at 1700.

The 50-year-old Russian chief engineer officer was completing his first contract on this ship and with this shipping company. He has held a chief engineer's licence since 2008.

The 36-year-old Russian second engineer has been working for the shipping company, Hansa Shipping, for three years. He has held a second engineer's licence since 2016. It was his first assignment on the KELLY, which started in September 2019.

The 35-year-old Ukrainian motorman who lost his life in the accident had been employed in seagoing service since 2005.

[6] AB: Able (or able-bodied) seaman. Qualified deck rating in the merchant navy with more than two years' seagoing service.

The 26-year-old Ukrainian motorman, who was also seriously injured in the accident, began his seafaring career as an engineer cadet in 2014. He has served as a motorman since 2015. He has been working for the shipping company, Hansa Shipping, since December 2018. He began his first contract on the KELLY in August 2019 in St. Petersburg. The daily hours of work were set at 0800 to 1700.

3.2.2 KELLY

The KELLY is a multi-purpose carrier without shipboard cranes and was built in 2004. In addition to general cargo and bulk cargo, the ship can also transport containers on her deck and in her hatches. She is a double-hulled ship and has an ice-class notation of 1A. The KELLY has two cargo holds. These are closed with pontoon hatch covers, which are moved by means of a gantry crane. The ship has a left-hand propeller, a standard rudder and a bow thruster.

She was managed by Wagenborg Agencies B.V. until October 2018. In January 2019, she was placed under the management of Hansa Shipping LTD-MTA following a change of ownership. In the intervening four months, she was laid up in Rotterdam without management. The ship was checked for seaworthiness at the time of or before she was placed under the management of Hansa Shipping. The scale of the defects found made it necessary for her to call at a shipyard for several weeks. *Inter alia*, and of relevance to the accident, it was found that there was considerable fuel contamination in the thermal oil system. The fuel had entered the thermal oil system through a defective heating loop in one of the storage tanks. This was marked in the tank plan as HFO No. 5 ps. The shipping company stated that the thermal oil was drained from the system during the repair. The defective heating loop was repaired by the shipyard. The thermal oil system was cleaned, flushed, refilled with fresh oil and then pressure tested.

The local description of the ship is primarily limited to the conditions relevant to the accident (Figure 7).

The engine room has two entrances. One is at the forward edge of the superstructure at main deck level (red arrows in Figure 7) via the workshop. The other is aft of the superstructure on the poop deck[7] (orange arrows in Figure 7). This is marked as a primary escape route on the ship's safety plan.

Forward of the superstructure on the main deck is a so-called equipment hatch. This is watertight and used for carrying spare parts and consumables into the engine room. The hatch cover is opened/closed with several bolts. Since opening and closing requires tools and a certain amount of time, it is not intended for use as an emergency exit.

[7] The poop deck is the deck of a superstructure above the main deck at the stern.

The engine room exit, intended as a secondary escape route, is on the starboard side in the immediate vicinity of the entrance to the engine control room.

The separator room is also on this tween deck but on the port side. The CO_2 fire extinguishing system release station for this space is located on the starboard side aft of the same level. The CO_2 fire extinguishing system release station for the entire engine room and the entrance to the CO_2 room are located on the port side aft of the superstructure.

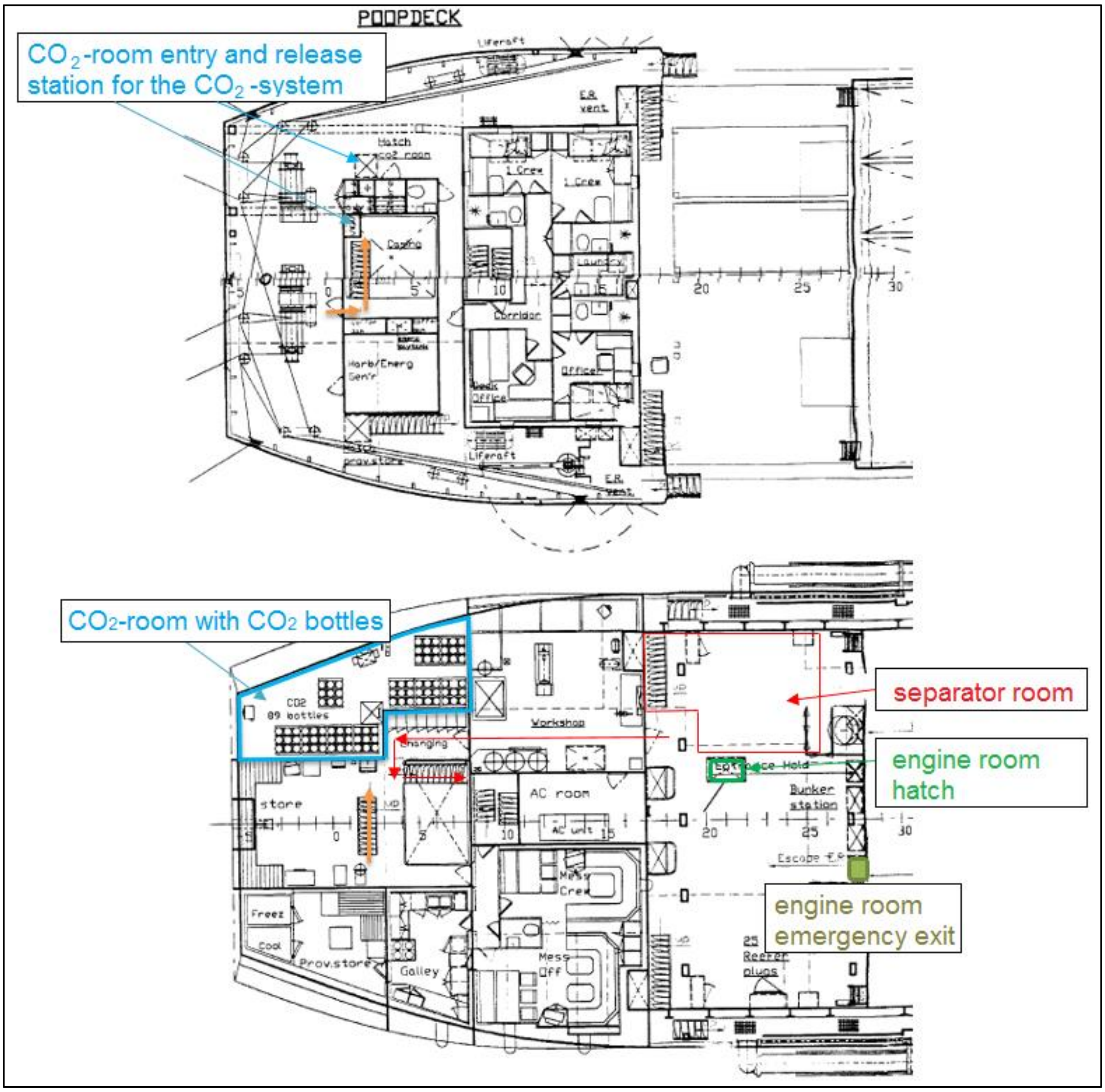


Figure 7: Entrances to the engine room

3.2.2.1 Heating system on ships

Steam is predominantly required on larger merchant ships for heavy oil processing (about 95 °C) and for final feed preheating (about 130 °C) before injection. It is also used for heating accommodation spaces and supplying hot water. The exhaust gas boiler and the auxiliary boiler are connected via the common steam system. The burner and the auxiliary boiler fan are switched on via a simple two-point controller when the pressure in the steam system falls below a lower limit value (e.g. 6 bar). In sea mode, the exhaust gas boiler usually delivers enough steam for the auxiliary boiler to only switch on when the load is low (estuary mode) or the engine is at a standstill (in port).

3.2.2.2 Heating system on the KELLY

Another method of heating, though rarely used on ships, is to use thermal oil instead of a water/steam circuit. It is produced using highly refined, paraffinic mineral base oils, which are mixed with additives to provide good thermal stability. Similar to the water/steam circuit, a heat exchanger heated by flue gas is used here, too. The advantages are a non-pressurised system, no corrosion, simple and precise temperature control, no water processing, no condensate losses and no risk of freezing when the system is not in operation. The disadvantages are the cost of thermal oil, contents hazardous to health, ageing tendency of the organic heat transfer medium and the higher risk posed by cracked pipes causing oil leaks and fires in the exhaust gas system. The TEXATHERM 32 used on the KELLY is designed for heat transfer systems operating in a temperature range of -15 °C to 300 °C.

3.2.3 Investigations on board the KELLY

Ten of the 13 crew members were on board when the BSU carried out its first survey on the day after the accident. The Managing Director and the Safety & Quality Manager of the shipping company, Hansa Shipping, were also present. Two lawyers represented the interests of the shipping company, the ship and the crew. A surveyor had been appointed by the P&I insurer[8]. Due to the shock and sadness over the loss of a colleague, the BSU staff refrained from interviewing the crew on that day. The shipping company as well as the lawyers confirmed to the BSU that the crew members would be available for questioning at a later stage. This interview was held on 9 September 2019.

In principle, it should be noted that the crew had carried out extensive rescue measures after the fire was detected on 6 September 2019 before the emergency services arrived. Conventional firefighting did not take place because the fire was extinguished by discharging CO_2. The crew did not enter the engine room again after the third person was recovered. The scene of the accident was only inspected for pockets of embers by personnel on board from the emergency services.

[8] P&I (protection and indemnity) insurance is a comprehensive liability insurance for damages inflicted upon a third party. It covers the insured party's liability risks arising from ship operation.

Moreover, the chief engineer entered the engine room in the presence of WSP officers to restore the ship's power supply. However, since the engine room had not been closed or sealed by the time the investigators arrived, it had to be assumed during the survey that its condition was not identical to that at the time the fire broke out. This also applies to the watertight integrity of the engine room's ventilation system. To that extent, certain findings are only addressed in more detail if they are related to the outbreak of fire, the firefighting operation, steps taken to recover personnel or if they constitute an aspect of interest to the investigators.

3.2.4 Findings made during the first survey on 7 September 2019 and the follow-up survey on 9 September 2019

Investigations on board began on the day after the accident at the south quay in Brunsbüttel. The effects of the previous day's events on the crew were visibly evident. For example, the chief engineer, who was still suffering from shock, did not respond to any form of address. Accordingly, the crew was not formally questioned on that day. Information on the course of the accident was obtained from the lawyers, the shipping company's two staff members, and the master. Crew members approached one of the investigators from time to time and gave a rough summary of the events. To begin with, every effort was made to ask as few questions as possible so as to avoid distorted statements and not influence the crew's recollections.

It is worth noting the different perceptions and observations of the various individuals. This was later also reflected in interviews with the crew members and the subsequently written statements, in which a 'harmonisation' was evident. Stress hormones are known to flood the brain, causing one's perception to be very narrowly focused and more or less blanking out everything in the periphery. This means that perception is often very limited in stressful situations. Accordingly, the investigators attributed primary and secondary relevance to the statements and information[9].

After consulting the officers from Cuxhaven Criminal Investigation Department, which was responsible for the case, by phone and on condition that they only survey the scene of the accident, the BSU's investigators entered the engine room together with the master and two representatives of the shipping company. The police had cordoned off the separator room, too, but gave permission for it to be entered and inspected.

Due to the destruction of the electrical equipment, the photographs shown below were taken with the aid of torches and the shipboard spotlights that were provided.

[9] For example, one crew member testified that the second engineer was engulfed in flames from head to toe. However, only part of his oil-drenched clothing was on fire. The perception and the image that had then become firmly established in his mind were thus different. Nevertheless, his statement was not false in principle.

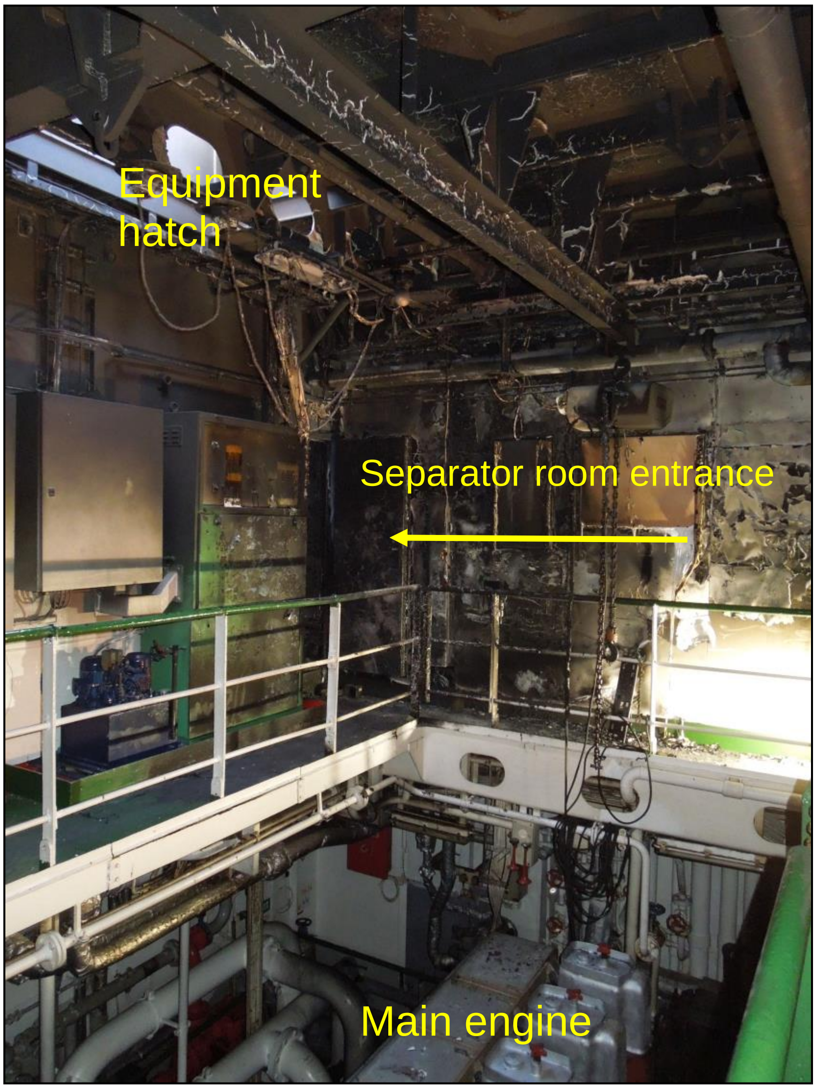


Figure 8: View ahead and of the separator room entrance

The damage in the actual engine room as well as in the adjoining separator room mainly affected the forward bulkhead and adjacent ceiling areas. The aft area and floor of the rooms were not affected. The main engine and the areas beneath the gallery had not been exposed to heat stress. When considering the extent of the damage, it was noted that the fire evidently started in the separator room. This was indicated by the traces of fire running out of the room into the engine room (Figure 8).

Figure 9: View from the separator room toward the exit of the engine room

Figure 10: View from the separator room toward the exit of the engine room

Figures 9 and 10 show the escape route chosen by the crew. An unused fire extinguisher (powder) can also be seen there. According to the rescuers' accounts, they had considerable problems recovering the last motorman, described as tall and bulky, from the engine room. Either his arm or leg reportedly caught in the left handrail several times, which complicated his evacuation considerably. The use of a stretcher was not considered. Presumably, positioning and securing the casualty in a timely manner would have been difficult due to the lack of space in the separator room. Added to this was the fact that visibility was still severely limited.

Figure 11: View from the engine control room opposite into the separator room

There was an open control cabinet on the right-hand side of the separator room's entrance area. The mounting height was measured at 1.40 m to the lower edge and 1.80 m to the upper edge. Integrated and attached parts of the cabinet were lying on the floor and in front of as well as behind the passage door. It was not possible to reconstruct whether these parts were hurled out of the room by the explosion or had found their way there as a result of the crew's recovery measures. The components only exhibited traces of fire on one side. They were located on the side facing out of the housing, i.e. the control panel.

Figure 12: Control valve's switch box with wiring harness hanging out

Figure 13: Alterations to the control cabinet

The images in Figure 13 show that a component previously lying on the floor had been reinserted in the door of the control cabinet, even though the police had already cordoned off the room as a crime scene. It is no longer possible to trace whether further alterations were made between the two survey dates. Similarly, the question remains as to who entered this cordoned off room and whether any alterations had an impact on the expert's report.

There were also clearly isolated areas beneath the engine room ceiling with extensive fire damage. The mean thermal impact zone was 1.5 m downwards. Apart from superficial contamination, the fixtures directly below exhibited only minor damage. When the focus shifted to the severity of the damage, it was noticeable that the fire had severely affected many areas. Directly adjacent areas were partially only slightly fouled by soot or exposed to heat stress (Figure 14).

Figure 14: Fire zone beneath the ceiling

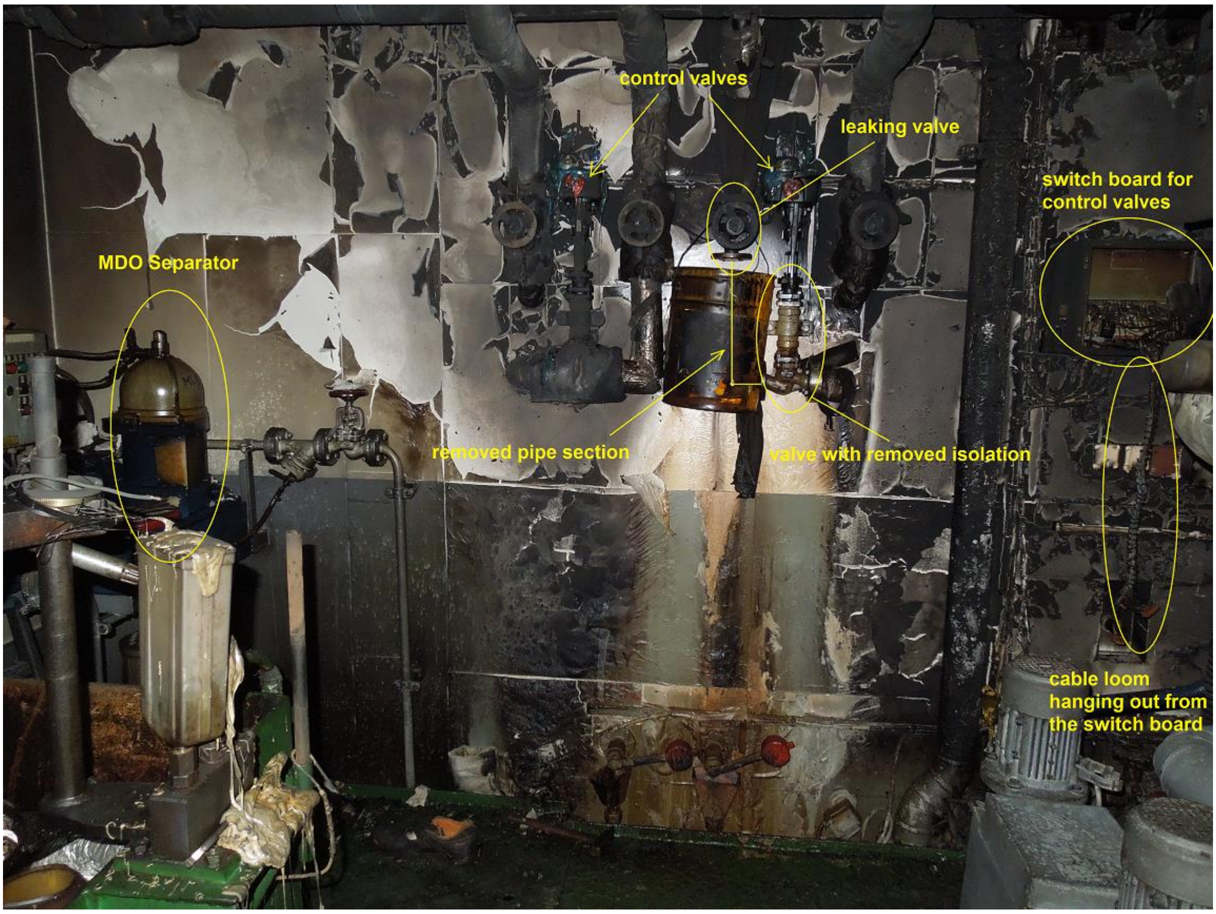


Figure 15: Explosion site

An open pipe system was located in the passage (or at the narrow end of the room toward the bow). An orange bucket that was almost completely filled with thermal oil was suspended from the valve handwheel on the right-hand pipe assembly. The traces of fire decreased further into the room and away from this pipe assembly.

Figure 16: Bucket filled with thermal oil below the valve

Figure 17: View from the separator room into the engine room

The entrance to the engine control room can be seen opposite.

Figure 18: View from the separator room into the engine room

An air hose that had been used for clearing the dismantled pipe section can be seen lying on the floor.

A fire funnel starting from the floor area and running toward the ceiling is visible beneath the pipe system (Figure 19). The fire funnel was to the left of the open pipe on the bucket suspended there. A burn mark coming out of the fire funnel was visible there, too.

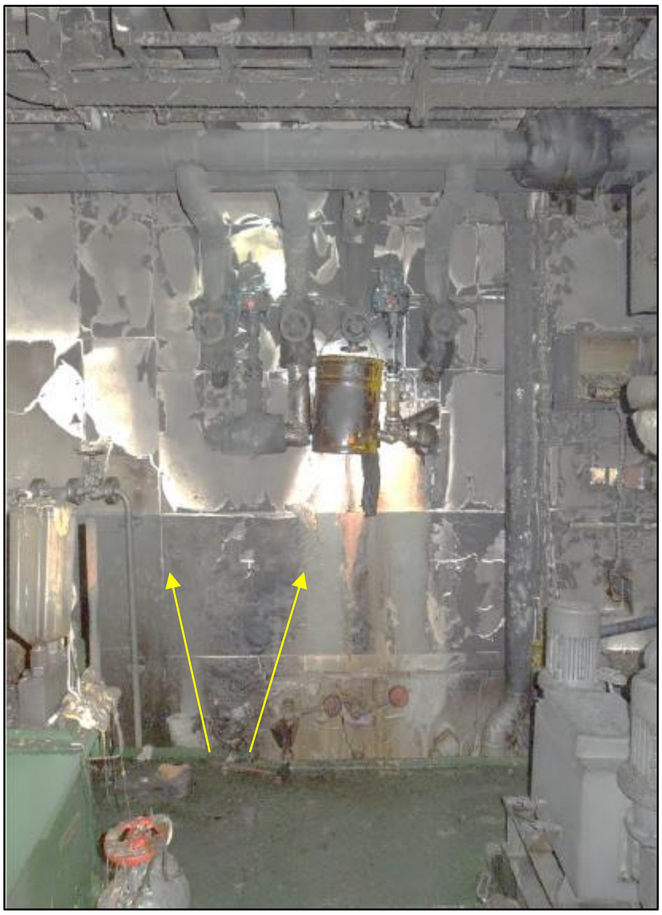


Figure 19: Partial overview of the scene of the fire with opened pipe system

Figure 20 shows a wash-stand in which the dismantled pipe section lay together with removed solid residues.

Figure 20: Wash-stand on the left and dismantled pipe section from the thermal oil system with removed solids residue on the right

Immediately to the left of the scene of the fire was a separator marked MDO[10] standing on a platform. The second engineer stated that this was not in operation.

Figure 21: MDO separator (less than 2 m away from the position at which the fire broke out)

A hammer with a work shoe next to it was on the floor below the bucket. Furthermore, to the left of the fire funnel was the removed insulation for the exposed control valve. This insulation exhibited a burn mark from the direction of the visible fire funnel. An electrical tank sensor unit was fitted in the floor area in the position at which the fire funnel started. A clean burn inside the fire funnel was visible immediately behind it.

Figure 22: Position at which the fire funnel starts

The red arrow points to the sensor unit and the yellow arrows indicate the fire funnel.

[10] MDO: **Marine diesel oil**. MDO is a fuel for marine diesel engines made up of various middle distillates from petroleum processing. Its international trade name is 'Marine (Distillate) Fuel Oil'.

Figure 23: Rear part of the separator room

In summary, with regard to the extent and severity of the damage in the engine room, it is noted that this is localised but in places severe on the forward bulkheads, ceilings, control cabinets and cable bundles, in particular. Other fixtures, such as lamps, have apparently only melted down. Consequently, it can be assumed that the event was rapid but spatially and temporally confined, even though no action was taken to cool down the area or actively contain the fire.

3.2.5 Investigation into the possible cause of the accident

In addition to the correct ratio of components, three further conditions had to be fulfilled for the explosion with fire to occur:

- the presence of combustible material (liquid, solid or gaseous);
- the presence of an oxidant, and
- a source of ignition capable of igniting the combustible system.

A variety of factors can influence the three above components. As a result, fires can be described as being extremely complex.

The ambient air provided the oxygen (i.e. the oxidant) required for this process. The thermal oil with the gas emissions came into focus as a fuel and should therefore be examined in laboratory tests. Based on the findings made during both the first survey and the follow-up survey on 9 September 2019, several possible ignition sources materialised and are explained in more detail below:

- open flame or spark from a lighter;
- open flame or spark from a Bunsen burner with gas cartridge;
- control valve switch box, and
- control valves.

3.2.5.1 Thermal oil as a fuel

The BSU secured three thermal oil samples on the day of the inspection, i.e. one day after the accident:

1. sample of fresh oil from the storage tank;
2. sample of oil from the bucket placed under the dismantled pipe section, and
3. sample of oil from the pipe system.

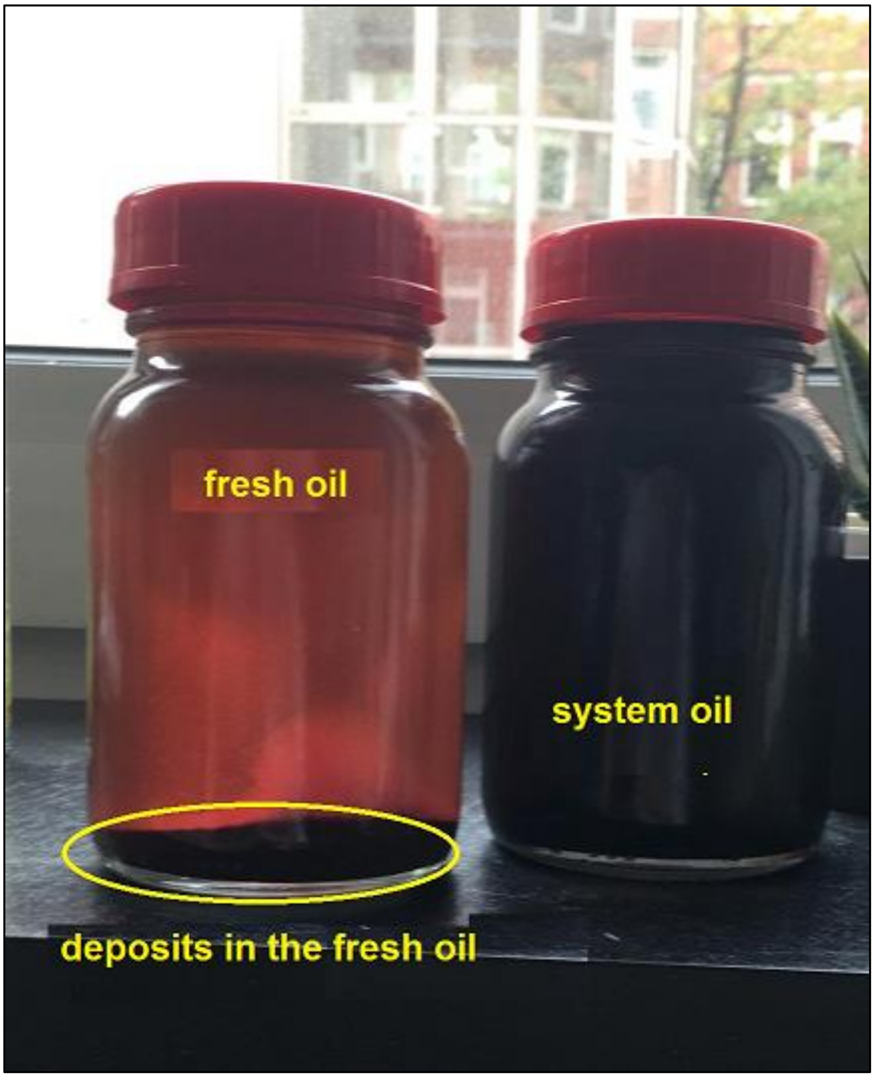


Figure 24: Thermal oil samples from the KELLY

To ensure representative sampling, the sample vials were filled to the brim and sealed without trapping air. This approach was taken to prevent the oil from oxidising. Unused thermal oil should range from light amber to a colour reminiscent of honey. Samples two and three were almost black. Tar-like deposits were visible at the bottom of the fresh oil sample (see bottle on left-hand side of Figure 24) after only 24 hours.

3.2.5.1.1 Findings of the oil analyses on 7 September 2019[11]

The three samples were delivered to an SGS Germany GmbH laboratory. The heat transfer oil used was TEXATHERM 32 from Caltex. Since the reference sample from the storage tank was also contaminated, the information from the product data sheet was used as the basis for the assessment.

Test	Test Methods	Results
Viscosity Grade ISO VG		32
Density at 15°C, kg/l	ASTM D1298	0,857
Coulor	ISO 2049	1,0
Kinematic viscosity at 40°C, mm^2/s	ISO 3104	32
Kinematic viscosity at 100°C, mm^2/s	ISO 3104	5,4
Viscosity Index	ISO 2909	101
Flash point, COC, °C	ISO 2592	220
Auto-ignition temperature, °C	ASTM E659	320

Spreadsheet 1: Typical characteristic values of Texatherm 32

To improve the comparability of the findings, the analyses of the three oil samples have been set against the typical characteristic values in the following spreadsheet.

[11] Dates shown in subsections 3.2.5.1.1 to 3.2.5.1.7 are the dates of sampling.

Test	Results				Comment
	typical characteristics	fresh oil sample from storage tank	oil sample from a bucket in the separator room	oil sample from pipeline system	
Density at 15 °C, kg/m³	857				
Density at 20 °C, kg/m³	860	831	823,3	822	values of all 3 samples to high
Color code	1	8	8	8	significant deviations from typical characteristic value
Appearance	light yellowish	cloudy-brownish, visible solids	black, visible solids	black, visible solids	
Kinematic Viskosity at 40 °C, mm²/s	32	6,039	2,138	2,085	values of all 3 samples extremly low
Auto-ignition temperature, °C	320	235	230	230	
Water, mg/kg	<50	364	185	161	
Content of light fraction DO/mass-%	0	24,7	81,5	85	DO = Diesel oil; light fragments correspond to a DO group
Flash point, COC, °C	>200	<140	<172	<172	In order to clarify how much smaller the actual flash point is, a supplementary analysis was carried out. At 100 ° C it was found that the sample burned immediately and could no longer be detected by the device.

Spreadsheet 2: Comparison of the oil analyses

In all three samples, 24.7-85.0 mass percentage of light fractions (corresponding to a diesel fraction) were detected. A large number of volatile components from the paraffinic, naphthenic and aromatic substance classes were identified. Furthermore, a supplementary analysis carried out in accordance with the method shown in DIN EN ISO 3679 revealed that the samples burn immediately at 100 °C and that the device could not detect the flashpoint. Based on that, the estimated flashpoint is well below 100 °C. The expected flashpoint should actually be 200 °C. The expert commissioned by the BSU, Dipl. Ing. Lars Tober (GSSOmbH Rostock), was able to determine during ignition tests that there was a very low flash point of the thermal oil between 55°C and 60°C. The initial boiling point was also not detectable due to the excessively high light fraction content. Since the light fractions contained in the samples were atypical for a thermal oil, the high-temperature simulated distillation could not be evaluated because these light fractions crossed into the solvent peak, making it impossible to evaluate them, too.

3.2.5.1.2 Shipping company's oil analysis

The thermal oil sample analysis that the shipping company ordered via Chevron's FAST service on 10 September 2019 concluded with the classification *URGENT* –

corrective action recommended[12]. A comment added to the report stated that the flashpoint is less than 140 °C and that this is indicative of fuel contamination or the presence of light fractions that arise when the oil has been exposed to extreme temperatures. The condition of the oil therefore precluded safe operation and an oil change should be considered. The presence of water was also indicated, as was a significant drop in viscosity.

3.2.5.1.3 Impurities in the thermal oil system subsequently

The shipping company provided the analysis report dated 5 December 2019. According to the information given, the shipyard had previously cleaned the thermal oil system mechanically and by means of steam circulation and then flushed it with fresh oil. They switched to TEXATHERM 46 when recharging the system. The reason for this was a higher flashpoint of 235 °C as compared to the 220 °C of Texatherm 32. Nevertheless, this report was also marked *ATTENTION – Oil suitable; Monitoring*[13] . The flashpoint determined was above the safety limit of 140 °C but below 190 °C. Evaporation (or degassing) was recommended to remove light fractions.

3.2.5.1.4 Findings made during the survey on 21 January 2020

Since there were still unanswered questions as regards the operation of the ship, two BSU investigators visited the KELLY again on 21 January 2020. The ship was in Rendsburg at the time and had been back in service since 6 December 2019. The crew (or people) from the day of the accident were no longer on board. As with the previous crew, communication proved to be extremely difficult. Although the designated on-board language is supposed to be English, retrieving the simplest facts was almost impossible. Only the master could speak English to an acceptable degree.

After sighting the latest thermal oil system analysis reports, it was found that the relevant characteristic values hardly differed from the results of the oil analyses of 7 and 10 September 2019. When asked what had been done to compensate for this, the chief engineer explained that the shipping company had reportedly instructed him to drain 200 litres of oil from the system and to top it up with fresh oil. After that, another sample was to be sent in for analysis so as to verify the desired mixing effect. The result of the latest sampling on 3 January 2020 was not available at the time of the survey and was to be forwarded to the BSU upon receipt.

The information on the total amount of thermal oil in the system (including storage tank) varies between 1,400 litres and 2,912 litres. For example, the shipping company refers to the statement of the chief engineer and indicated a quantity of 1,400 litres. However, the transfer of 2,912 litres of TEXATHERM 46 from barrels to the storage tank was noted in the machinery space log book on 9 September 2019. Due to the communication barrier, it is reasonable to assume that the 2,912 litres refers to the thermal oil system with storage tank and the 1,400 litres only to the quantity in the system.

[12] n/a
[13] n/a

3.2.5.1.5 Findings made on 3 January 2020

The shipping company ordered an analysis of two samples. One sample was taken directly from the thermal oil system and the second from the storage tank. The oil had been circulating for 300 operating hours at that time. A Castrol laboratory was commissioned on this occasion.

The result of the two analyses was provided on 27 January 2020. The laboratory classified the sample from the system as *critical* and considered it unsuitable for further use. A recommendation that part or even all of the oil should be changed was made. The flashpoint was 120 °C instead of 235 °C and the kinematic viscosity at 40 °C was found to be 38.09 mm²/s instead of 46 mm²/s. Compared to all earlier analyses, there was a significant increase in iron (39 ppm), which is indicative of system corrosion. In terms of colour, the sample was classified as amber-cloudy.

The analysis of the oil sample from the store tank revealed no anomalies. The appearance was given as colourless-clear and the flashpoint determined at >190 °C.

3.2.5.1.6 Findings of the oil analysis on 22 January 2020

A new sample was taken on 22 January 2020 and the findings of the corresponding analysis were available on 29 January 2020. A Chevron laboratory carried out the analysis on this occasion. The number of operating hours was indicated as 400, i.e. 100 hours more than in the previous analysis. The sample (or all the oil) was marked *ATTENTION – Oil suitable; Monitoring* and a comment stating that the flashpoint is above 140 °C (safety limit) but below 190 °C had been added. The kinematic viscosity at 40 °C was given as 43.0 mm²/s. Furthermore, safe venting and degassing of the system was recommended to remove light fractions from the oil.

3.2.5.1.7 Findings of the oil analysis on 11 February 2020

The last analysis provided to the BSU originates from 11 February 2020 (report date: 14 February 2020). As before, a Chevron laboratory had carried out the analysis. Since the operating hours of the system and of the oil had evidently been entered incorrectly, this information is not included here. This sample was also marked *ATTENTION – Oil suitable; Monitoring* and contained the same comment as the sample from 22 January 2020 did. The kinetic viscosity at 40 °C had dropped marginally to 42.8 mm²/s. On the other hand, the iron content had increased to 18 ppm as compared to the previous sample (11 ppm).

3.2.5.2 Open flame or spark from a lighter as the source of ignition

An open packet of cigarettes was found at the scene of the accident (directly in the passage[14]). A lighter could not be secured. Similarly, there was no ashtray or the receptacles usually used on board for such purposes. Investigations revealed that at least two of the three casualties were smokers. It was no longer possible to determine which of the three people was the owner of this packet of cigarettes. According to the second engineer, no one had been smoking in the separator or engine room when the accident happened or at any other time. A general ban on smoking existed in the entire

[14] Entry into the separator room from the engine room.

area. It is conceivable that the cigarettes fell out of a pocket when the second engineer fell or during the recovery of the other two crew members.

Abbildung 25: Cigarette packet at the scene of the accident

3.2.5.3 Open flame or spark from a Bunsen burner with gas cartridge as the source of ignition

Figure 26: Bunsen burner between the separators

A Bunsen burner with gas cartridge was on the floor between the wash-stand and separator marked HFO[15]. Based on its location, the position of the second engineer, his burn injuries and the fire pattern in the separator room's entrance area, the BSU's investigators believe that the Bunsen burner did not cause the explosion. It was not possible to establish what it was being used for.

3.2.5.4 Control valve switch box as the source of ignition

As already discussed, a control cabinet responsible for adjusting the control valves was situated in the separator room's entrance area. The cabinet's door was open on the date of the first inspection of the scene of the accident and a cable harness was hanging out of it. According to the second engineer, the control cabinet was not opened on the day of the accident in order to disconnect the control valves from the power supply before works started.

Scandinavian Underwriters Agency GmbH (SCUA), which had been appointed by the ship's insurer, requested an expert report on a possible cause based on the fire starting in the control cabinet. In the course of preparing the expert report, the focus shifted to the cable harness already discussed and it was sent to an accredited materials testing laboratory for metallurgical examination. The inspection summary report is annexed

[15] HFO: **Heavy fuel oil**. HFO is a residual oil from distillation or from crackers used in the petroleum processing industry.

below (Annex 8.3). Based upon the information provided, which concerns the control cabinet alone, an accident cause which is completely inconceivable in the opinion of the BSU's investigators was then determined. At the instigation of the insurer, no information could be provided in response to questions about the expert report and partial expert report from the BSU.

The summary of the report reads:
Based upon the investigations, the expert assumes with a very high degree of probability that a short circuit with arcing at the lower edge of the control cabinet for the day tank and the settling tank control valves constituted the source of ignition for an ignitable vapour/air mixture created by thermal oil in the separator chamber.

The control cabinet was not closed when the damage occurred. Due to the cable harness hanging down from the control cabinet being crushed by the door of the control cabinet, single conductors in the cable harness were damaged, causing a short circuit in at least one live conductor.

The cigarette packet with unconsumed cigarettes found on the floor of the separator room will have fallen out of the pocket of one of the casualties during their recovery. Cigarette ends and a lighter were not located in that room or in the engine room.

The expert is not aware of the extent to which preliminary investigation results are available from the WSP, nor of any objects that may have been seized during their investigations.[16]

The summary of the opinion on the expert's report goes on to state:
The findings of the materials testing laboratory confirm the theory put forward by the expert in his interim report that closing the control cabinet door caused an electrical short circuit with arcing in the cable harness hanging out of the control cabinet, igniting the explosive vapour/air mixture in the separator room in the process.[17]

The expert's report was drawn up 20 days after the accident on 26 September 2019 and finalised with an opinion on 22 January 2020. It seems to the BSU that impurities in the thermal oil or a possible defect in the actual control valves were not so much as considered or were only hinted at as a cause. The materials testing laboratory stated that it drew conclusions from the expert's findings and the information provided.

Material aspects of the possible cause of the accident were neither questioned nor considered. For example, the investigators believe there are three theories as to how the control cabinet door could have opened and resulted in damage to the cables.

[16] Expert's report on the fire in the motor vessel KELLY (IMO number 9255622). 26 September 2019. P 16.
[17] Opinion on the fire in the motor vessel KELLY (IMO number 9255622). 22 January 2020. P 2.

1. The explosion may have caused the cabinet door to swing open violently. The control elements (blocks) in the door and parts of the closing mechanism may have been ejected and landed outside the separator room. The cable harness could also have been torn out of the control elements when the control cabinet door swung open violently.
2. The closed but unlocked cabinet door was opened unintentionally and the cable harness torn out and damaged in the process during the recovery of the two motormen. The last (deceased) motorman had to be taken out of the separator room by five people because of his size and weight.
3. Although seriously injured and still burning himself, the second engineer was able to leave the room unassisted. He testified that he had slipped on the oily floor and fell several times in the passage. Here, too, the unlocked cabinet could have been opened unintentionally and the cable harness torn out and damaged.

In the case of the second and third theories, there is a possibility that mechanical damage to the cables could have occurred as a result of the recovery operation, as well as that the control elements and parts of the locking system landed on the floor in front of the separator room's entrance area. Assuming that the cables had suffered mechanical damage in the course of the explosion or due to the second engineer's escape attempt, a short circuit could have occurred even after the explosion or ignition. Similarly, the cables may have melted due to heat stress during the fire. The fire was only extinguished when CO_2 was discharged into the engine room by the second engineer. A blackout did not occur until several minutes later. This means that the switch box or the cables were still conducting immediately after the explosion.

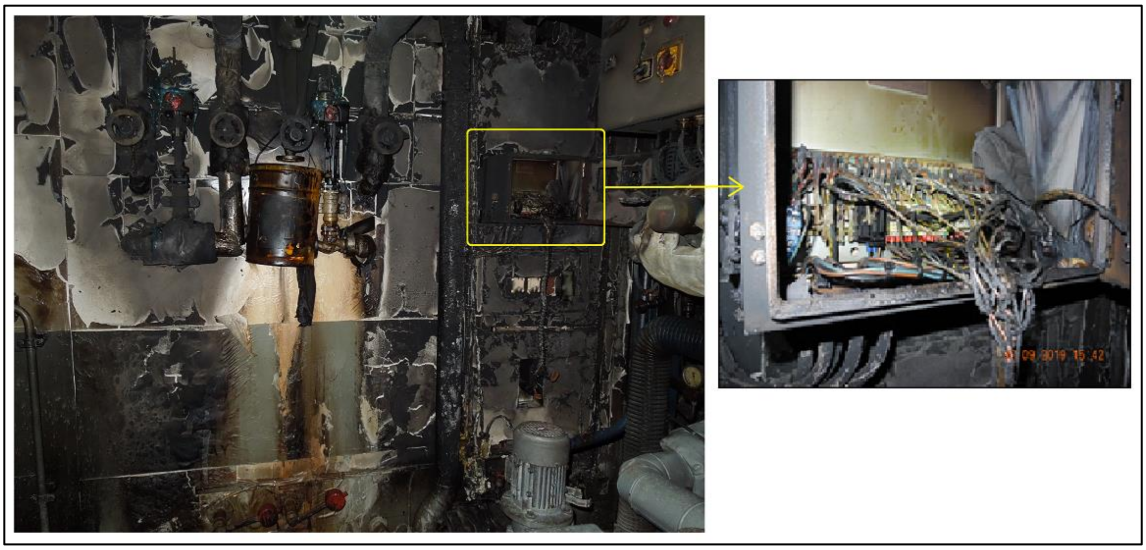
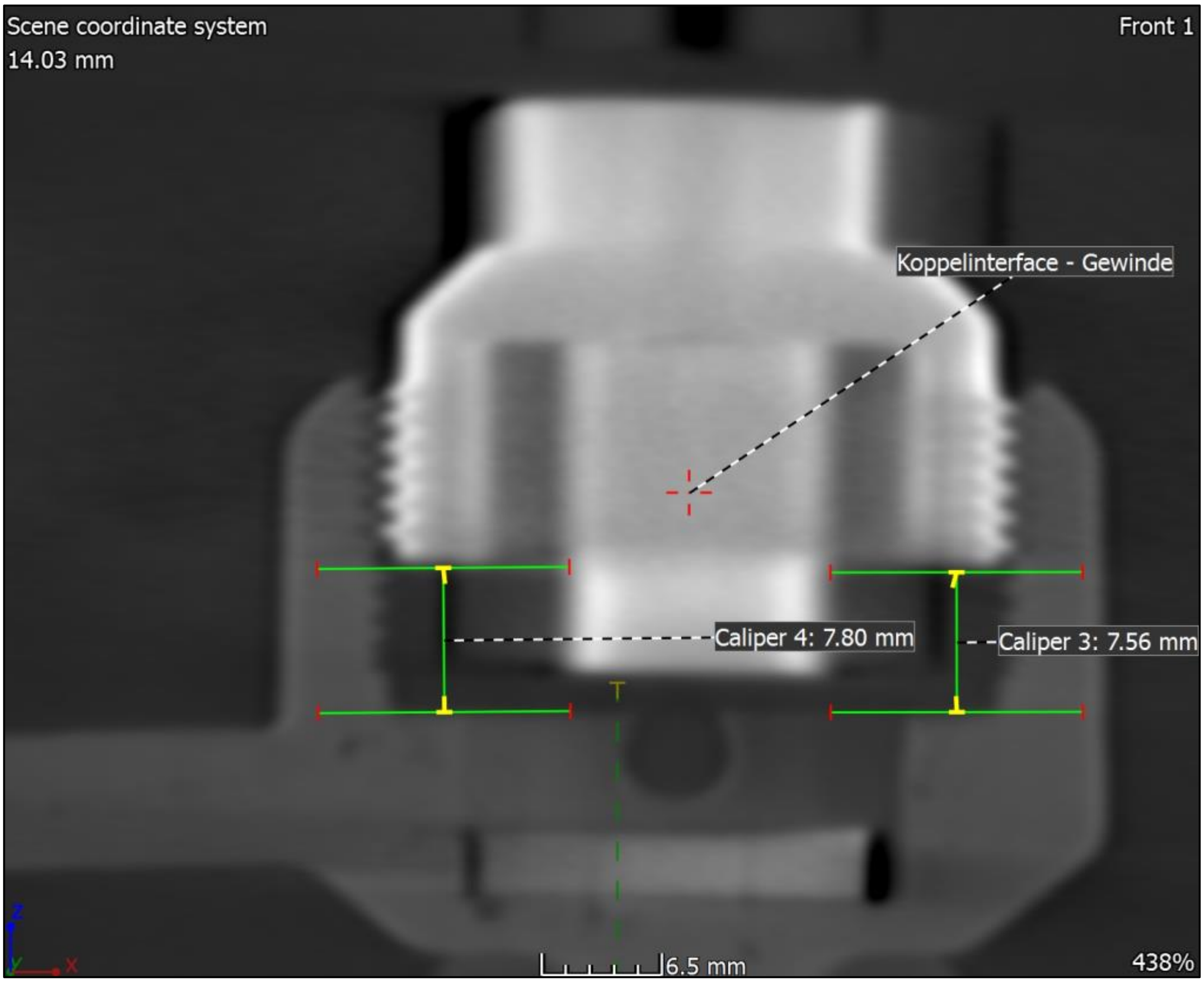


Figure 27: Open control valve control cabinet

3.2.5.5 Control valve as the source of ignition

The BSU secured two control valves during the inspection of the scene of the accident and sent them to the Herrgesell inspection agency for further assessment. The second engineer had testified that the two control valves had not been disconnected from the power supply and that the associated control cabinet had not been worked on by any of the three crew members. The BSU suspected that one or both of the valves had been permanently activated and could thus have served as a source of ignition. Using the available circuit diagram, the valves for controlling the heating circuit have been installed in the feed. A temperature sensor was installed in the fuel tanks behind it, which interacts with the control valve. According to the second engineer, the system is operated at 6 bar and 120 °C.

Both valves were subjected to non-destructive testing using computer tomography so as to determine their functional performance. It was evident from the threaded connection between the control unit and the pipe valve (referred to as the coupling interface in Figure 28) that the valve (immediately to the right of the bucket) was not closed. At the same time, the thread guide exhibited a thread misalignment, indicating that the valve was no longer fully functional.



Source: Herrgesell inspection agency

Figure 28: Coupling interface

Source: Herrgesell inspection agency

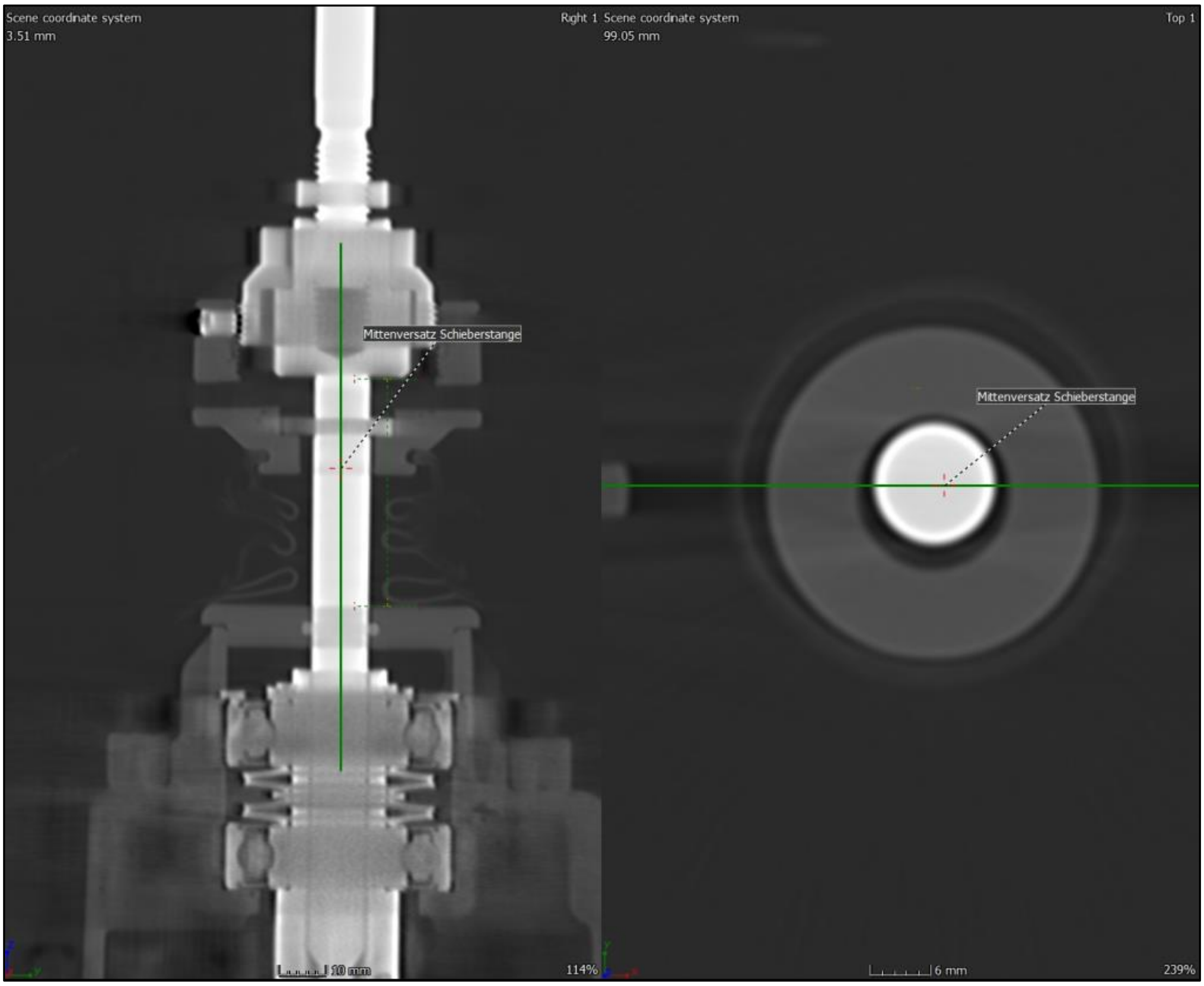


Figure 29: Centre offset valve rod

Based on the facts available, the expert assumed that this valve was already defective before the removal of the pipe section (or the start of the cleaning works).

Figure 30: Control valves after the accident on the left and after the repair on the right

3.2.6 Investigation into the cause of death

As already discussed above, two crew members from the engine room were seriously injured during the accident. Another crew member (a motorman) lost his life. At the time of the initial investigation, it was not possible to clarify whether the motorman in question lost his life as a result of the discharged CO_2 or whether other fire and explosion-related causes existed. Therefore, the competent public prosecutor's office ordered a post-mortem examination. An analysis of the victim's blood for carbon monoxide had already been ordered.

The following findings were made during the post-mortem examination of the deceased person:
There was no evidence of blast trauma from a blast wave that could cause internal injuries. Moreover, there were no signs of internal disease or external injury that might have caused or contributed to death.

The findings made during the chemical and toxicological examination revealed extremely high concentrations of carboxyhaemoglobin (55%). These findings mean that death is very likely to have been caused by carbon monoxide poisoning. The post-mortem also revealed findings that could be interpreted as an indication of carbon monoxide poisoning (rather bright red lividity, salmon-coloured musculature). There were also signs of breathing (aspiration of stomach content and soot to the periphery of the respiratory tract and possible soot deposits in the oesophagus and upper section of the stomach). The examinations did not provide any evidence to suggest that Mr [...] was under the influence of alcohol or any other centrally acting substance at the time of death. The preliminary immunochemical examination did reveal evidence to suggest the presence of ecstasy. This preliminary finding was not confirmed during the evidentiary examination. […]

In summary, there is no indication that Mr [...] was under the influence of the aforementioned centrally acting substances at the time of death. The findings are indicative of fatal carbon monoxide poisoning.

It was also suggested that a test for carbon monoxide be carried out. Since the samples had not been preserved in gas-tight conditions, such an examination, which would have necessitated external shipment, did not seem expedient.[18]

[18] Autopsy report dated 21 September 2019 and 20 January 2020, Hamburg-Eppendorf University Clinic, Institute of Forensic Medicine.

4 ANALYSIS

The accident occurred due to works on a thermal oil system containing fuel contaminated oil and a low flashpoint as a result of this. The source of the ignition could not be clearly identified, however.

4.1 Assessment of possible causes of the accident

The multi-purpose carrier KELLY was placed under the management of Hansa Shipping LTD-MTA after being laid up for a period of four months. Deficiencies found at the time of the transfer were remedied during a call at a shipyard. *Inter alia*, the thermal oil system was heavily contaminated by fuel ingress via a defective heating coil in one of the fuel storage tanks. The entire system was drained, cleaned, flushed and then refilled with fresh oil (TEXATHERM 32 from Chevron). Although an oil quality check is stipulated after work of this nature, this was not carried out.

The BSU received the following reply in response to an enquiry to Chevron Deutschland GmbH, the supplier of the thermal oil used after the ship was transferred:

[...] „… contamination with fuels, replacement of the thermal oil system's entire charge is recommended. All types of fuel are unstable when exposed to thermal stress for a prolonged period. They produce carbon deposits and a huge variation of light fractions. The latter of the two aspects directly affects operational safety because it directly affects the flashpoint. Proper cleaning and flushing is critical, as the smallest amount of solvent/fuel (with the low flashpoint) in the thermal oil system can lead to a low flashpoint throughout the system. Therefore, the crew is strongly advised to replace the entire charge of thermal oil with fresh oil after completion of the necessary repair and cleaning works. Most OEMs[19] provide special instructions or support services for such cases."

On 6 September 2019, the KELLY was en route from Rotterdam to Kaliningrad via the NOK. Shortly before reaching the lock at Brunsbüttel, an explosion and fire occurred in the separator room. One crew member lost his life and two others were seriously injured. The crew was able to extinguish the fire by discharging CO_2. The three people directly affected by the incident were tasked with dismantling and cleaning a clogged pipe in the thermal oil system.

The assessment of possible sources of ignition and the findings of the investigation revealed that:

1. *Oil analyses*
   The oil analyses ordered by the BSU revealed a significant percentage of light fractions of diesel. This suggests that the thermal oil was heavily contaminated with fuel. It was not possible to clearly determine the source of this ingress in the thermal oil but the investigators have the following theory:

[19] OEM: engl. Original Equipment Manufacturer

- the measures initiated to clean the thermal oil system during the first call at the shipyard included draining and cleaning the system. According to the shipping company, the works included mechanically cleaning the blocked pipes and subsequent flushing with superheated steam to loosen remaining residues. This is a common and more cost-effective option than the use of chemicals alone or a chemical/diesel mixture. The entire system was then flushed with fresh oil. Either these measures were not sufficient to remove all the deposits or thorough flushing with fresh oil did not take place. During further operation, there was a further washout in the system, which then contaminated the fresh oil accordingly and consequently forced the flashpoint to drop well below the safe operating limit of 140 °C.

The shipping company was unable to show that the oil was checked after the system (or the ship) was put back into operation by means of analysis reports. In accordance with the specifications of the system's manufacturer, the oil must be tested after repairs and extended periods out of service and an analysis must be made every six months thereafter during operation. The oil was evidently not tested in the period leading up to the accident.

2. *Open flame or spark from a lighter*
   This theory can be disregarded because there was no evidence in the separator room to suggest that smoking took place there when the explosion happened or at any other time. The statement of the second engineer also confirmed this.

3. *Open flame or spark from a Bunsen burner with gas cartridge*
   Based on the location of the Bunsen burner, the position of the second engineer, his burn injuries and the fire pattern in the separator room's entrance area, it is reasonable to assume that the Bunsen burner did not cause the explosion.

4. *Control valve switch box*
   Although the expert from the Herrgesell inspection agency and an official from the State Office of Criminal Investigation's Department 45 (responsible for fires and special accident events) have both ruled out an explosive short circuit in the switchboard, they do not consider it impossible, either. The two above individuals question the theory that a short circuit in the switch box caused the ignition because of the formation of a fire funnel in the area of the floor a good 1.5 m away from the switch box. A current-conducting tank sensor is also located in this area. The formation of a fire funnel is not visible in the immediate vicinity of the switch box.

5. *Control valves*
   The removed pipe section was taken from between the handwheel and the control valve. Closing the hand valve interrupts the pressure supply in the system. If the control valve is opened slightly (the control valve was apparently defective and did not close completely separately), then the pressure could escape from the remaining pipe section (or the pressure in the system would drop), meaning a flammable aerosol could not have formed. The fire pattern found also opposes an ignition at the level of the control valve.

4.2 Preventability of the accident

The delivery documents found on board showed that TEXATHERM 32 had been received several times.

- 23/01/2019 1,040 l → 5x 208 l barrels
- 18/02/2019 1,040 l → 5x 208 l barrels
- 18/04/2019 416 l → 2x 208 l barrels
- 19/06/2019 832 l → 4x 208 l barrels

- 04/11/2019 2,912 l → 14x 208 l barrels (TEXATHERM 46)

The BSU's investigators believe that the delivery on 23 January 2019 was to recharge the thermal oil system (without storage tank) in the course of the repairs in the shipyard. The delivery took place shortly before the end of the first call at the shipyard in early 2019. However, the quantity does not correspond to the 1,400 litres specified by the shipping company. Barrels containing a total quantity of 2,288 litres of TEXATHERM 32 were regularly delivered at intervals of about two months subsequently. Even on the assumption that the delivery of 18 February 2019 was for recharging the storage tank, there is still a quantity of 1,248 litres of oil that was consumed up until the accident. Since this is not a consumable oil and both the chief and the shipping company stated that there were no leaks in the system, it must be assumed that they were aware of the thermal oil's poor quality and therefore repeatedly exchanged partial quantities. This would also be consistent with the statement of crew members that based upon the knowledge of the former contamination of the system, it was assumed that residues of the fuel remaining in the thermal oil had clogged the pipe. This in turn justified dismantling the pipe section on the day of the accident.

4.3 General evaluation of oil analyses

Essentially, the thermal oil is examined with regard to an increased fire hazard that such a system can pose if too many readily combustible oil components have formed in the oil. Spreadsheet 3 below lists the criteria that can be assessed by means of an oil analysis. They are an important tool for monitoring the heat transfer oils and the complete systems, as changes in the oil can give rise to an increased fire risk or damage can occur. The accumulation of oil carbon on the inside of pipes in the boiler plant can lead to the destruction of a pipe due to heat stress, for example.

If heat transfer oil ages disproportionately quickly, undiscovered problems in the operation of the system are usually the reason. For example, a system may be shut down several times a week without the oil still being moved through the circulation pump until it has completely cooled down in the system. The cause of a rapid decline in an oil's performance should be determined as soon as possible because prematurely aged oil contains acids, which can cause corrosion. Polymerisation products are also formed, which cause solid or paste-like deposits.

There may also be serious problems if the oil charge heats up too quickly or if the oil is permanently overheated. Products with a low boiling point are formed in the oil even under 'normal' operating conditions. They usually evaporate into the ambient air via the expansion tank. However, if the oil is heated higher, e.g. to compensate for the reduction in heating power that has already set in, then cracking may actually occur as in a refinery. In the process, an extremely high proportion of hydrocarbon compounds with a low boiling point is formed, which drastically lowers the flashpoint. Moreover, the oil may also start to boil in the boiler, resulting in increased steam pressure in the system. In addition, the oil becomes thinner (similar to petrol) and the circulation pumps are at risk of failure due to cavitation.

At the same time as the products with a low boiling point, those with a high boiling point are left as long-chain molecular compounds. These leave coke-like deposits on the heating surfaces and in the pipe system. Ultimately, they impair heat transfer, obstruct the flow of oil and clog the system.

Analytical values	Assessment	Warning and limit values
Wearing metals: Iron, copper, lead, aluminium	Iron, in particular, is an indication of plant corrosion. Aluminium points to wear in the circulation pump, copper and lead to possible non-ferrous metal corrosion.	Fe< 25 Al< 10 Cu, Pb < 5 others< 1
Additives: Phosphorus, zinc, sulphur, calcium, barium	Additives should not be present in the heat transfer oil (except for small amounts of phosphorus). If they are present, mixing or residues from the process.	P< 50 other< 1
Impurities: Silicon, potassium, sodium, water	Small amounts of silicon originate from antifoam additives. Water is usually only found in systems that frequently stand still. It must be carefully evaporated by slow heating.	Si< 5 Na, K < 2 H_2O 0.05%
Oil condition: Vis. 40°, 100 °C, VI, oxidation, colour	The oil must not become too 'thin' due to cracking products or too 'thick' due to oxidation products. Fourier-transform infrared spectroscopy reveals possible oxidation. The appearance and colour should not differ significantly from the previous sample in trend analyses.	Vis.: +/- 10% Oxi.:10 A/cm Colour6
Neutralisation number (NN), acid number (AN)	Oil becomes increasingly 'acidic', NN rises due to the accumulation of oxygen molecules and thus gives further clear indications of oil ageing.	NN: < 0.25mgKO/g
Flashpoint	The flashpoint drops due to volatile oil components. An excessively low flashpoint promotes the risk of fire in a system.	> 100 °C
Conradson carbon residue	Carbon residue indicates the risk of deposits forming, which develop especially in the boiler area (even in the absence of air) and cannot be removed by changing the oil.	< 0.5%

Spreadsheet 3: Analytical values and assessment of thermal oil samples

An advanced ageing process and/or cracking at elevated temperatures change the viscosity of the heat transfer medium. Oil ageing usually causes it to increase, cracked oil with a reduced flashpoint causes it to decrease. Since these processes are partly overlaid, the determination of viscosity must be combined with other methods of analysis. If the required viscosity is no longer present, then the circulation pumps will no longer be tuned appropriately. This may impair the performance of the entire system. Important criteria include

- a reduced flashpoint as evidence of products with a low boiling point from a possible cracking process;
- oxidation and neutralisation number as characteristic values for the ageing and/or remaining performance of the oil, and
- the Conradson carbon residue, which is used to detect coke-like residues and suspected products with a high boiling point from a cracking process.

4.4 Shipping company's safety management system

The shipping company provided the Safety Management Manual (SMM) and the Fleet Procedures Manual (FPM) derived from that. English is the designated working language according to the SMM. This was also noted on the first page of the deck log book. However, parts of each manual were additionally drawn up in Russian. The shipping company stated in response to a query that the reason for this was to ensure that all crew members could understand the relevant passages in their first language, thus confirming the finding that the English skills of all crew members were not equal or almost non-existent. The same impression emerged during the questioning of witnesses.

According to the FPM, the master and the chief engineer are responsible for carrying out a risk assessment whenever necessary. Risk assessment is the process of evaluating health and safety hazards to workers resulting from workplace hazards. It is a systematic study of all aspects of work to establish:

- what could cause injury or harm;
- how the hazards can be eliminated, and if not,
- what preventative or protective measures are or should be in place to contain the hazards.

If this analysis – i.e. the starting point of a health and safety management approach – is not carried out thoroughly or at all, then the appropriate measures cannot be identified or implemented, either.

When the documents on board were examined, a hazard analysis was neither available for the engine department nor for the deck department. This fact calls into question general safety awareness on board. Non-compliance with the FPM on board the ship did not give rise to any requests, checks or enquiries from the person ashore responsible for this (DPA[20]).

The survey of the scene of the accident also included an inspection of the life-saving appliances and escape routes shown in the safety plan. The life-saving appliances, including fire-protection suits, were located in the designated places and in good condition. The primary escape route, marked with a solid green arrow in the safety plan, is also the exit from the engine room chosen by the rescuers. The secondary escape route, marked with a dotted green arrow, exited the engine room via a shaft. The distance from the separator room to the emergency exit via the shaft was 3.40 m, which was many times shorter and would have been easier to pass than the chosen escape route. However, recovering the casualty via this route would have failed due to the absence of a harness or recovery system, which is required for such emergency exits. It should be noted in this context that putting a safety harness around an unconscious person would certainly have been more time-consuming. However, if this escape route is the only way to get out of the burning engine room, then the escape and thus the evacuation of unconscious people must be ensured regardless of any additional effort involved. Since the use of the secondary escape route was not an option in this case and had no effect on the rescue operation, a safety recommendation will not be made in this report.

[20] DPA: Designated person ashore. According to the ISM Code, the DPA plays a key role in the effective implementation of a safety management system and is responsible for reviewing and monitoring all safety and environmental protection measures.

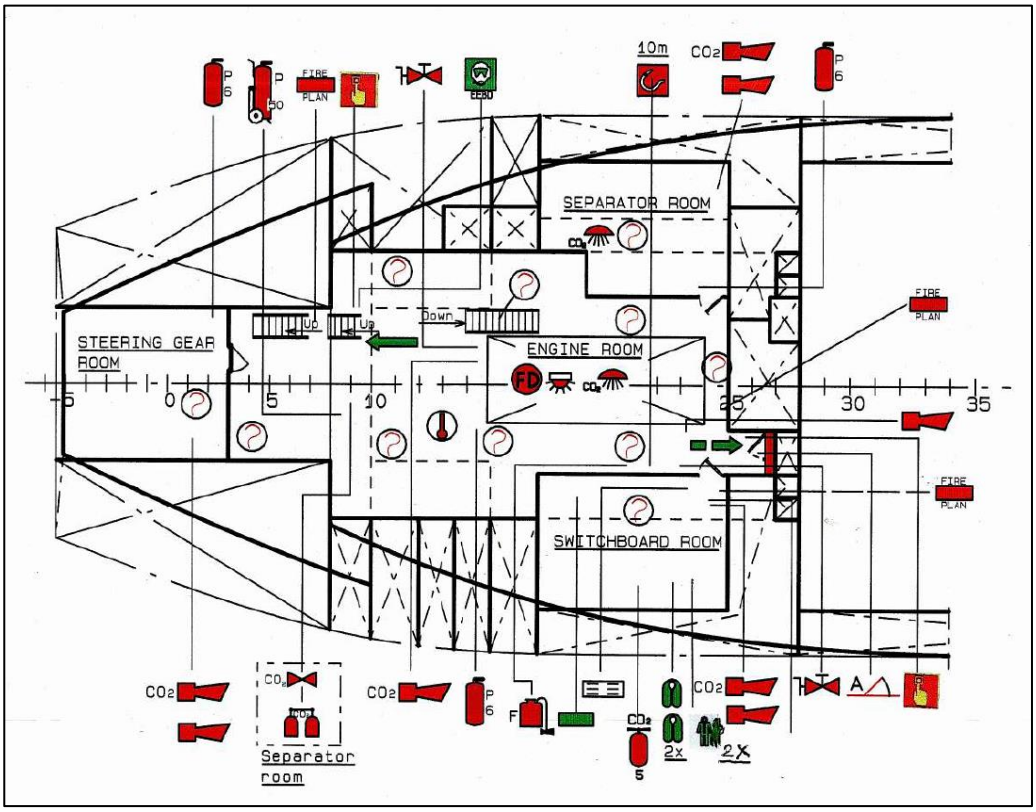


Figure 31: Extract from the safety plan

4.5 Port State controls and inspection by the classification society

According to the classification society's records, the KELLY was classed on 11 January 2019 with effect from 30 January 2019. This took place in connection with the transfer to the management of Hansa Shipping. All certificates were issued without any restrictions when the ship was put back into service.

In the course of the investigation, the classification society was asked how specific the requirements are for:

- thermal oil boilers being returned to service after a prolonged period of inactivity, and
- thermal oil boilers being returned to service after repairs.

Only parts of the enquiry were actually answered. RINA referred to the rules and instructions for the general boiler survey. According to the documents provided, the surveyor's inspection also includes reviewing the heat transfer oil analysis, but only for the annual survey.

The KELLY was inspected by the Baltic port State control authority once prior to the accident, on 21 February 2019. No deficiencies were found.

5 ACTIONS TAKEN

Since it was apparent that a positive trend in the analyses was not to be expected, the shipping company decided at the end of February 2020 to have the thermal oil system chemically cleaned by GLOBAL BOILER, a company based in Aalborg. This involved connecting a cleaning system to the ship's boiler system and charging it with about 1,300 litres of conventional diesel oil and 300 litres of carbon remover[21]. After allowing this solution to circulate for 15 hours, a further 100 litres of carbon remover were added to optimise the cleaning result. This mixture was then circulated for another 6-8 hours. The result was seen as residues in the filter mats and in the bottom of the cleaning tank. The company recommended that the system be flushed thoroughly to remove any diesel or chemical residues. It was also recommended that the thermal oil be tested (or analysed) regularly after the cleaning procedure. The BSU is not aware of whether and with what result this was carried out.

Source: Global Boiler Aalborg A/S

Figure 32: Residues in the filter mats

[21] Unitor™ Carbon Remover™ is a powerful, non-corrosive cleaning agent for removing carbon deposits.

Source: Global Boiler Aalborg A/S

Figure 33: Residues in the cleaning tank

6 CONCLUSIONS

Impurities in the thermal oil were unequivocally identified as the cause of the accident during the BSU's investigations. Five possible sources of ignition for the explosion in the KELLY's separator room were further identified:

1. Open flame or spark from a lighter.
2. Open flame or spark from a Bunsen burner.
3. Short circuit in the control valve switch box.
4. Control valves.
5. Tank sensor.

A typical fire pattern with a clearly formed fire funnel was identified 1.5 m away from the control cabinet in the area of the floor. A current-conducting tank sensor was located immediately below the funnel. Based on that, the investigators believe it possible that the explosion started in this area.
Since this source of ignition only became evident in the further course of the investigation, the sensor could no longer be secured and subjected to a technical inspection.

The findings gained from the thermal oil samples revealed significant fuel contamination. This was a contributing factor in the accident. The investigators believe that an explosion or flashover would not have occurred had the oil complied with the parameters shown in the safety data sheet. Moreover, they are of the opinion that it has been proven that the contaminated thermal oil was the cause of the accident on 6 September 2019.

However, the fact that this accident could have been avoided had there been an awareness of the potential danger of thermal oil contaminated with fuel has been established indisputably and unequivocally.

7 SAFETY RECOMMENDATIONS

The following safety recommendations do not constitute a presumption of blame or liability in respect of type, number or sequence.

7.1 Hansa Shipping

The Federal Bureau of Maritime Casualty Investigation recommends that the shipping company, Hansa Shipping, comply with the requirements laid down in its Safety Management Manual and Fleet Procedures Manual (Chapter 19: Risk Management, Section 0, Subitem 3.2 Risk Analysis). This applies to operations on board and at the shipping company.

7.2 Hansa Shipping

The Federal Bureau of Maritime Casualty Investigation recommends that the shipping company, Hansa Shipping, fully compile any quality-related documents in English, as well as in Russian if necessary due to language deficiencies of the crew.

7.3 Hansa Shipping

The Federal Bureau of Maritime Casualty Investigation recommends that the shipping company, Hansa Shipping, comply with the supplier's rules for testing heat transfer oil after repairs, as laid down in the safety data sheet.

7.4 Hansa Shipping

The Federal Bureau of Maritime Casualty Investigation recommends that the shipping company, Hansa Shipping, supplement its Fleet Procedure Manual (Chapter 10: Maintenance, Section 0, Subitem 3.2.3 Lubrication Oil Samples) to the effect that sampling of the thermal oil must also be carried out at six month intervals.

7.5 The classification society, RINA

The Federal Bureau of Maritime Casualty Investigation recommends that the classification society, RINA, expand upon its rules to the effect that a quality analysis of the heat transfer oil must be sent to the classification society after the boiler plant has been repaired or out of service for an extended period.

8 SOURCES

- Enquiries of the WSP
- Written explanations/submissions
  - Ship's command
  - Shipping company
  - Classification society
- Witness testimony
- Expert opinion/technical paper
- Navigational charts and ship particulars, BSH
- Official weather report of Germany's National Meteorological Service
- Radar recordings, ship safety services/vessel traffic services (VTS)
- Documentation, Ship Safety Division (BG Verkehr)
  - Accident Prevention Regulations for Shipping Enterprises
  - Guidelines and codes of practice
  - Ship files

9 ANNEXES

9.1 Texatherm 32, 46 safety data sheet

SECTION 1 IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

1.1 Product identifier
Texatherm 32, 46

Product Number(s): 219352, 219353, 801507, 821159

1.2 Relevant identified uses of the substance or mixture and uses advised against
Identified Uses: Industrial Oil

1.3 Details of the supplier of the safety data sheet
YX Smøreolje AS
Lysaker Torg 35
NO-1366 Lysaker
Norway
www.olje.yx.no
email : olje@yx.no

1.4 Emergency telephone number
Transportation Emergency Response
Europe: 0044/(0)18 65 407333
Health Emergency
Europe: 0044/(0)18 65 407333
Poison Control Centre Norway: 0047/22591300
Product Information
Technical Information: (+47)04210

SECTION 2 HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

CLP CLASSIFICATION: Not classified as dangerous according to EU regulatory guidelines.

2.2 Label elements
Under the criteria of Regulation (EC) No 1272/2008 (CLP):
Not classified

2.3 Other hazards Not Applicable

SECTION 3 COMPOSITION/ INFORMATION ON INGREDIENTS

3.2 Mixtures
This material is a mixture.

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Figure 34: Extract from the safety data sheet

COMPONENTS	CAS NUMBER	EC NUMBER	REGISTRATION NUMBER	CLP CLASSIFICATION	AMOUNT
Highly refined mineral oil (C15 - C50)	Mixture	*	***	None	65 - 99 %weight
Highly refined mineral oil (C15 - C50)	Mixture	*	***	Asp. Tox. 1/H304	0 - 35 %weight

The full text of all CLP H-statements is shown in Section 16.

*Contains one or more of the following EINECS numbers: 265-090-8, 265-091-3, 265-096-0, 265-097-6, 265-098-1, 265-101-6, 265-155-0, 265-156-6, 265-157-1, 265-158-7, 265-159-2, 265-160-8, 265-166-0, 265-169-7, 265-176-5, 276-736-3, 276-737-9, 276-738-4, 278-012-2.
*** Contains one or more of the following REACH registration numbers: 01-2119488706-23, 01-2119487067-30, 01-2119487081-40, 01-2119483621-38, 01-2119480374-36, 01-2119488707-21, 01-2119467170-45, 01-2119480375-34, 01-2119484627-25, 01-2119480132-48, 01-2119487077-29, 01-2119489287-22, 01-2119480472-38, 01-2119471299-27, 01-2119485040-48, 01-2119555262-43, 01-2119495601-36, 01-2119474889-13, 01-2119474878-16.

SECTION 4 FIRST AID MEASURES

4.1 Description of first aid measures
Eye: No specific first aid measures are required. As a precaution, remove contact lenses, if worn, and flush eyes with water.
Skin: No specific first aid measures are required. As a precaution, remove clothing and shoes if contaminated. To remove the material from skin, use soap and water. Discard contaminated clothing and shoes or thoroughly clean before reuse.
Ingestion: No specific first aid measures are required. Do not induce vomiting. As a precaution, get medical advice.
Inhalation: No specific first aid measures are required. If exposed to excessive levels of material in the air, move the exposed person to fresh air. Get medical attention if coughing or respiratory discomfort occurs.

4.2 Most important symptoms and effects, both acute and delayed
IMMEDIATE SYMPTOMS AND HEALTH EFFECTS
Eye: Not expected to cause prolonged or significant eye irritation.
Skin: Contact with the skin is not expected to be harmful.
Ingestion: Not expected to be harmful if swallowed.
Inhalation: Not expected to be harmful if inhaled. Contains a petroleum-based mineral oil. May cause respiratory irritation or other pulmonary effects following prolonged or repeated inhalation of oil mist at airborne levels above the recommended mineral oil mist exposure limit. Symptoms of respiratory irritation may include coughing and difficulty breathing.

DELAYED OR OTHER SYMPTOMS AND HEALTH EFFECTS: Not classified.

4.3 Indication of any immediate medical attention and special treatment needed
Not applicable.

SECTION 5 FIRE FIGHTING MEASURES

5.1 Extinguishing media

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Figure 35: Extract from the safety data sheet

Use water fog, foam, dry chemical or carbon dioxide (CO2) to extinguish flames.

5.2 Special hazards arising from the substance or mixture
Combustion Products: Highly dependent on combustion conditions. A complex mixture of airborne solids, liquids, and gases including carbon monoxide, carbon dioxide, and unidentified organic compounds will be evolved when this material undergoes combustion.

5.3 Advice for firefighters
This material will burn although it is not easily ignited. See Section 7 for proper handling and storage. For fires involving this material, do not enter any enclosed or confined fire space without proper protective equipment, including self-contained breathing apparatus.

SECTION 6 ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures
Eliminate all sources of ignition in vicinity of spilled material. Refer to Sections 5 and 8 for more information.

6.2 Environmental precautions
Stop the source of the release if you can do it without risk. Contain release to prevent further contamination of soil, surface water or groundwater.

6.3 Methods and material for containment and cleaning up
Clean up spill as soon as possible, observing precautions in Exposure Controls/Personal Protection. Use appropriate techniques such as applying non-combustible absorbent materials or pumping. Where feasible and appropriate, remove contaminated soil and dispose of in a manner consistent with applicable requirements. Place other contaminated materials in disposable containers and dispose of in a manner consistent with applicable requirements. Report spills to local authorities as appropriate or required.

6.4 Reference to other sections
See sections 8 and 13.

SECTION 7 HANDLING AND STORAGE

7.1 Precautions for safe handling
General Handling Information: Avoid contaminating soil or releasing this material into sewage and drainage systems and bodies of water.
Precautionary Measures: Do not get in eyes, on skin, or on clothing. Do not taste or swallow. Wash thoroughly after handling.
Static Hazard: Electrostatic charge may accumulate and create a hazardous condition when handling this material. To minimize this hazard, bonding and grounding may be necessary but may not, by themselves, be sufficient. Review all operations which have the potential of generating and accumulating an electrostatic charge and/or a flammable atmosphere (including tank and container filling, splash filling, tank cleaning, sampling, gauging, switch loading, filtering, mixing, agitation, and vacuum truck operations) and use appropriate mitigating procedures.
Container Warnings: Container is not designed to contain pressure. Do not use pressure to empty container or it may rupture with explosive force. Empty containers retain product residue (solid, liquid, and/or vapor) and can be dangerous. Do not pressurize, cut, weld, braze, solder, drill, grind, or expose such containers to heat, flame, sparks, static electricity, or other sources of ignition. They may explode and cause injury or death. Empty containers should be completely drained, properly closed, and promptly returned to a drum reconditioner or disposed of properly.

7.2 Conditions for safe storage, including any incompatibilities
Not Applicable

7.3 Specific end use(s): Industrial Oil

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Figure 36: Extract from the safety data sheet

SECTION 8 EXPOSURE CONTROLS/PERSONAL PROTECTION

GENERAL CONSIDERATIONS:
Consider the potential hazards of this material (see Section 2), applicable exposure limits, job activities, and other substances in the work place when designing engineering controls and selecting personal protective equipment. If engineering controls or work practices are not adequate to prevent exposure to harmful levels of this material, the personal protective equipment listed below is recommended. The user should read and understand all instructions and limitations supplied with the equipment since protection is usually provided for a limited time or under certain circumstances. Refer to appropriate CEN standards.

8.1 Control parameters
Occupational Exposure Limits:

Component	Country/ Agency	Form	TWA	STEL	Ceiling	Notation
Highly refined mineral oil (C15 - C50)	Norway	--	1 mg/m3	--	--	--

Consult local authorities for appropriate values.

8.2 Exposure controls
ENGINEERING CONTROLS:
Use in a well-ventilated area.

PERSONAL PROTECTIVE EQUIPMENT
Eye/Face Protection: No special eye protection is normally required. Where splashing is possible, wear safety glasses with side shields as a good safety practice.
Skin Protection: No special protective clothing is normally required. Where splashing is possible, select protective clothing depending on operations conducted, physical requirements and other substances in the workplace. Suggested materials for protective gloves include: 4H (PE/EVAL), Nitrile Rubber, Silver Shield, Viton.
Respiratory Protection: No respiratory protection is normally required. If user operations generate an oil mist, determine if airborne concentrations are below the occupational exposure limit for mineral oil mist. If not, wear an approved respirator that provides adequate protection from the measured concentrations of this material. For air-purifying respirators use a particulate cartridge.

ENVIRONMENTAL EXPOSURE CONTROLS:
See relevant Community environmental protection legislation or the Annex, as applicable.

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Attention: the data below are typical values and do not constitute a specification.

9.1 Information on basic physical and chemical properties
Appearance
Color: Colorless to yellow
Physical State: Liquid
Odor: Petroleum odor
Odor Threshold: No data available
pH: Not Applicable
Melting Point: No data available
Freezing Point: Not Applicable
Initial Boiling Point: No data available
Flashpoint: (Cleveland Open Cup) 200 °C (392 °F) (Minimum)
Evaporation Rate: No data available
Flammability (solid, gas): Not Applicable
Flammability (Explosive) Limits (% by volume in air):
Lower: Not Applicable Upper: Not Applicable

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Figure 37: Extract from the safety data sheet

Vapor Pressure: No data available
Vapor Density (Air = 1): No data available
Density: 0.8545 kg/l - 0.8597 kg/l @ 15°C (59°F) (Typical)
Solubility: Soluble in hydrocarbons; insoluble in water
Partition coefficient: n-octanol/water: No data available
Auto-ignition temperature: No data available
Decomposition temperature: No data available
Viscosity: 29.10 mm2/s @ 40°C (104°F) (Minimum)
Explosive Properties: No Data Available
Oxidising properties: No Data Available

9.2 Other Information: No Data Available

SECTION 10 STABILITY AND REACTIVITY

10.1 Reactivity: May react with strong acids or strong oxidizing agents, such as chlorates, nitrates, peroxides, etc.
10.2 Chemical Stability: This material is considered stable under normal ambient and anticipated storage and handling conditions of temperature and pressure.
10.3 Possibility of hazardous reactions: Hazardous polymerization will not occur.
10.4 Conditions to Avoid: Not applicable
10.5 Incompatible materials to avoid: Not applicable
10.6 Hazardous decomposition products: None known (None expected)

SECTION 11 TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects
Product Information:
Serious Eye Damage/Irritation: The eye irritation hazard is based on evaluation of data for product components.

Skin Corrosion/Irritation: The skin irritation hazard is based on evaluation of data for product components.

Skin Sensitization: The skin sensitization hazard is based on evaluation of data for product components.

Acute Dermal Toxicity: The acute dermal toxicity hazard is based on evaluation of data for product components.

Acute Toxicity Estimate (dermal): Not Applicable

Acute Oral Toxicity: The acute oral toxicity hazard is based on evaluation of data for product components.

Acute Toxicity Estimate (oral): Not Applicable

Acute Inhalation Toxicity: The acute inhalation toxicity hazard is based on evaluation of data for product components.

Acute Toxicity Estimate (inhalation): Not Applicable

Germ Cell Mutagenicity: The hazard evaluation is based on data for components or a similar material.

Carcinogenicity: The hazard evaluation is based on data for components or a similar material.

Reproductive Toxicity: The hazard evaluation is based on data for components or a similar material.

Specific Target Organ Toxicity - Single Exposure: The hazard evaluation is based on data for components or a similar material.

Specific Target Organ Toxicity - Repeated Exposure: The hazard evaluation is based on data for components or a similar material.

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Figure 38: Extract from the safety data sheet

9.2 SGS oil sample test report[22]

SGS

DAkkS Deutsche Akkreditierungsstelle D-PL-11020-01-00

Datum: 15/Jan/2020

Prüfbericht: SP19-04411.001 Revision: 1

** Dieser Bericht annulliert und ersetzt das von SGS ausgefertigte Protokoll Nr. SP19-04411.001 vom 07/Jan/2020. **

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GERMANY
33142

Die Ergebnisse in diesem Bericht beziehen sich auf die untersuchten Proben, wenn nicht anders vermerkt. Alle Untersuchungen wurden nach den neuesten Ausgaben der Normen durchgeführt, außer wenn eine Datierung genannt ist. Für die Ergebnisse gelten die in der Norm genannten Präzisionsangaben, die auf Anforderung berechnet werden. Beim Vergleich der Werte mit Spezifikationen oder anderen Anforderungen sind die in ISO 4259, ASTM D 3244, IP 367 und IP Anhang E genannten Erläuterungen und Verfahren zu berücksichtigen. Prüfberichte werden als pdf-Datei ohne Unterschrift versendet. Ein unterschriebenes Exemplar kann jederzeit angefordert werden. Dieses Dokument wurde von der Gesellschaft im Rahmen ihrer Allgemeinen Geschäftsbedingungen für Dienstleistungen erstellt, die auf Anfrage erhältlich sind. Es wird ausdrücklich auf die darin enthaltenen Regelungen zur Haftungsbeschränkung Freistellung und zum Gerichtsstand hingewiesen. Jeder Besitzer dieses Dokuments wird darauf hingewiesen, dass die darin enthaltenen Angaben ausschließlich die im Zeitpunkt der Dienstleistung von der Gesellschaft festgestellten Tatsachen im Rahmen der Vorgaben des Kunden, sofern überhaupt vorhanden, wiedergeben. Die Gesellschaft ist allein dem Kunden gegenüber verantwortlich. Dieses Dokument entbindet die Parteien von Rechtsgeschäften nicht von ihren insoweit bestehenden Rechten und Pflichten. Jede nicht genehmigte Änderung Fälschung oder Verzerrung des Inhalts oder des äußeren Erscheinungsbildes dieses Dokuments ist rechtswidrig. Ein Verstoß kann rechtlich geahndet werden.

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193414390

KUNDENAUFTRAGSNR.:	nicht vorhanden	SGS AUFTRAGSNUMMER	55722753_5191925
KUNDENIDENTIFIKATION :	Probe 1	SCHIFF:	Kelly
STANDORT:	Brunsbüttel	PRODUKTBESCHREIBUNG:	Frischöl - Texatherm 32
HERKUNFT DER PROBE:	Storage Tank		
PROBENTYP:	Wie übergeben	PROBENEHMER:	Kunde
PROBENAHME:	07/Sep/2019 09:28	ERHALTEN AM:	04/Dez/2019 09:30
ANALYSIERT:	05/Dez/2019 08:55 - 15/Jan/2020 13:24	ABGESCHLOSSEN:	15/Jan/2020 13:24
TEIL-PROBE :	[1: 250 ml Glas Flasche]		
PROBENKOMMENTAR:	Cargo/Containership IMO:9255622		

EIGENSCHAFT:	METHODE	ERGEBNIS:	EINHEIT:	MIN	MAX
Konjugierte Diene und Styrol / GC-MS *	SGS M1786				
Dien-Gehalt *		siehe Kommentar	% (m/m)	--	--
(Ergebnis: In der Probe wurden eine Vielzahl an leichtflüchtigen Komponenten der Substanzklassen Paraffine, Naphthene und Aromaten identifiziert.)					
Dichte bei 20 °C	ASTM D4052-18a	831,0	kg/m³	--	--
Temperatur *	Visual	22	°C	--	--
Aussehen *	Visual	trüb, Feststoffe, frei von ungelöstem Wasser	---	--	--
Farbzahl	DIN ISO 2049:2002	D 8.0	---	--	--
Cleveland Flash Point (Open cup) *	DIN EN ISO 2592:2018	<140	°C	--	--

ZEICHNUNGSBERECHTIGTER

i.V. STEFAN HEPPES
Division Manager Lab Operations

15012020164900000048002 Seite 1 von 6 OGC-DE_Report-2014-12-10_v60a

SGS Germany GmbH | Am Neuen Rheinhafen 12a, D-67346 Speyer, Germany (t)+49 6232 1301-0

Member of the SGS Group (Société Générale de Surveillance)

Geschäftsführer: Stefan Steinhardt, Sitz der Gesellschaft: Hamburg, HRB 4951 Amtsgericht Hamburg, Aufsichtsratvorsitzender: Dirk Hellemans

Figure 39: Oil sample test report

[22] The sample test reports are only available in German language.

SGS

DAkkS Deutsche Akkreditierungsstelle D-PL-11020-01-00

Datum: 15/Jan/2020

Bundesstelle für Seeunfallunterssuch
Bernhard-Nocht-Str. 78
Büren
GERMANY
33142

Prüfbericht: SP19-04411.001 Revision: 1

** Dieser Bericht annulliert und ersetzt das von SGS ausgefertigte Protokoll Nr. SP19-04411.001 vom 07/Jan/2020. **

Nach DIN EN ISO/IEC 17025 durch die DAkkS akkreditiertes Prüflaboratorium. Die hier berichteten Ergebnisse wurden im Rahmen der Akkreditierungsbedingungen ermittelt, mit Ausnahme der mit Stern (*) gekennzeichneten Untersuchungen, die nicht im Bereich der Akkreditierung dieses Labores liegen.

EIGENSCHAFT:	METHODE	ERGEBNIS:	EINHEIT:	MIN	MAX
(Erwarteter Flammpunkt: 200 °C Ergänzte Analyse gemäß Methode DIN EN ISO 3679 bei 100°C ergab, dass die Probe sofort brennt und vom Gerät nicht detektiert wird. Vermutlich liegt der Flammpunkt daher deutlich unter 100 °C.)					
Zündtemperatur *	DIN 51794:2003	235	°C	--	--
Siedebeginn *	EN 15199-1:2006	siehe Kommentar	°C	--	--
(Nicht auswertbar, Gehalt leichte Anteile zu hoch)					
Wassergehalt	ASTM D6304-16e1 (Procedure C)	364	mg/kg	--	--
Kinematische Viskosität bei 40°C *	ASTM D7042-16e3	6,039	mm²/s	--	--
Kommentar *	DIN 51405:2004	Auswertung DIN 51380 (DK): leichte Anteile 24,7 m-%	---	--	--

Dieses Dokument ist nur in seiner Gesamtheit gültig, bitte richten Sie Ihre Aufmerksamkeit auf die Bedingungen und Konditionen auf Seite 1 des Berichts

ZEICHNUNGSBERECHTIGTER

i.V. STEFAN HEPPES
Division Manager Lab Operations

15012020155000000048002 Seite 2 von 6 OGC-DE_Report-2014-12-10_v60a

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Member of the SGS Group (Société Générale de Surveillance)

Geschäftsführer: Stefan Steinhardt, Sitz der Gesellschaft: Hamburg, HRB 4951 Amtsgericht Hamburg, Aufsichtsratvorsitzender: Dirk Hellemans

Figure 40: Oil sample test report

SGS

DAkkS Deutsche Akkreditierungsstelle D-PL-11020-01-00

Datum: 15/Jan/2020

Bundesstelle für Seeunfalluntersuch
Bernhard-Nocht-Str. 78
Büren
GERMANY
33142

Prüfbericht: SP19-04411.002 Revision: 1

** Dieser Bericht annulliert und ersetzt das von SGS ausgefertigte Protokoll Nr. SP19-04411.002 vom 07/Jan/2020. **

Die Probe(n), auf die sich die hier dargelegten Erkenntnisse (die „Erkenntnisse") beziehen, wurde(n) durch den Kunden oder durch im Auftrage des Kunden handelnde Dritte entnommen. Die Erkenntnisse geben keine Garantie für den repräsentativen Charakter der Probe bezüglich irgendwelcher Waren und beziehen sich ausschließlich auf die Probe(n). Die Gesellschaft übernimmt keine Haftung für den Ursprung oder die Quelle aus der die Probe angeblich/tatsächlich entnommen wurde.

Nach DIN EN ISO/IEC 17025 durch die DAkkS akkreditiertes Prüflaboratorium. Die hier berichteten Ergebnisse wurden im Rahmen der Akkreditierungsbedingungen ermittelt, mit Ausnahme der mit Stern (*) gekennzeichneten Untersuchungen, die nicht im Bereich der Akkreditierung dieses Labores liegen.

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KUNDENAUFTRAGSNR.:	nicht vorhanden	SGS AUFTRAGSNUMMER	55722753_5191925
KUNDENIDENTIFIKATION :	Probe 2	SCHIFF:	Kelly
STANDORT:	Brunsbüttel	PRODUKTBESCHREIBUNG:	Öl - Texatherm 32
HERKUNFT DER PROBE:	Separator room		
PROBENTYP:	Wie übergeben	PROBENEHMER:	Kunde
PROBENAHME:	09/Sep/2019 09:31	ERHALTEN AM:	04/Dez/2019 09:31
ANALYSIERT:	05/Dez/2019 08:55 - 15/Jan/2020 13:24	ABGESCHLOSSEN:	15/Jan/2020 13:24
TEIL-PROBE :	[1: 250 ml Glas Flasche]		
PROBENKOMMENTAR:	Cargo/Containership IMO:9255622		

EIGENSCHAFT:	METHODE	ERGEBNIS:	EINHEIT:	MIN	MAX
Konjugierte Diene und Styrol / GC-MS *	SGS M1786				
Dien-Gehalt *		siehe Kommentar	% (m/m)	--	--
(Ergebnis: In der Probe wurden eine Vielzahl an leichtflüchtigen Komponenten der Substanzklassen Paraffine, Naphthene und Aromaten identifiziert.)					
Dichte bei 20 °C	ASTM D4052-18a	823,2	kg/m³	--	--
Temperatur *	Visual	22	°C	--	--
Aussehen *	Visual	sehr dunkel, schwarz, Spuren von Feststoffen, frei von ungelöstem Wasser	---	--	--
Farbzahl	DIN ISO 2049:2002	D 8.0	---	--	--
Cleveland Flash Point (Open cup) *	DIN EN ISO 2592:2018	<172	°C	--	--
(Erwarteter Flammpunkt: 200 °C Ergänzte Analyse gemäß Methode DIN EN ISO 3679 bei 100°C ergab, dass die Probe sofort brennt und vom Gerät nicht detektiert wird. Vermutlich liegt der Flammpunkt daher deutlich unter 100 °C.)					
Zündtemperatur *	DIN 51794:2003	230	°C	--	--
Oxidation und Nitration von gebrauchten Motorenölen mittels IR	DIN 51453:2004				
Oxidation		30,2	A/cm	--	--

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i.V. STEFAN HEPPES
Division Manager Lab Operations

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Geschäftsführer: Stefan Steinhardt, Sitz der Gesellschaft: Hamburg, HRB 4951 Amtsgericht Hamburg, Aufsichtsratvorsitzender: Dirk Hellemans

Figure 41: Oil sample test report

SGS

DAkkS Deutsche Akkreditierungsstelle D-PL-11020-01-00

Datum: 15/Jan/2020

Bundesstelle für Seeunfalluntersuch
Bernhard-Nocht-Str. 78
Büren
GERMANY
33142

Prüfbericht: SP19-04411.002 Revision: 1

** Dieser Bericht annulliert und ersetzt das von SGS ausgefertigte Protokoll Nr. SP19-04411.002 vom 07/Jan/2020. **

Nach DIN EN ISO/IEC 17025 durch die DAkkS akkreditiertes Prüflaboratorium. Die hier berichteten Ergebnisse wurden im Rahmen der Akkreditierungsbedingungen ermittelt, mit Ausnahme der mit Stern (*) gekennzeichneten Untersuchungen, die nicht im Bereich der Akkreditierung dieses Labores liegen.

EIGENSCHAFT:	METHODE	ERGEBNIS:	EINHEIT:	MIN	MAX
Nitration		0,0	A/cm	--	--
Siedebeginn * (Nicht auswertbar, Gehalt leichte Anteile zu hoch)	EN 15199-1:2006	siehe Kommentar	°C	--	--
Wassergehalt	ASTM D6304-16e1 (Procedure C)	185	mg/kg	--	--
Kinematische Viskosität bei 40°C *	ASTM D7042-16e3	2,183	mm²/s	--	--
Kommentar *	DIN 51405:2004	Auswertung DIN 51380 (DK): leichte Anteile 81,5 m-%	---	--	--

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Division Manager Lab Operations

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Member of the SGS Group (Société Générale de Surveillance)

Geschäftsführer: Stefan Steinhardt, Sitz der Gesellschaft: Hamburg, HRB 4951 Amtsgericht Hamburg, Aufsichtsratvorsitzender: Dirk Hellemans

Figure 42: Oil sample test report

SGS

DAkkS Deutsche Akkreditierungsstelle D-PL-11020-01-00

Datum: 15/Jan/2020

Bundesstelle für Seeunfalluntersuch
Bernhard-Nocht-Str. 78
Büren
GERMANY
33142

Prüfbericht: SP19-04411.003 Revision: 1

** Dieser Bericht annulliert und ersetzt das von SGS ausgefertigte Protokoll Nr. SP19-04411.003 vom 07/Jan/2020. **

Die Probe(n), auf die sich die hier dargelegten Erkenntnisse (die „Erkenntnisse") beziehen, wurde(n) durch den Kunden oder durch im Auftrage des Kunden handelnde Dritte entnommen. Die Erkenntnisse geben keine Garantie für den repräsentativen Charakter der Probe bezüglich irgendwelcher Waren und beziehen sich ausschließlich auf die Probe(n). Die Gesellschaft übernimmt keine Haftung für den Ursprung oder die Quelle aus der die Probe angeblich/tatsächlich entnommen wurde.

Nach DIN EN ISO/IEC 17025 durch die DAkkS akkreditiertes Prüflaboratorium. Die hier berichteten Ergebnisse wurden im Rahmen der Akkreditierungsbedingungen ermittelt, mit Ausnahme der mit Stern (*) gekennzeichneten Untersuchungen, die nicht im Bereich der Akkreditierung dieses Labores liegen.

193414390

KUNDENAUFTRAGSNR.:	nicht vorhanden	SGS AUFTRAGSNUMMER	55722753_5191925
KUNDENIDENTIFIKATION :	Probe 3	SCHIFF:	Kelly
STANDORT:	Brunsbüttel	PRODUKTBESCHREIBUNG:	Öl - Texatherm 32
HERKUNFT DER PROBE:	Engine Room		
PROBENTYP:	Wie übergeben	PROBENEHMER:	Kunde
PROBENAHME:	09/Sep/2019 09:31	ERHALTEN AM:	04/Dez/2019 09:32
ANALYSIERT:	05/Dez/2019 08:55 - 15/Jan/2020 13:24	ABGESCHLOSSEN:	15/Jan/2020 13:24
TEIL-PROBE :	[1: 250 ml Glas Flasche]		
PROBENKOMMENTAR:	Cargo/Containership IMO:9255622		

EIGENSCHAFT:	METHODE	ERGEBNIS:	EINHEIT:	MIN	MAX
Konjugierte Diene und Styrol / GC-MS *	SGS M1786				
Dien-Gehalt *		siehe Kommentar	% (m/m)	--	--
(Ergebnis: In der Probe wurden eine Vielzahl an leichtflüchtigen Komponenten der Substanzklassen Paraffine, Naphthene und Aromaten identifiziert.)					
Dichte bei 20 °C	ASTM D4052-18a	822,0	kg/m³	--	--
Temperatur *	Visual	22	°C	--	--
Aussehen *	Visual	sehr dunkel, schwarz, Spuren von Feststoffen, frei von ungelöstem Wasser	---	--	--
Farbzahl	DIN ISO 2049:2002	D 8.0	---	--	--
Cleveland Flash Point (Open cup) *	DIN EN ISO 2592:2018	<172	°C	--	--
(Erwarteter Flammpunkt: 200 °C Ergänzte Analyse gemäß Methode DIN EN ISO 3679 bei 100°C ergab, dass die Probe sofort brennt und vom Gerät nicht detektiert wird. Vermutlich liegt der Flammpunkt daher deutlich unter 100 °C.)					
Zündtemperatur *	DIN 51794:2003	230	°C	--	--
Oxidation und Nitration von gebrauchten Motorenölen mittels IR	DIN 51453:2004				
Oxidation		31,9	A/cm	--	--

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Division Manager Lab Operations

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Member of the SGS Group (Société Générale de Surveillance)

Geschäftsführer: Stefan Steinhardt, Sitz der Gesellschaft: Hamburg, HRB 4951 Amtsgericht Hamburg, Aufsichtsratvorsitzender: Dirk Hellemans

Figure 43: Oil sample test report

SGS

DAkkS Deutsche Akkreditierungsstelle D-PL-11020-01-00

Datum: 15/Jan/2020

Bundesstelle für Seeunfalluntersuch
Bernhard-Nocht-Str. 78
Büren
GERMANY
33142

Prüfbericht: SP19-04411.003 Revision: 1

** Dieser Bericht annulliert und ersetzt das von SGS ausgefertigte Protokoll Nr. SP19-04411.003 vom 07/Jan/2020. **

Nach DIN EN ISO/IEC 17025 durch die DAkkS akkreditiertes Prüflaboratorium. Die hier berichteten Ergebnisse wurden im Rahmen der Akkreditierungsbedingungen ermittelt, mit Ausnahme der mit Stern (*) gekennzeichneten Untersuchungen, die nicht im Bereich der Akkreditierung dieses Labores liegen.

EIGENSCHAFT:	METHODE	ERGEBNIS:	EINHEIT:	MIN	MAX
Nitration		0,0	A/cm	--	--
Siedebeginn *	EN 15199-1:2006	siehe Kommentar	°C	--	--
(Nicht auswertbar, Gehalt leichte Anteile zu hoch)					
Wassergehalt	ASTM D6304-16e1 (Procedure C)	161	mg/kg	--	--
Kinematische Viskosität bei 40°C *	ASTM D7042-16e3	2,085	mm²/s	--	--
Kommentar *	DIN 51405:2004	Auswertung DIN 51380 (DK): leichte Anteile 85,0 m-%	---	--	--

** Ende der Analysenergebnisse **

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ZEICHNUNGSBERECHTIGTER

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Division Manager Lab Operations

150120201550000048002 Seite 6 von 6 OGC-DE_Report-2014-12-10_v60a

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Member of the SGS Group (Société Générale de Surveillance)

Geschäftsführer: Stefan Steinhardt, Sitz der Gesellschaft: Hamburg, HRB 4951 Amtsgericht Hamburg, Aufsichtsratvorsitzender: Dirk Hellemans

Figure 44: Oil sample test report

9.3 MQ Engineering inspection summary report[23]

MQ Engineering GmbH
Hansestraße 27
18182 Rostock-Bentwisch
Tel.: 0381/ 1283 60
info@mq-engineering.com

DAkkS
Deutsche Akkreditierungsstelle
D-IS-19274-01-00

Die Akkreditierung gilt für die in der Urkundenanlage D-IS-19274-01-00 aufgeführten Verfahren

engineering

Inspektionskurzbericht Nr. 51 142 -1

Auftraggeber:	**Sachverständigenbüro Dipl.- Ing. Harald Eden** Jeversche Str.17 26434 Wangerland **Herr Eden**
Aktenzeichen:	GTA-SCUA-09-19
Untersuchungsmaterial:	1 Stück Kabelbaum sowie mehrere bereits durch den Auftraggeber entnommene Einzeldrähte
Aufgabenstellung:	Untersuchung von Kupferdrähten des Kabelbaums auf Kurzschlussmerkmale
Zweck der Untersuchung:	Versicherungsfall/ Gerichtsfall
Datum der Untersuchungen:	05.11.2019 bis 15.11.2019
Angaben des Auftraggebers/ Mitgeltende Unterlagen:	siehe Seite 2
Durchgeführte Untersuchungen/ Verzeichnis der Anlagen:	**A** Bildmaterial von der Einbausituation des Kabelbaums nach dem Schadensereignis sowie von dem Kabelbaum selbst, bereitgestellt durch den Auftraggeber (Anlage A) **B** Untersuchungsmaterial/ Ergebnisse der visuellen Prüfung (Anlage 1) **C** Ergebnisse der REM-, BSE- und EDX-Analyse (Anlage 2)
Erbrachte Prüfleistungen:	MQ Engineering GmbH, D-PL-19274-01-00 (MQE)
Untersuchungsdurchführung*:	
Fotodokumentation:	Techn. Ass. M. Büttgenbach (MQE)
Rasterelektronenmikroskopie und EDX-Analyse:	Techn. Ass. M. Büttgenbach (MQE)
Technische Dokumentation:	P. Möller
Erstellung des Berichtes/ Kurzbewertung der Ergebnisse:	**H. Oelschner, M. Sc.**

** sofern Untersuchungen durchgeführt wurden und sofern nicht Bestandteil der Inspektionstätigkeit des Verfassers*
Stichworte: Kupferdrähte, Kurzschlussmerkmale
Ablage: U:\Untersuchungsberichte 2019\51142 SV Eden\51142-1 Inspektionskurzbericht.docx

Die Ergebnisse beziehen sich ausschließlich auf die Untersuchungsmaterialien.
Eine auszugsweise Vervielfältigung des Berichtes ist nicht gestattet.
Das geprüfte Material wird 6 Monate bei der MQ Engineering GmbH aufbewahrt.

Durch die DAkkS akkreditierte Inspektionsstelle Typ A nach DIN EN ISO/IEC 17020; Registriernummer: D-IS-19274-01-00

Figure 45: MQ Engineering inspection summary report

[23] The MQ Engineering inspection summary report is only available in German language.

Inspektionskurzbericht Nr. 51 142 -1

Untersuchung von Kupferdrähten eines Kabelbaums auf Kurzschlussmerkmale/ GTA-SCUA-09-19

Seite 2 von 4

engineering

Übergebene Exemplare:	2 x Auftraggeber in Deutsch und Englisch in Schriftform 1 x Auftraggeber per E-Mail in Deutsch und Englisch als PDF-Datei
Der Bericht umfasst:	4 Seiten und 3 Anlagen
Datum:	15.11.2019
Revisions-Nr.:	000

1. Sachverhalt/ Angaben des Auftraggebers/ Aufgabenstellung

Durch den Auftraggeber waren ein Abschnitt eines Kabelbaums sowie einzelne bereits durch den Auftraggeber auf Objektträgern fixierte Einzeldrähte des Kabelbaums aus einem Schaltschrank zur Untersuchung übersandt worden (Bild 1.1).

Zur Bearbeitung der Aufgabenstellung war durch den Auftraggeber Bildmaterial von der Einbausituation des Kabelbaums nach dem Schadensereignis sowie von dem Kabelbaum selbst übermittelt worden (siehe Anlage A).

Zusätzlich war durch den Auftraggeber ein Bereich des Kabelbaums gekennzeichnet worden, in dem auffällige Trennungen von Einzeldrähten vorlagen (siehe Bild 1.3).

Aufgabenstellung für die Untersuchungen war es gewesen, die z.T. getrennten Kupferdrähte des Kabelbaums hinsichtlich des Vorliegens von Kurzschlussmerkmalen zu untersuchen.

2. Durchgeführte Untersuchungen/ Kurzbewertung der Ergebnisse

Zur Bearbeitung der Aufgabenstellung wurden folgende Arbeitsschritte/ Untersuchungen durchgeführt:

1. Fotodokumentation,
2. visuelle Prüfung unter Zuhilfenahme eines Digitalmikroskops

sowie

3. Untersuchungen im Rasterelektronenmikroskop (REM) unter Zuhilfenahme von Rückstreuelektronen- (BSE-) Detektor und EDX-Analyse.

Die Ergebnisse der durchgeführten Untersuchungen lassen sich wie folgt zusammenfassen und bewerten:

1. Der zur Untersuchung übersandte Kabelbaum sowie die bereits durch den Auftraggeber entnommenen Einzeldrähte wurden zunächst einer visuellen Prüfung unter Zuhilfenahme eines Digitalmikroskops unterzogen. Die Ergebnisse dieser Untersuchungen sind in Anlage 1 dokumentiert und lassen sich wie folgt zusammenfassen:
    a. Die Isolierung der Kabel war überwiegend aufgeschmolzen und z.T. nicht mehr vorhanden, so dass die Kupfereinzeldrähte sichtbar waren (Bilder 1.2 bis 1.6).
    b. In dem durch den Auftraggeber markierten Bereich war der Kabelbaum auffällig deformiert („geknickt“) und die einzelnen Kupferkabel des Kabelbaums lagen frei (Bilder 1.3 bis 1.5).

Figure 46: MQ Engineering inspection summary report

Inspektionskurzbericht Nr. 51 142 -1

Untersuchung von Kupferdrähten eines Kabelbaums
auf Kurzschlussmerkmale/ GTA-SCUA-09-19

Seite 3 von 4

engineering

c. Die in dem durch den Auftraggeber markierten Bereich vorliegende Einzeldrahttrennung wies eine auffällig unebene Trennfläche auf, während der unmittelbar angrenzende Drahtabschnitt keine Oberflächenunregelmäßigkeiten aufwies (Bild 1.5).
d. Die Trennflächen der bereits durch den Auftraggeber entnommenen Einzeldrähte wurden unter Zuhilfenahme eines Digitalmikroskops hinsichtlich der Trennflächenmerkmale untersucht (Bilder 1.8 bis 1.13).
e. Im Rahmen dieser Untersuchung wurden an den Drahttrennflächen lokalisierte Materialaufschmelzungen aufgefunden. Diese aufgeschmolzenen Drahtenden waren eindeutig von den zur Probenentnahme mechanisch erzeugten Drahttrennungen zu unterscheiden (vergleiche z.B. Bilder 1.8 und 1.9).

2. Basierend auf den Ergebnissen der visuellen Prüfung wurden mehrere Einzeldrähte ausgewählt (siehe Bild 1.14) und im Rasterelektronenmikroskop (REM) unter Zuhilfenahme von Rückstreuelektronen-(BSE-) Detektor und EDX-Analyse hinsichtlich der Merkmale der Materialtrennungen untersucht. Die Ergebnisse dieser Untersuchungen sind in Anlage 2 dokumentiert und werden in nachfolgender Tabelle 1 zusammengefasst.

Tabelle 1: Ergebnisse der REM-, BSE- und EDX-Analyse

Pos.	Untersuchungsteil	REM-Probe Nr./ Probenentnahme in Anlage 1	Befund	Bilder in Anlage 2
1	**Kabelbaum**	**REM-Probe 1/** Bild 1.14	die Drahttrennung wies die nach Vergleichsbildern aus /1/ typischen Merkmale einer kurzschlussbedingten Materialtrennung in Form einer unregelmäßigen Oberfläche sowie einer „Schmelzperle" bei gleichzeitigem Vorliegen eines intakten Drahtquerschnitts des angrenzenden Drahtbereichs auf (Bild 2.3); bei der „Schmelzperle" handelte es sich nachweislich um aufgeschmolzenes Kupfer (Bild 2.4, Spektrum 1); die angrenzende Drahtoberfläche wies Ablagerungen/ Verbrennungsrückstände der Isolierung auf (Bild 2.4. Spektrum 2)	2.2 bis 2.4
		REM-Probe 2/ Bild 1.14	die im Rahmen der Probenentnahme erzeugte mechanische Trennung wies die hierfür typischen Scher- und Deformationsmerkmale auf (Bild 2.6); das zweite Drahtende wies hingegen eine unregelmäßige Trennfläche auf, die aufgrund des zusätzlichen Vorliegens von Kupfermaterial auf der Drahtoberfläche selbst auf eine lokalisierte Aufschmelzung infolge eines Kurzschlusses zurückgeführt werden muss (Bild 2.7)	2.5 bis 2.7
		REM-Probe 3/ Bild 1.14	die mechanische Trennung zur Probennahme war eindeutig identifizierbar (Bild 2.9); die zweite Trennfläche war nicht eindeutig auswertbar (Bild 2.10)	2.8 bis 2.10
		REM-Probe 4/ Bild 1.14	unmittelbar im Bereich des Drahtendes lag eine „Schmelzperle" aus Kupfer vor (Bilder 2.12 und 2.13, Spektrum 3); dieses geschmolzene Kupfer lag auf der eigentlichen Drahtoberfläche und wurde offensichtlich auf die Oberfläche „geschleudert" (Bild 2.12)	2.11 bis 2.13
		REM-Probe 5/ Bild 1.14	auch die Trennfläche dieses Einzeldrahtes wies Merkmale einer lokalisierten Aufschmelzung auf (Bild 2.15)	2.14 und 2.15

Figure 47: MQ Engineering inspection summary report

3. Zusammenfassung/ Schlussfolgerungen

Im Rahmen der durchgeführten Untersuchungen konnte gezeigt werden, dass sowohl die Einzeldrahttrennung in dem durch den Auftraggeber gekennzeichneten Bereich des Kabelbaums als auch mehrere der bereits durch den Auftraggeber aus dem Kabelbaum entnommenen Einzeldrahttrennungen die charakteristischen Merkmale von Materialtrennungen infolge von Kurzschlussereignissen aufwiesen.

So wurden an mehreren Drähten stark lokalisierte Aufschmelzungserscheinungen aufgefunden, wie sie durch Lichtbögen bei Kurzschlussereignissen gebildet werden. Das Vorliegen von intakten (d.h. unaufgeschmolzenen) Drahtoberflächen unmittelbar angrenzend an diese Aufschmelzungserscheinungen muss als charakteristisches Merkmal von Kurzschlussereignissen eingestuft werden /1/.

4. Literatur

/1/ Berkely Research Company: Copper Wire in Fire: experiments to produce arc beads in copper wires. Informationen aus dem Internet:
http://www.berkeleyrc.com/arcing.html,
(zuletzt abgerufen am 14.11.2019)