



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

## **Summary Investigation Report 310/16**

### **Less Serious Marine Casualty**

**Fire in the vicinity of the combined boiler  
with two injured crew members  
on board the tanker WEICHSELSTERN  
in the Neue Weser Nord Reede roadstead  
on 19 August 2016**

30 July 2020

This summary report within the meaning of Article 27(5) of the Law to improve safety of shipping by investigating marine casualties and other incidents (Maritime Safety Investigation Law – SUG) is a simplified report pursuant to the second sentence of Article 14(1) of Directive 2009/18/EC of the European Parliament and of the Council of 23 April 2009 establishing the fundamental principles governing the investigation of accidents in the maritime transport sector.

The investigation was conducted in accordance with the above legislation. According to said legislation, 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 report.

Issued by:  
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## 1 FACTUAL INFORMATION

### 1.1 Photograph of the ship



Figure 1: WEICHSELSTERN

### 1.2 Ship particulars

Name of ship:	WEICHSELSTERN
Type of ship:	Chemical tanker
Flag:	Portugal
Port of registry:	Madeira
IMO number:	9183829
Call sign:	CQLI
Owner:	MT "Weichselstern" Schiffahrtsgesellschaft mbH & Co. KG
Operator:	Nordic Tankers Trading A/S
ISM manager:	TB Marine Shipmanagement GmbH & Co. KG
Year built:	1999
Shipyard:	Stocznia Gdynia SA
Classification society:	American Bureau of Shipping (ABS)
Length overall:	162.16 m
Breadth overall:	27.0 m
Draught (max.):	8.8 m
Gross tonnage:	14,400
Deadweight:	21,823 t
Engine rating:	7,860 kW
Main engine:	H. Cegielski-Poznan S.A., 6S46MC-C
(Service) speed (max.):	12.1 kts
Hull material:	Steel
Hull design:	Double hull, Ice Class 1A

### 1.3 Voyage particulars

Port of departure:	Wilhelmshaven, Germany
Port of call:	Roadstead, waiting for orders
Type of voyage:	Merchant shipping/international
Cargo information:	Ballast
Manning:	21
Draught at time of accident:	Df= 4.7 m, Da= 6.5 m
Pilot on board:	No
Number of passengers:	0

### 1.4 Marine casualty information

Type of marine casualty:	Less serious marine casualty; fire in the vicinity of the combined boiler with two injured crew members
Date, time:	19 August 2016, 0115 <sup>1</sup>
Location:	North Sea, Neue Weser Nord Reede roadstead
Latitude/Longitude:	$\phi$ 53° 53.6'N $\lambda$ 007° 51.6'E
Ship operation and voyage segment:	Roadstead
Consequences:	Two injured crew members and damage to the combined boiler installation

Extract from Navigational Chart (21) 87 (INT 1413),  
Federal Maritime and Hydrographic Agency (BSH)

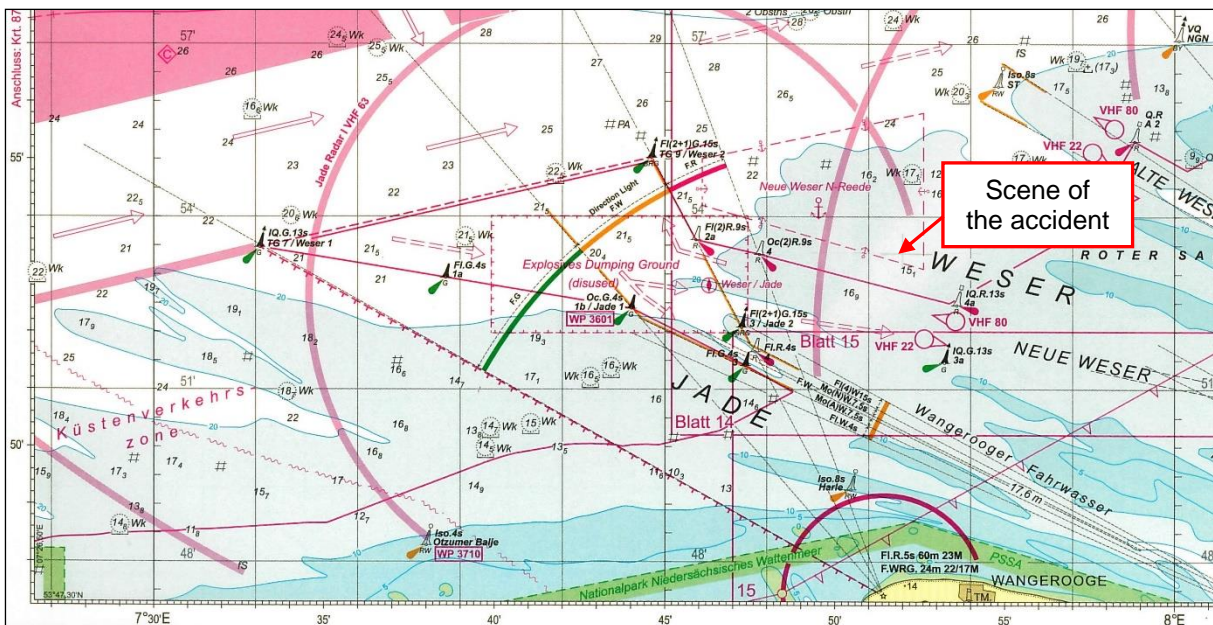


Figure 2: Scene of the accident

<sup>1</sup> All times shown in this report are local (UTC + 2 hours), which was also ship's time.

## 2 COURSE OF THE ACCIDENT AND INVESTIGATION

### 2.1 Course of the accident

The Portuguese-flagged tanker WEICHSELSTERN anchored in the Neue Weser Nord Reede roadstead on 18 August 2016. The ship was in ballast and waited there for a new assignment. The WEICHSELSTERN is a chemical and products tanker.

A north-east wind of 2 Bft prevailed. The sea state and swell were correspondingly low.

The following description of the course of the accident is based on the accounts of the second engineer officer (hereinafter referred to as 2<sup>nd</sup> Eng) and of the third engineer officer (hereinafter referred to as 3<sup>rd</sup> Eng), who were interviewed by the BSU's investigators. Entries in the deck log book, in the engine log book, as well as in the engine room's electronic alarm log were also referred to.

Operation of the WEICHSELSTERN's machinery in the roadstead was carried out without a watch. They switched to this mode in the evening of 14 August 2016. A final check of the engine room was carried out regularly at 2200 since then to prepare the machinery for the night. This usually took between 30 and 60 minutes. Responsibility for this check alternated between the 2<sup>nd</sup> Eng and the 3<sup>rd</sup> Eng on a daily basis.

The 2<sup>nd</sup> Eng performed this check on the day of the accident. He reported in to the bridge by phone for this purpose at 2200. Just before the 2<sup>nd</sup> Eng intended to leave the engine room (he had already reported in to the bridge with notification of this at 2300<sup>2</sup>) an alarm sounded for the combined boiler installation. There were two boiler<sup>3</sup> installations on board and only this one was in operation at the time. The 2<sup>nd</sup> Eng acknowledged the alarm and notified the bridge about his continued stay in the engine room at 2305<sup>4</sup>.

At this point, the combined boiler installation was fired with marine diesel oil (MDO) and operated in automatic mode. In this mode, the boiler's burner starts when the steam pressure falls below a certain level and stops automatically when a pre-set level is reached. "*Between these two limits the burner's output is controlled by the compound*

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<sup>2</sup> According to the entry in the engine log book.

<sup>3</sup> The second installation is an auxiliary boiler operated exclusively by oil burner.

<sup>4</sup> According to the entry in the engine log book. According to the entry in the bridge's watch log, this report was made at 2240.



regulator, which regulates the fuel flow and simultaneously adjusts the flow of air supplied. The steam pressure is the compound regulator's control variable."<sup>5</sup>

The monitoring system registered the alarm as **Comb. Boiler Burner Stop 222943 (ON-Time)** (see Figure 3). A signal light on the switch cabinet was triggered and identified this alarm as a *Flame Failure*. The 2nd Eng acknowledged the alarm at **223101 (OFF-Time)**, when he pressed the reset button. This reset the boiler's control system and cleared all alarms (Figure 6). A system restart would not have been possible before this happened. The 2<sup>nd</sup> Eng then went to the boiler to check the condition there. A flame was not visible anymore through the boiler room's sight glass. He then returned to the engine control room (ECR) and phoned the 3<sup>rd</sup> Eng to ask about the boiler's last service because the boilers fell within the latter's area of responsibility. The 3<sup>rd</sup> Eng was also asked to go to the ECR.

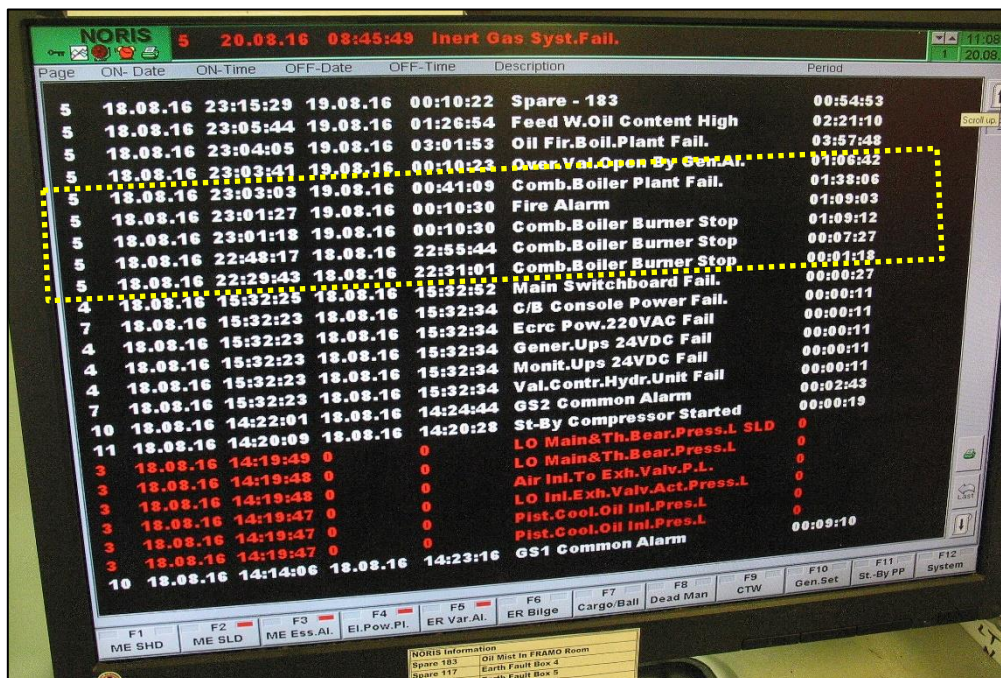


Figure 3: Alarms displayed for the combined boiler

<sup>5</sup> Buro, Norbert: Analysis of the fire on the MT WEICHSELSTERN (marine casualty) on 19 August 2016 in the outer roads at Emden, page 5, 18 July 2017 (referred to below as boiler opinion). See Annexes to the report on the BSU's website for the complete opinion.

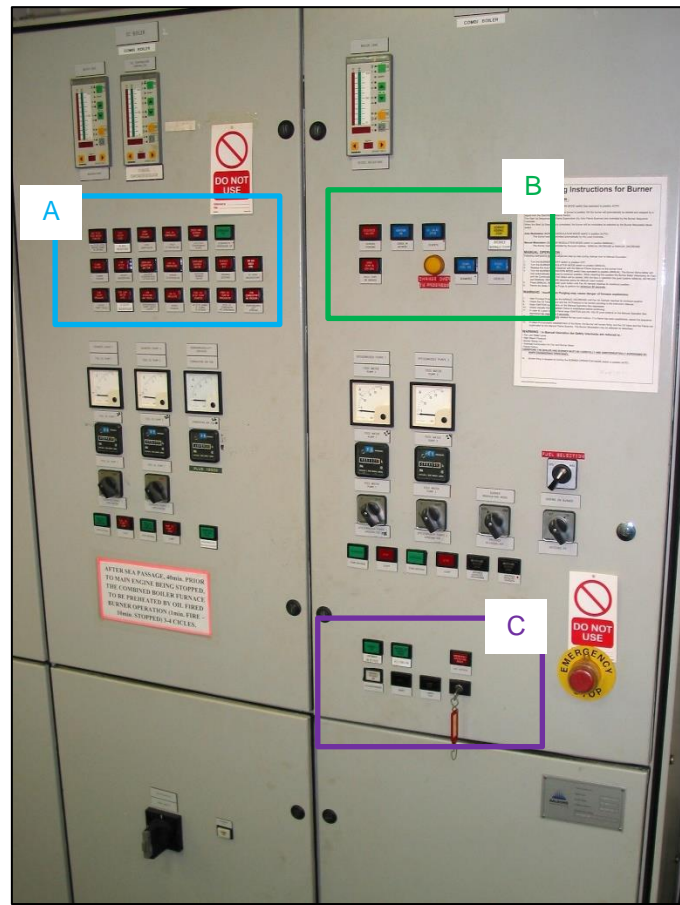


Figure 4: Combined boiler's switch cabinet  
 Control and switch areas (A, B and C)



Figure 5: Area A: Alarm panel (extracted from Figure 4)  
 Flame Failure/Flamme Störung indication outlined in yellow.



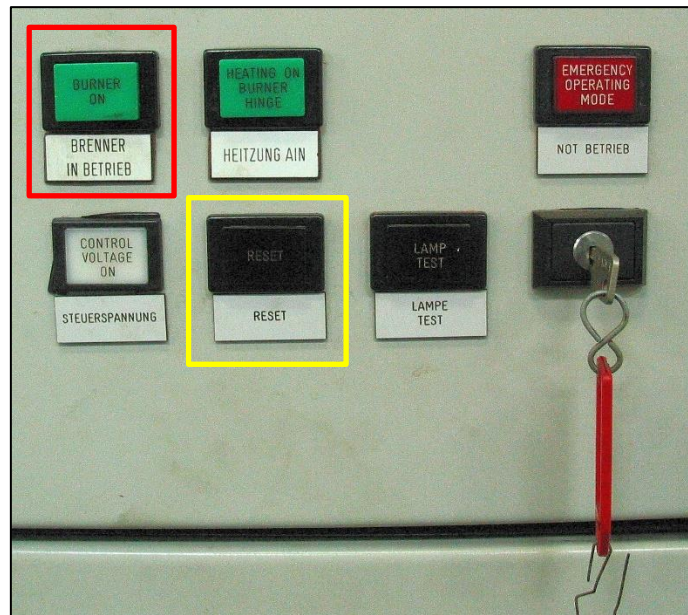


Figure 6: Area **B**: Reset button and Burner On/Brenner in Betrieb button within the panel

The 3<sup>rd</sup> Eng entered the ECR shortly after. Both engineers then went to the boiler and checked the two flame monitoring sensors and the ignition burner with the burner door already opened. The ignition burner was pulled out of the guide tube for this purpose. No contamination or damage was found, so the ignition burner was reinstalled in the guide tube and the burner door closed.

The boiler was then started automatically in the ECR. This involved pressing the *Burner On* button. The 2<sup>nd</sup> Eng stated that the main burner's *Ignition On* indicator light failed to illuminate afterwards.

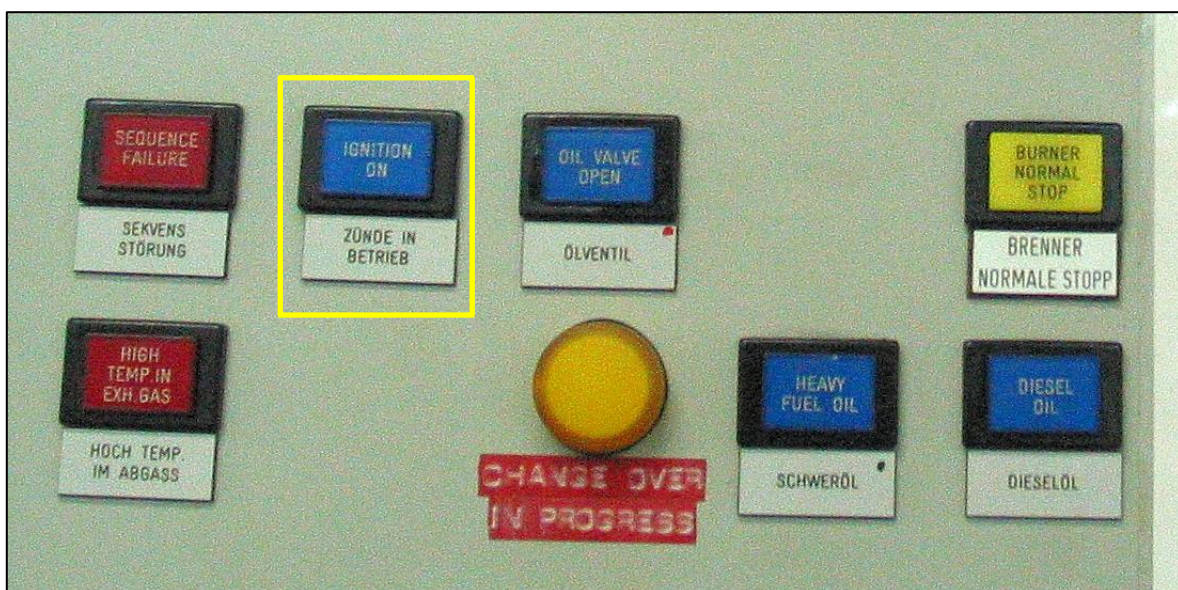


Figure 7: Area **C**: Ignition On/Zünde in Betrieb indicator light outlined in yellow

Due to the sequence of alarms, the investigators assume that the two engineers were still in the ECR during this start-up procedure. The next alarm was triggered with the same indication at **224817**. This alarm was reset at **225544** (see Figure 3) and may have been caused by the absence of the ignition.

The investigators also assume that the engineers carried out a second automatic start-up shortly afterwards, contrary to the information given by the two witnesses. This is supported by the alarms recorded. The two of them went to the boiler after the start-up to monitor the start-up procedure directly at the burner. The pre-aeration process had not finished when they arrived. The ventilation flap then closed slowly. The two individuals positioned themselves in front of the burner. The 3<sup>rd</sup> Eng was standing to the right behind the 2<sup>nd</sup> Eng when the latter bent down to the burner's shut-off valves to check them. The burner door flew open unexpectedly at this very moment and the burner's remaining flame first swept over parts of the engine room located to the left of the boiler and then over the two engineers. The **Comb. Boiler Burner Stop 230118 ON-Time** alarm was generated in the monitoring system when the door flew open. This was followed by the **Fire Alarm** at **230127**.

In particular, the 2<sup>nd</sup> Eng was seriously injured by the flame. The less affected 3<sup>rd</sup> Eng hurried to the engine room to press the emergency-stop there. He then informed the chief engineer officer. In the meantime, the 2<sup>nd</sup> Eng started to extinguish a fire in the area around the burner door caused by the flame emission with hand fire extinguishers. In particular, the electrical cabling had caught fire. The 3<sup>rd</sup> Eng came to his assistance later. Due to the heat and fact that the fire extinguishers had to be obtained from different parts of the engine room, they fought the fire alternately. They used seven extinguishers to extinguish the isolated fire.

Crew members who had hurried to the scene then gave the two engineers initial medical care. The master contacted the Telemedical Maritime Assistance Service in Cuxhaven to obtain support in the treatment of burn injuries. The latter evidently referred him to the Maritime Rescue Coordination Centre (MRCC) in Bremen, which the WEICHSELSTERN's master then called directly at 0017 on 19 August 2016.

Since there was no emergency physician available for the helicopter stationed on Heligoland, the MRCC cancelled its deployment and a helicopter from Northern HeliCopter GmbH and emergency physician was deployed. This helicopter took off from the island of Baltrum at 0107 and reached the ship at 0127. After the two casualties were taken on board at 0200, the helicopter flew them to a special hospital in Hamburg. The ship remained in the roadstead.

## **2.2 Findings of the investigation**

### **2.2.1 Boiler installation**

The boiler installation on the WEICHSELSTERN connected with the accident is a combined boiler installation. Accordingly, the steam required on board can be generated by exhaust gases directed through the boiler when the main engine is in operation. If there is not enough exhaust gas or if the main engine is not running, the necessary heat can be generated by means of a burner operated with heavy fuel oil (HFO). The boiler installation and the burner are manufactured by Aalborg Industries<sup>6</sup> (designation: Mission OC). Saacke GmbH converted the installation (or burner) in 2012 to provide the additional option of operation with MDO for SECA<sup>7</sup> areas. The former classification society, Germanischer Lloyd (GL), had approved the conversion earlier and inspected/accepted it after completion in October 2013. The ship's current classification society, ABS, surveyed the boiler installation in October 2014. The boiler installation was surveyed again in January 2016 as part of the annual survey of the machinery. All surveys were completed without any anomalies.

The owner submitted two maintenance reports (June 2016 and July 2016). They did not contain any indication of irregularities found.

The combined boiler is installed vertically. The basic design is shown in Figure 8.

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<sup>6</sup> Aalborg Industries has been part of Alfa Laval – Marine Boilers & Heaters since 2011.

<sup>7</sup> SECA: Sulphur emission control area.

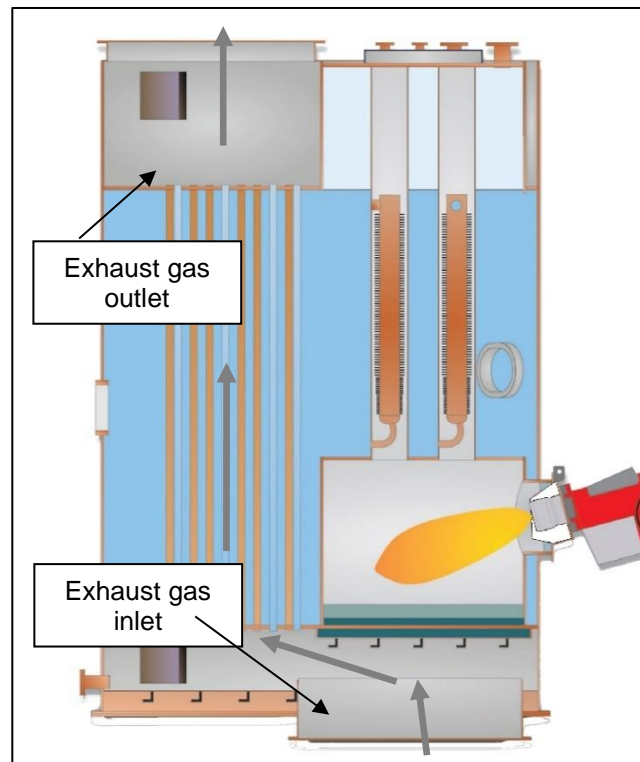


Figure 8: Schematic of the combined boiler installation<sup>8</sup>

In burner operation, the supplied fuel is finely sprayed by the rotation of a rotary atomiser burner and an air nozzle, mixed with air (primary air), and blown into the combustion chamber. A separate ignition burner is responsible for ignition. This is also supplied with fuel (diesel), which is ignited electrically. To achieve optimum combustion, a blower forces more air (secondary air and tertiary air) through the windbox into the combustion chamber, where it is swirled on entry by a swirler (a ring with fan-shaped plates). The amount of air is controlled by an actuating system and the controlled amount of fuel injected thus adapted (see also Figures 9, 10 and 11).

*"The combined boiler's controls are implemented via a programmable logic controller from Messrs Telemecanique (TSX 17) and located in the ECR in two switch cabinets with the separately installed electrical safety system. With the exception of manual operation (emergency operation), this provides a control option for switching the burner on and off, acknowledging faults and other processes, as well as setting limits for starting/stopping the burner in the ECR, inter alia [...]."*<sup>9</sup>

<sup>8</sup> <https://www.alfalaval.de/produkte/waermeuebertragung/heizkessel/oel-gasbetriebener-dampfkessel-fuer-verbundstoffe/aalborg-oc/>, retrieved 15 October 2019.

<sup>9</sup> Boiler opinion, page 6.



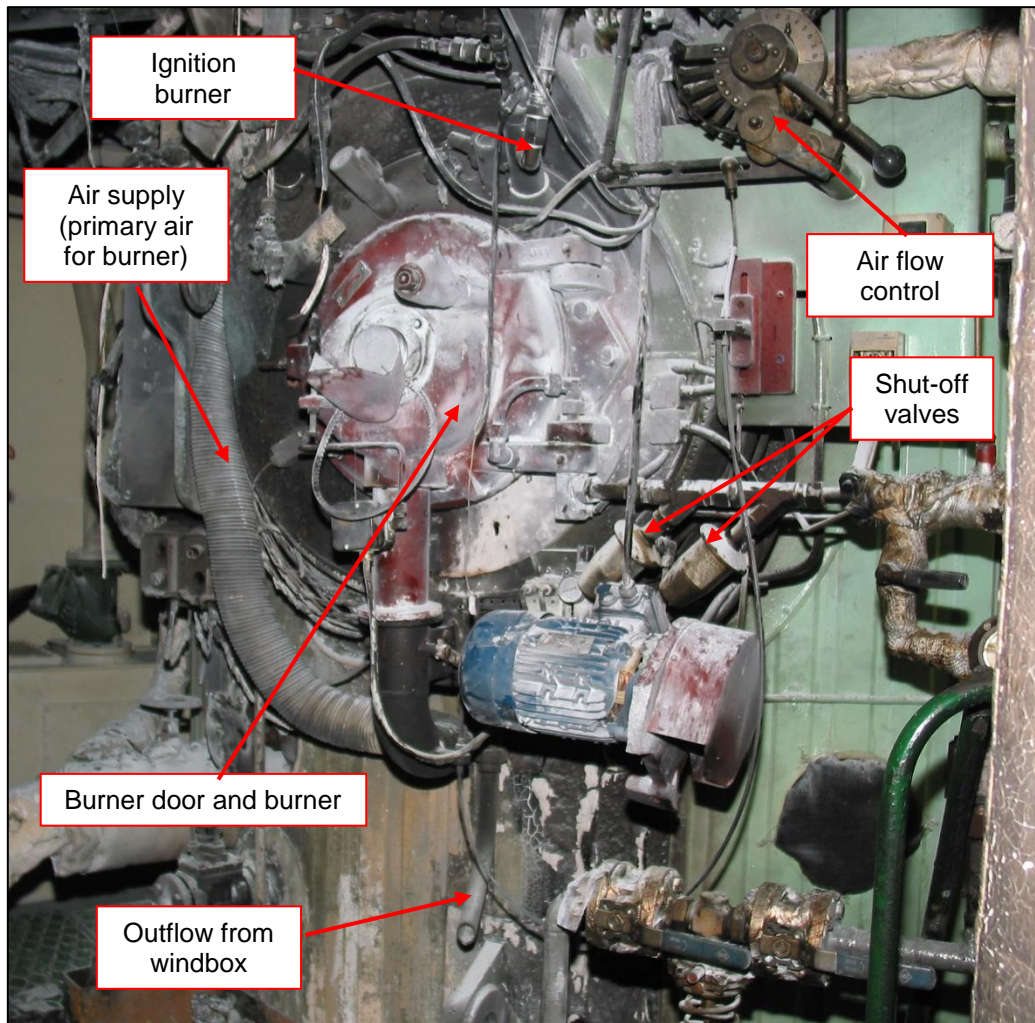


Figure 9: Combined boiler and its burner

The electric motor for driving the rotary atomiser burner is torn off and hanging in front of the burner door on a cable.

The automatic firing process takes place in pre-programmed stages. It begins with purging the combustion chamber by means of the blower with all control butterfly valves fully open. The control butterfly valves are closed when purging has finished and the ignition burner is then started. This is used to ignite the fuel-air mixture produced by the rotary atomiser burner in the combustion chamber. The ignition burner is switched off after ignition of the main burner. In a further step, all air flows and the amount of fuel are increased.

The burner in this boiler installation is monitored by a flame failure device for the main flame. An additional emergency operation flame sensor is provided for the main flame. The flame sensor (for the ignition burner flame) originally intended for operation with MDO could not be installed due to the structural conditions. The system was nevertheless approved by GL and not objected to during the surveys carried out by the new classification society, ABS.



An electric motor located outside the combustion chamber causes the rotary atomiser burner to rotate via a toothed belt. Primary air is supplied via a movable armoured hose. The whole assembly forms a kind of door, which can be moved by a hinge on the right and opens almost 180°, then making it possible to look inside the combustion chamber. The door is secured by means of a lock. A control switch monitors the locked door when the burner is in operation. The two electro-pneumatic valves located in the fuel supply line close immediately when the door is opened. According to information given by the manufacturer, it takes the valves less than one second to close.

There are other safety devices in addition to those already discussed. They concern boiler water level, fuel, and air supplied, for example. Since they are of no significance to the event discussed here, they have not been described further.

The combustion chamber is also equipped with a window through which an external check or assessment of the main burner's flame can be made.

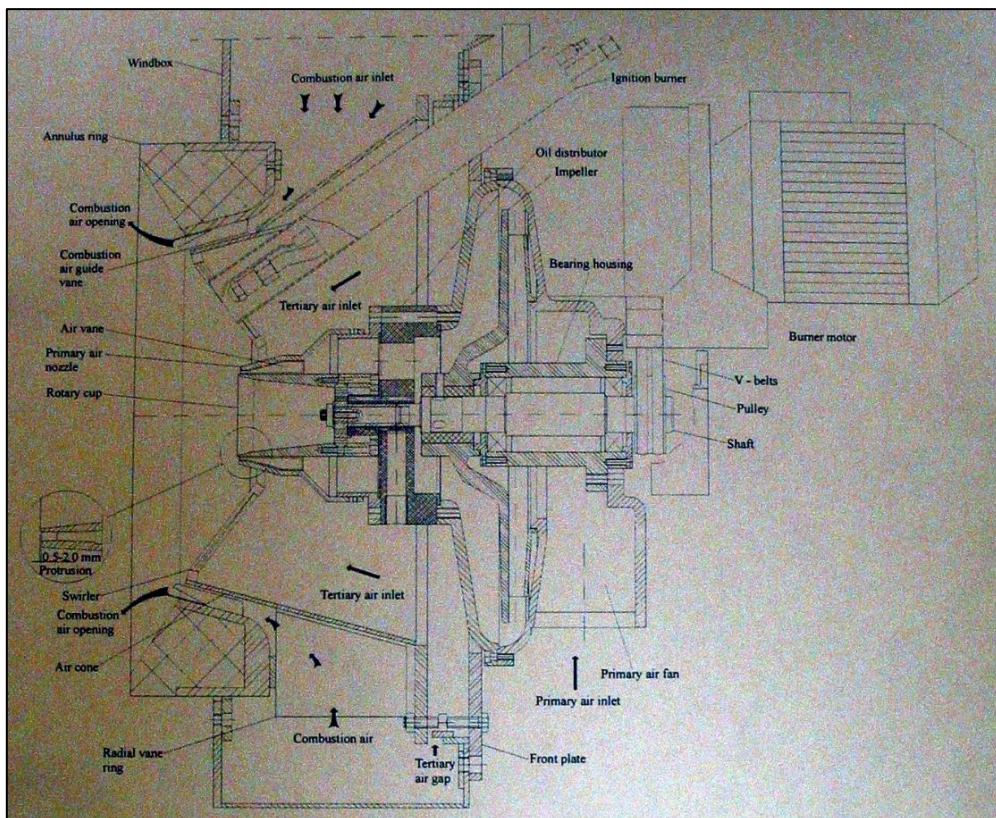


Figure 10: Basic design of burner, windbox and air supply<sup>10</sup>

<sup>10</sup> Taken from Aalborg Industries SD5590#01.0.

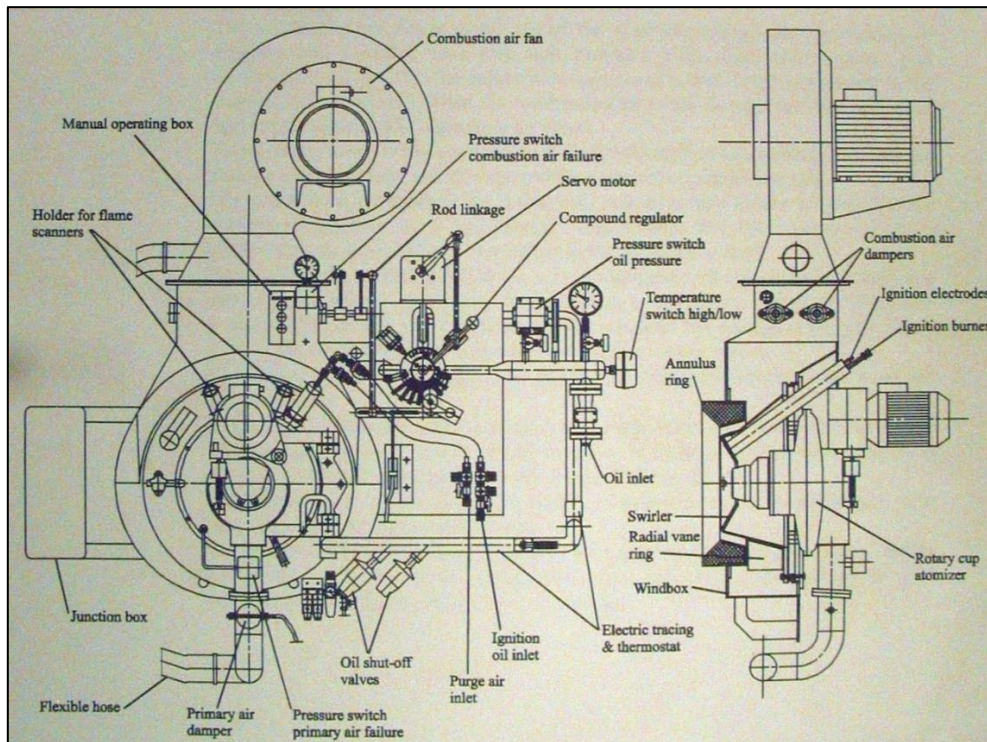


Figure 11: Rotary atomiser burner and associated components<sup>11</sup>

## 2.2.2 Investigations on board

The event was brought to the notice of the BSU on the morning of 19 August 2016 via Maritime Security Centre Cuxhaven's daily situation report. Following a corresponding request, Waterway Police (WSP) Wilhelmshaven advised that a patrol boat is reportedly proceeding to the WEICHSELSTERN to gather preliminary information. A survey of the WEICHSELSTERN was arranged and carried out with the extremely cooperative ship's management at the roadstead on 20 August 2016. Prof. Dr.-Ing. Buro offered his services to the BSU at short notice as an expert. He took part in the survey of the ship.

During the survey on board, the conditions in the ECR and engine room were inspected in the combined boiler's report. The engine room's crew demonstrated the usual procedure for starting the burner. The visible condition of the boiler installation and the fire damage were documented and investigated.

## 2.2.3 Burner door locking mechanism

It was found during the investigation that the burner door's locking mechanism was broken. "*The burner door is locked mechanically by a rotatable hook mounted on the boiler, which includes a bolt in the burner door [Figure 14]. The hook also comprises a locking screw with hand wheel, which creates a frictional connection between the hook and bolt.*"<sup>12</sup> The fragment of the door's locking mechanism was found. The BSU secured the entire door locking mechanism. As can be seen in Figure 12, the hook had been welded.

<sup>11</sup> Ibid.

<sup>12</sup> Boiler opinion, page 6.

To assess the starting material and quality of the welding, Prof. Dr.-Ing. Müller was requested to provide an opinion. The following tests were carried out in connection with the opinion<sup>13</sup>:

- a) direct visual inspection in accordance with DIN EN ISO 5817 (2014-06);
- b) assessment of the welded joint in accordance with DIN EN ISO 5817 (2014-06);
- c) chemical analyses of the base material and weld metal;
- d) examination of the fracture surface;
- e) microsectioning and metallographic testing, and
- f) hardness tests in accordance with DIN EN ISO 9015-1.

The expert's findings include:

- a) *"A welded joint can be found in the connecting piece between the pivot joint and hook. There is a clear difference between the colour of the weld metal and that of the base material, indicating that the filler metal is dissimilar. The fracture is located at the edge of the welded joint. The crack edges show no macroscopic evidence (e.g. vibration grooves) of a vibration fracture. Rather, the macroscopic formation of the crack edges indicates a forced fracture, [...], where it becomes clear that the filler metal surrounds the base material in a ring shape."*<sup>14</sup>
- b) *"If these criteria are used for the assessment [...], then the welded joint does not satisfy even the lowest requirements of this standard.<sup>15</sup> As Figure [...] shows, filler metal has been deposited on the head of the pivot joint during welding, supporting the assumption that it was installed when the weld was applied."*<sup>16</sup>
- c) *"Since the base material and the weld metal each exhibit different colouring, they have both been analysed. The chemical analyses were performed in accordance with SLV-AA WT011:2014. The chemical analysis shows the typical composition of grey cast iron with relatively low levels of sulphur and phosphorus."*<sup>17</sup>
- d) *"The high level of nickel in measurement 1 clearly indicates the use of a nickel-based filler metal, as used for 'dissimilar welding' (formerly also referred to as cold welding). Measurement 2 is conspicuous, however."*

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<sup>13</sup> Müller, Lutz: Technical opinion for the BSU (welded joint on a grey cast iron part), 2016 (referred to below as welding opinion). See Annexes to the report on the BSU's website for the complete opinion.

<sup>14</sup> Ibid., pages 2-3.

<sup>15</sup> DIN EN ISO 5817 (2014-06).

<sup>16</sup> Ibid., page 3.

<sup>17</sup> Ibid., page 4.



*The ratio of the elements carbon and nickel cannot be explained so clearly by a mixture of base material and filler metal. It is possible that a highly ferrous filler metal with only low levels of nickel was used at certain points in the repair."*<sup>18</sup>

- e) *"Figures [...] show the crack edge fracture surfaces. The crack surface clearly shows the pattern of a violent fracture. No evidence of vibration cracking could be found. Moreover, it is clear that the weld metal surrounds the base material as a ring. In some places a thin layer forms between the filler metal and base material [...] and in other places slag inclusions have collected in this area [...]."*<sup>19</sup>
- f) *"To interpret the structure over the welded joint and to measure the hardness, the latch was cut lengthwise. Figure [...] gives an overview of the weld area (light base material and dark filler metal). Another crack is visible in the left part of the figure. Moreover, it becomes clear that edge preparation is substandard and the weld metal has a significant reinforcement. A general view of the weld metal reveals that very different structural areas are formed by mixing base metal and dissimilar base metal [...]. However, the type and quantity of the structures forming depends not only on the chemical composition but also on the thermal conditions during welding."*<sup>20</sup>
- g) *"[...] extremely different hardness levels have formed around the melting bond lines. For example, the transition to the weld metal containing high levels of nickel exhibits only moderate hardness levels over the entire area [...]. This is different in the area where martensite and residual austenite have formed [...]. Hardness levels well in excess of 500 HV are measured here, which explains the hardening cracks. The levels measured correspond to the structural formations identified in the micrograph."*<sup>21</sup>

Prof. Dr.-Ing. Müller summarises:

*"The welded joint was welded with a filler metal containing high levels of nickel. The execution of the weld (end crater, notches in the seam transition) can only just be classified to Group D (no weld seam quality requirements) according to DIN EN ISO 5817 (2014-06), for example. This also applies to other assessment guidelines.*

*The crack edges do not exhibit the characteristics of vibration cracking but rather those of a brittle fracture.*

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<sup>18</sup> Ibid., page 5.

<sup>19</sup> Ibid., page 6.

<sup>20</sup> Ibid., pages 6-7.

<sup>21</sup> Ibid., page 8.

*As the micrographs indicate, brittle structures (ledeburite, martensite, hardness levels in excess of 550 HV) have formed in the seam transition area as a result of the thermal conditions under the selected welding conditions. This means that the heat-induced stresses cannot be compensated for when the welded joint cools down, causing cracks to form.*

*On the other hand, hot cracks have formed in the nickel filler metal, which are caused firstly by low-melting eutectics that form on the grain boundaries of these materials and secondly by the heat-induced tensile stresses.*

*The improperly welded joint must be regarded as the cause of the component's failure. In addition to substantial external irregularities, it also exhibits internal defects (hardening structure with cracks, stress-induced hot cracks). Moreover, nickel alloys have lower strengths than the base material, cast iron.*

*Accordingly, it is reasonable to assume that when viewed in its entirety this deficiency has severely limited the welded joint's load-bearing capacity."<sup>22</sup>*

The crew stated that none of its members on board had carried out welding work on the door's locking mechanism. It was not possible to establish when the welded joint was produced.

With regard to the door's locking mechanism, it was also found that the original bolt, which is the mating part of the hook on the burner door (Figure 15), had been replaced by a threaded rod on the WEICHSELSTERN. It was not possible to establish the reason or when this happened, either. However, the investigators believe that the replacement did not restrict functionality or safety.

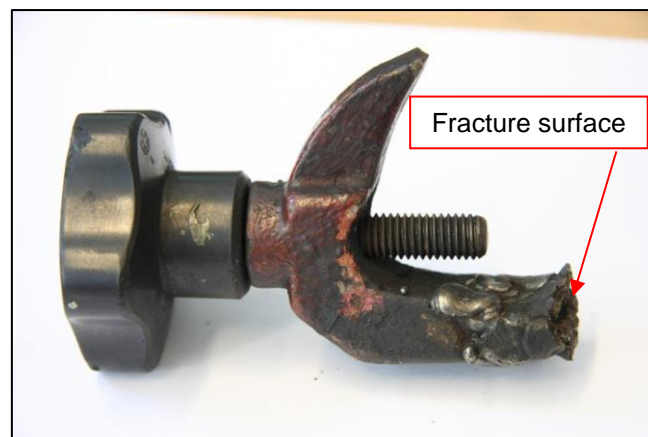


Figure 12: Broken hook from the door's locking mechanism

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<sup>22</sup> Ibid., pages 9-10.



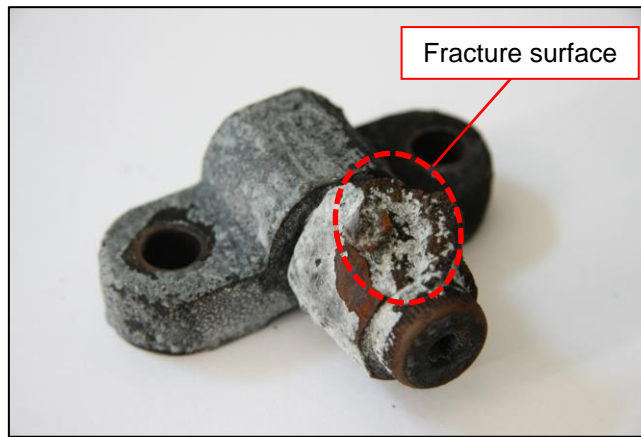


Figure 13: Mating part previously mounted on the boiler (Figure 15)

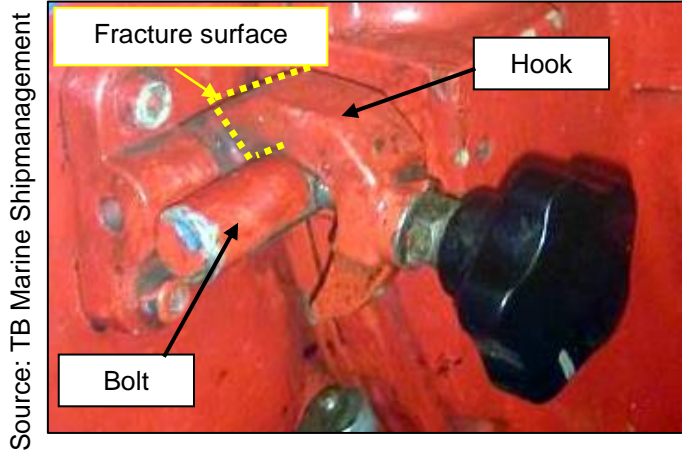


Figure 14: Similar component from a sister ship

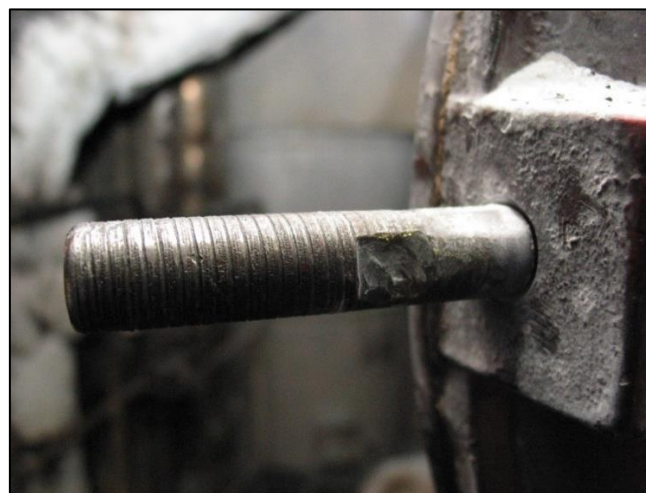


Figure 15: Bolt from the door's locking mechanism

#### 2.2.4 Findings with regard to the windbox and the burner

During the survey of the windbox (Figures 10, 11 and 16) it was found that the ignition burner was not fully inserted into its guide tube (Figure 16). The ignition burner is usually secured in the guide tube with a wing screw. During the investigation it could

not be conclusively determined whether the ignition burner had been pushed about 5 cm out of its actual position, and if so, which event was responsible for this.

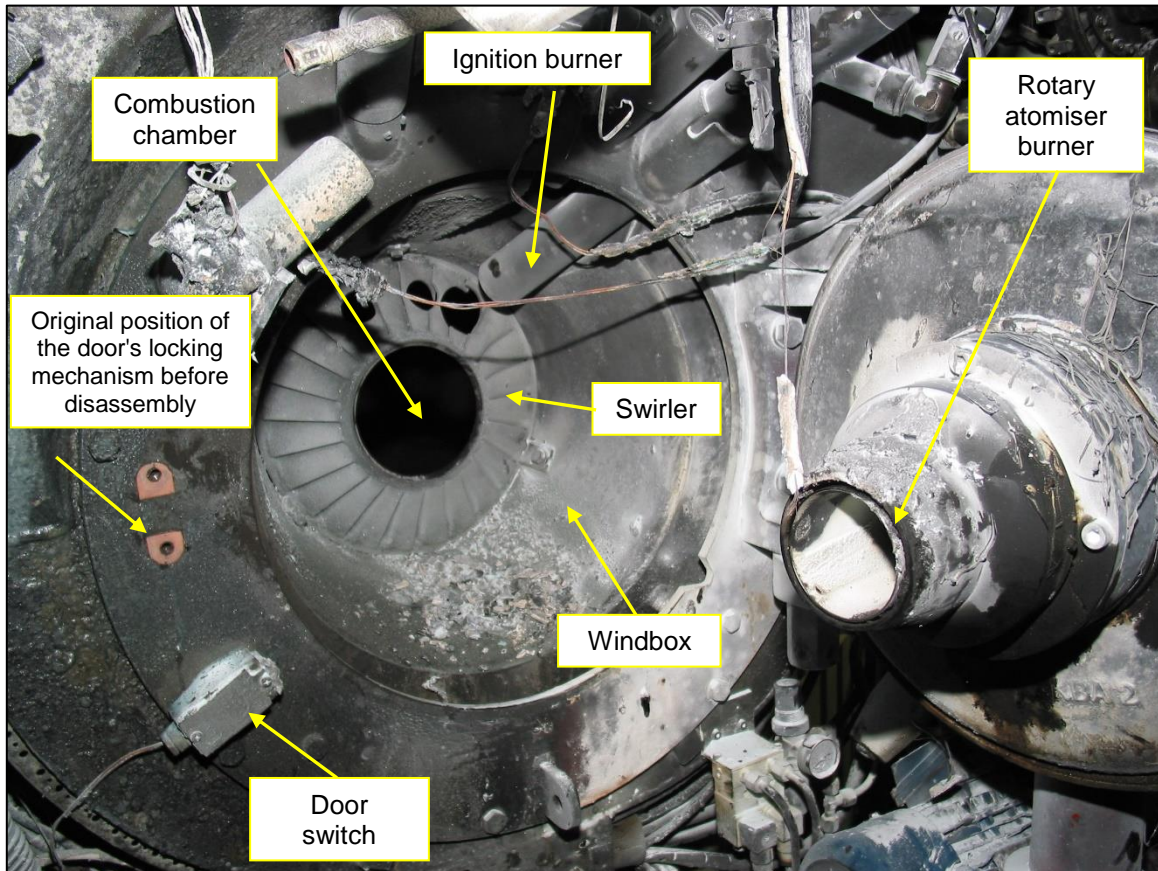


Figure 16: Burner door with rotary atomiser burner and windbox

To gain better access to the combustion chamber, the swirler was disassembled. After removal it was found that there was a substantial amount of MDO in the lower part of the windbox (Figure 17).



Figure 17: Fuel in the windbox



It was not possible to drain the fuel via the drain pipe at the bottom of the recess provided for this purpose (see Figure 9) to begin with because the shut-off valve was extremely stiff and the entire pipe was clogged with HFO residues. The amount of fuel found was determined to be about 2 litres.



Figure 18: Fuel drained from the windbox

Expert Prof. Dr.-Ing. Buro notes the following about this in his report:

*"The source of this quantity was discussed with the boiler's manufacturer (Aalborg Industries) and the company that made the conversion (Saacke) and the following possible causes were mentioned:*

- a) *incorrectly installed ignition burner;*
- b) *worn protective tube on the ignition burner;*
- c) *precipitating oil mist due to incorrect flame control;*
- d) *low pressure in the engine room may cause flame recirculation;*
- e) *leaking electro-pneumatic fuel valves.*

*Aalborg believes causes b), c) and d) are rather unlikely, which is a reasonable assumption. Cause a) is only feasible when no ignition flame is produced, which cannot be excluded due to the lack of a flame failure device for the ignition burner. If the rotary atomiser were not rotating, then cause e) would lead to an ingress of fuel which could accumulate both on the bottom of the boiler and in the windbox.*

*The electro-pneumatic fuel valves were therefore tested for leak tightness for 15 minutes at a static pressure of 16 bar after the accident. No leakage was found. Nevertheless, MDO can still enter via the rotary atomiser even with tight fuel valves, as diesel can still enter the boiler in the outlet of the rotary atomiser. This is no longer atomised and can run outwards over the edge of the cup and into the rear of the*

*windbox. A large number of switch-off procedures can thus cause a lot of diesel to accumulate in the windbox. This danger hardly exists in the case of HFO on its own due to the significantly lower fluidity.*

*Leaking rotary atomiser connections are another possible source of the MDO. Oily surfaces were found on the burner's rear wall in the area of the pipe fitting. Consequently, the latter two alternatives are the most likely cause of the MDO in the windbox."<sup>23</sup>*

The investigation failed to clarify for how long the fuel had accumulated at this point but the clogging found in the drain pipe indicates that this condition has persisted for quite some time. The two maintenance reports submitted for the boiler installation for the months of June and July did not provide any further information.

The BSU's investigators assume that the burner door flew open with some force. This can be inferred from the electric motor for driving the rotary atomiser burner breaking off (see Figure 9). The combustion chamber's excess pressure is usually in the range of 8-20 mbar. Higher pressures may occur for a short period during the burner's ignition process. The manufacturer has no measurements for this, however.

The investigators also assume that the flame of the burner had formed. This is indicated by the injuries of the two engineers and fire damage in the area where the burner door opens/closes. The investigators are of the opinion that although the fuel supply was switched off immediately upon opening, the fuel in the line to the burner continued to feed the flame for a longer period (one or two minutes) because the burner continued to run.

It was not possible to examine in detail the steps taken when starting the burner or to determine the time at which the error message occurred during the start-up procedure. *"This would have required logging of the individual ignition steps (data acquisition) and a flame failure device for the ignition flame, neither of which are available in this installation."<sup>24</sup>*

During the investigation, the Alfa Laval plant in Aalborg was also surveyed and certain findings made in the course of the investigation on board were discussed in the process. It was thus possible to clarify that the shape of the swirler's fans (a rounding of the fans was detected) had occurred during the production process and was not the result of an explosive event in the combustion chamber. The manufacturer stated that the hooks on the door's locking mechanism are still made of grey cast iron. The BSU's concerns with regard to the brittleness of the material used as compared to steel was understood. When asked about this, the classification society, DNV GL, stated that the mechanical design of the burner is the sole responsibility of the manufacturer.

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<sup>23</sup> Boiler opinion, pages 10-11.

<sup>24</sup> Ibid., page 7.

### **2.2.5 Crew**

The 2<sup>nd</sup> Eng's assignment on the WEICHSELSTERN started on 11 July 2016. It was his first contract on this ship. He has served on tankers as 2<sup>nd</sup> Eng since 2011. From 2007 to 2011 he was contracted to serve on tankers as 3<sup>rd</sup> Eng and therefore had a detailed knowledge of the operation of boiler installations from this period, as they formed part of his area of responsibility at the time.

The 3<sup>rd</sup> Eng started his service on the WEICHSELSTERN on 8 August 2016. He was trained by the chief engineer officer when he started work. The 3<sup>rd</sup> Eng stated that he served as an able seafarer engine to begin with after a three-year apprenticeship. According to the documents submitted, he has signed contracts as 4<sup>th</sup> and 3<sup>rd</sup> Eng from 2007 onwards and for the most part been employed on tankers. During this period, he also served on a sister ship from September 2012 for about five months.

The hourly time sheets submitted for the two engineers showed no evidence of fatigue.

### **2.2.6 Actions taken**

The owner took wide-ranging measures after the accident. For example, a separate investigation into the cause of the accident was carried out with the involvement of the manufacturer of the boiler installation and all similar boiler installations were inspected with the involvement of service companies. All safety equipment was inspected in this context and renewed or readjusted if necessary. In addition, the descriptions of maintenance works were expanded upon and completed. This also includes checking the drain pipe belonging to the windbox.

Due to the extensive measures taken by the shipping company, the BSU was able to dispense with safety recommendations.



### 3 CONCLUSIONS

Expert Prof. Dr.-Ing. Buro summarises:

- No evidence of an explosion was found during the survey of the combustion chamber, the windbox and the other burner components. *"Assuming the MDO had already been in the windbox for an extended period, an explosion at precisely the same moment as the accident also seems rather unlikely. Consequently, although the issues of poor maintenance and checks may be noted, it is hardly likely that they caused the accident."*<sup>25</sup>
- The expert is of the opinion *"[...] that the accident would have been avoided if the hook in the lock had not been damaged beforehand. The pressure pulse generated during ignition was sufficient to exceed the number of load cycles of the damaged hook's fatigue strength, which would not have been the case with an undamaged hook."*<sup>26</sup>
- *"The boiler's manufacturer has allowed for various safety interlocks but failed to check their efficacy. For example, although a system for interrupting the fuel supply is installed (electro-pneumatic double valve), fuel is still being burnt for one to two minutes after the valves have been closed for one second (oral statement by Aalborg Industries). There is still sufficient fuel in the line between the double valve and rotary atomiser, which is burnt in the rotary atomiser as it comes to a halt. A significant reduction of this residual combustion time can be achieved initially by placing the double valve closer to the rotary atomiser, thus reducing the amount of residual fuel available."*

*Another important aspect is the stopping time of the rotary atomiser, which is determined by the kinetic energy of the drive train or its mass moments of inertia. One effective measure here would be the installation of a motor brake that brings the drive to a quick standstill. These measures would reduce the residual combustion time."*<sup>27</sup>

- *"The conversion of the boiler for diesel operation, too, does not take into account the fact that unlike HFO, MDO can enter the windbox more easily when the rotary atomiser comes to a halt."*<sup>28</sup>
- *"A structural evaluation of the lock on the burner door reveals deficiencies in safety. The door is held by only one lock (the hook) and there is no back up if this lock fails. Furthermore, the hook in the lock is made of grey cast iron and therefore more susceptible to damage than ductile steel."*<sup>29</sup>
- *"The boiler is equipped with a flame failure device but this only monitors the main flame and not the ignition flame. This makes it possible for diesel oil to enter the boiler unnoticed via the ignition burner, thus increasing the risk of a boiler explosion."*

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<sup>25</sup> Boiler opinion, page 11.

<sup>26</sup> Ibid., page 11.

<sup>27</sup> Ibid., page 12.

<sup>28</sup> Ibid., page 13.

<sup>29</sup> Ibid., page 12.

*This safety deficiency has not only existed since production of the boiler but was not remedied even during the conversion to MDO operation. Rather, both classification societies, GL and ABS, accepted this condition."*<sup>30</sup>

- *"Automatic operation of the boiler and its status displays is controlled from the ECR. Labelling for the controls and displays there is not always clear and can lead to incorrect operation, especially in emergency situations. This applies all the more so if frequently changing operating personnel are expected."*<sup>31</sup>

The established facts suggest that the combined boiler installation was operated in the normal and proper manner at the time of the accident. The installation was operated in automatic mode, meaning the engineers present were not handling the controls at the time of the accident. It is highly unlikely that the burner door flew open due to an extraordinary event such as an explosion within the boiler. The investigators believe it far more likely that the normal ignition process and associated slight increase in pressure caused the welded joint on the burner door's locking mechanism to fail at this point in time. As discussed in the welding opinion, the amateurishly welded joint did not meet the minimum requirements for such work.

The rotary atomiser's stopping time (or the continued flame after the door is opened despite the associated shutdown of the fuel supply) was consistent with specifications and complies with current technical regulations. Nevertheless, improvements could be achieved here due to the modifications identified by the expert. This would also increase safety if the burner door were opened quickly and intentionally.

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<sup>30</sup> Ibid., page 12.

<sup>31</sup> Ibid., page 13.

## **4 SOURCES**

- Prof. Dr.-Ing. Buro: Analysis of the fire on the MT WEICHSELSTERN (marine casualty) on 19 August 2016 in the outer roads at Emden. Opinion on behalf of the BSU, 18 July 2017
- Prof. Dr.-Ing. Müller: Technical opinion for the BSU (welded joint on a grey cast iron part), 2016
- WSP Wilhelmshaven's investigations in connection with the investigation file of the Oldenburg Public Prosecutor's Office
- Statements of the owner, of Alva Laval Aalborg – Marine Boilers & Heaters, and of Saacke
- Testimony of the crew
- Technical documentation for the combined boiler installation
- Documents and statements of the classification society DNV GL and documents of the classification society ABS

## **5 ANNEXES**

The two opinions drawn up in German on behalf of the BSU in connection with the investigation of this case can be downloaded from the BSU's website.