Marine Safety Investigation Unit

SAFETY INVESTIGATION REPORT

201801/030 REPORT NO.: 02/2019 January 2019

MV *NEW HAMPSHIRE TRADER*

Boiler furnace blowback and injuries to two crew members about 30 nautical miles from Qingdao Pilot Station
31 January 2018

SUMMARY

The vessel was on a passage from Dalian to Qingdao when the engineering OOW of the watch noticed that the auxiliary boiler was not operating normally and that several alarms had activated.

Although the electrician reset the boiler control system, the fault was not rectified, raising suspicions that the flame detector and the low water level sensor were both faulty. The boiler was restarted with these two sensors deactivated and it worked well for several hours. In the meantime, advice was sought from the boiler manufacturers.

Guidance was received from the manufacturer on what signals need to be checked. The electrician and the second engineer switched off the boiler to check the signals. During their inspection, a boiler furnace blowback occurred, injuring both of them.

The safety investigation concluded that the boiler furnace contained an explosive mixture of fuel and air which was ignited either by the residual heat inside or during a restart attempt by the two crew members.


MV *New Hampshire Trader*

FACTUAL INFORMATION

Vessel

New Hampshire Trader is a 35,708 gt container vessel, built in 2011 and registered in Malta. She is owned by New Hampshire Trader Shipping Ltd., managed by Columbia Shipmanagement Ltd. of Cyprus and classed by DNV GL.

New Hampshire Trader has a length overall of 212.60 m and a moulded breadth of 32.2 m. The vessel has a summer draught of 12.50 m and a summer deadweight of 41,411.

Propulsive power was provided by a Wärtsilä 8-cylinder 8RT-flex68, two-stroke, slow speed diesel engine, producing 25,040 kW at 95 rpm. This drove a single fixed pitch propeller, reaching a service speed of about 22.50 knots.

Manning

New Hampshire Trader's Minimum Safe Manning Certificate required a crew of 15. At the time of the accident, the vessel had a crew complement of 20, mostly Filipino nationals.

The crew members included the master, a chief officer and a chief engineer, two OOW (deck), an electrical engineer and the third engineer. The deck ratings included a bosun, pumpman, two able seafarers (ABs), and three ordinary seafarers (OS). An engine fitter, two oilers, a cook and a messman completed the crew compliment on board the vessel.

The two injured crew members were the second engineer, who was 39 years old and the 30 year old electrical engineer. Both crew members suffered from various injuries, including burns and blisters to their faces and hands.

The second engineer was a Chinese national and had joined the vessel more than one month before the accident happened. He was in possession of the current certificate of competency for four years. He had been with the Company for 22 months, always serving in this rank.

The electrical engineer was a Chinese national. He had just over four years of seagoing experience, with the last three years serving in his current rank. The electrical engineer had been on board for eight months before the accident happened.

Auxiliary marine boiler construction

The auxiliary boiler in question, constructed by Alfa Laval, was oil-fired. The mountings were mainly mounted on the top of the boiler body, allowing for a simple connection to the piping systems on board the ship. The control system provided for a fully automated operation of the boiler and the burner. As shown in Figure 1, the boiler was of a vertical cylindrical design with a shell surrounding a cylindrical furnace, and a convective section consisting of pin tube elements. The maximum design pressure was 9 bars, with a maximum continuous steam capacity of 2700 $kghr^{-1}$.

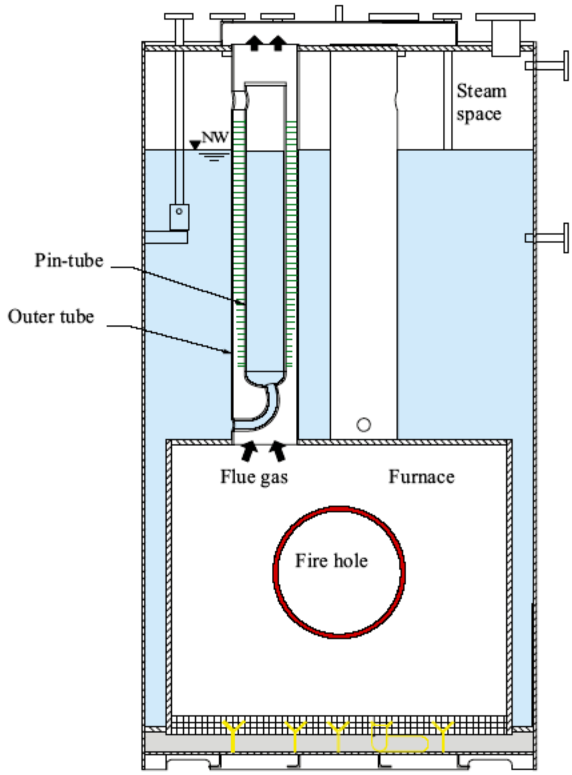

Figure 1: Auxiliary boiler arrangement

The pin tube elements consisted of an outer tube, which enclosed the pin tube. The pin tube was a plain seamless steel tube provided with an inlet pipe at the bottom and an outlet pipe at the top. A significant number of pins were welded around the outside of the tube, creating an extended heating surface to transfer heat from the flue gas to the steam/water mixture in the pin tube.

The furnace floor consisted of a steel plate, protected from heat radiation by a refractory lining. A socket for the draining of washing water was also provided at the furnace bottom.

Water level control

The water level control was an on / off regulating system. The system consisted of one independent safety device electrode for 'too low water level' shut down and 'burner stop'. For the measuring and the controlling of water level, one capacitance level electrode was provided to give water level alarms / shut downs and start / stop signals to the feed water pumps.

Burner firing sequence

The burner was designed to use both heavy fuel oil (FO) and marine diesel oil (MDO). The burner firing sequence was managed by the control system. The sequence was divided into a number of steps, executed one by one. Each step activates outputs and indicators to ensure that the necessary execution and surveillance of these actions had been performed. The burner firing sequence consisted of 13 steps. The first nine steps (0-8) were for the burner start sequence, with steps 10-13 for the burner stop sequence.

As for any boiler, this system was also fitted with a flame safeguard. The flame guard (a photo cell) monitored the flame when the burner was running in manual mode (it had no function when the system was running in automatic mode). In case of a non-ignition or an eventual flame failure, the supply of fuel was interrupted instantaneously.

Environment

At the time of the accident, the weather was clear with a Northeasterly gentle breeze. The air and sea temperature were both recorded at 4 °C.

Narrative

The vessel was performing a coastal passage from Dalian to Qingdao. On 31 January 2018, at around 0400, it was observed that the auxiliary boiler was deviating from the set parameters and several alarms had also activated. The electrician was made aware of the problem.

The electrician reset the boiler's control system, however, upon restart, the alarms reactivated. He checked all the cables and settings but observed nothing abnormal. He did notice, however, that the local panel board was not operating as indicated in the boiler's manual, with several unusual and unrelated lights flashing inside the local panel board. Moreover, it was noticed that one of the relays was continuously energised although he was not sure about the reason behind this.

In an attempt to rectify the situation, the electrician switched on the control panel to manual operation mode (using the switch key). He then proceeded to try and restart the boiler but the several attempts failed to start the boiler. Eventually, the boiler was started but with both the flame detector and the water low level sensor deactivated. The electrician's interpretation of the situation was that either these two sensors were faulty or else it was the electronic system controlling them which was defective.

After the boiler restart, the vessel contacted the boiler manufacturers to report the boiler malfunction and to seek their guidance. In the meantime, the boiler was left running on manual mode from 1300 when it was started successfully, with no abnormalities observed. Later in the afternoon, the manufacturers advised the electrical engineer to inspect the signals being sent by the two by-passed sensors through the boiler digital control panel.

The electrical engineer and the second engineer proceeded to inspect the boiler system as advised by the boiler manufacturers. Prior to the inspection, the boiler was switched off and the alarms reset. The two crew members could recall that at about 1807, while performing the mentioned operation, a furnace blowback happened. The burner housing was forced open. Escaping hot gases and flames injured the two crew members.

Sustained injuries

Both crew members suffered burns to their faces, chest areas and right hands. They were transferred to a hospital ashore, administered medication, and kept in hospital for observations and further specialised treatment. Eventually, their health conditions improved and several days later, they were both discharged from hospital.

Damages to the boiler

The Classification Society (DNV GL) was invited on board to carry out a damage survey. The boiler survey was carried out on 02 February 2018. It was reported that the:

- hinge mounting of the rotary cup burner was cracked and the upper hinge pin house was broken (Figure 2);
- locking pin of the burner house was found broken (Figure 3);
- burner motor was found cracked on the forward end, at the connection plate to the motor housing; and
- the control panel was malfunctioning.

The burner was swung out and the internal side of the furnace was inspected. No damages, deformation or cracks were sighted. The boiler's exhaust gas side was also checked and found in order.

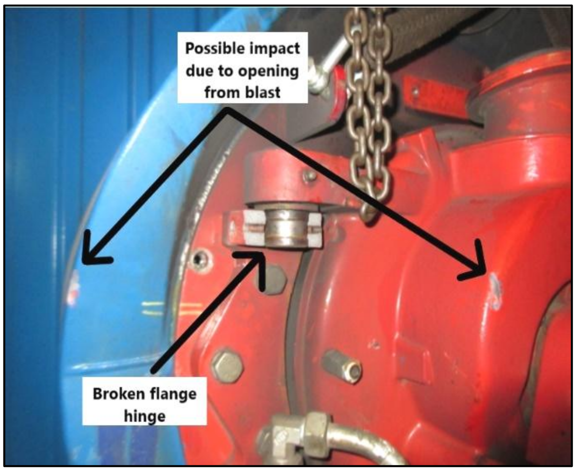

Figure 2: Cracks to the mounting and damaged upper hinge

Figure 3: Broken locking pin

On 03 February 2018, an inspection was carried out by one of the manufacturers' service engineers. Further to the damages sustained by the blowback, the service engineer identified a fault in the water level switch and a faulty combustion air flow timer, both within the control system of the boiler.

The electronic motherboard and a set of other electronic control units were replaced and when tested, the boiler functioned as designed after a number of other features were either deactivated or else temporary repaired.

A final inspection was carried out on 09 March 2018 by another service engineer, whereby it was confirmed that the system had been permanently repaired and was working well.

ANALYSIS

Aim

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

Immediate cause of the furnace blowback

Evidence available to the safety investigation did not indicate clearly the cause of the blowback. However, it was definite that the boiler furnace contained an explosive mixture of fuel and air, which had been ignited either by the residual heat inside or during a restart attempt by the two crew members.

Purging of boiler furnace

Purging of boiler furnaces is an important step in the start-up and shut down processes whereby a forced draught fan is started and air is passed through the furnace and out of the uptake. During the process, exhaust gases or fuel oil vapours are cleared from the furnace. This procedure takes several minutes and is normally regulated by an automatic control.

The dangers of boiler furnace explosions have been investigated for a number of years and reflect the potential issues which may be created when flammable gases are either not purged properly or not purged at all from the boiler furnace (and the gas passages).

It would appear that the furnace blowback happened during the inspection, following guidance received by the manufacturers. Evidence from the crew members involved indicated that there was no restart attempt of the boiler. Rather, it would seem that the furnace blowback happened during the inspection and therefore after (and with) the boiler stopped.

The safety investigation did not exclude the possibility that MDO leaked inside the furnace after the boiler was shut down[1]. At the time of shut down, the boiler was operating on MDO and this would have led to an increased risk of an explosion inside the boiler's furnace.

The evidence available did not confirm whether there was post-shut down purging of the boiler furnace, *i.e.*, before the system was checked as recommended by the manufacturers. If indeed, there was a post-shut down purge, no records were available as to the duration of the purge.

These points had been raised during the course of the safety investigation for two main reasons. If there was no post-shut down purging and MDO did leak inside the furnace, then, the residual heat would have evaporated the lighter distillates of the MDO and creating an explosive air/diesel mixture inside the furnace.

The duration of the post-shut down purge is also a very important factor which had to be taken into consideration, especially with the boiler not working in automatic mode. The scope of post-shut down purging is to allow fresh air inside the furnace and in so doing, unwanted exhaust gases and / or (flammable) gases are expelled from the system.

[1] This possibility has to be seen in the light that the flame detector had been deactivated because there were indications that this was one of two sensors which was triggering alarms and possibly the fuel valves had not been closed after shut down.

An automatic control of this process would ensure that the volume of fresh air pumped inside the boiler furnace is large enough to dilute the flammable gases outside the explosive envelope and eventually expel them out through the uptake.

In practice, the initial volume of post-shut down purge air is not clean air but a mixture of flue gases with a concentration of unburnt fuel (potentially from unsuccessful repetitive starting attempts or, as it is probably the case on board this vessel, a MDO leak after shut down). In this case, the post-shut down purge air was actually compromised and this would have been an effect on the decay rate of the flue gas mixture, which should have been expelled out of the boiler furnace.

The MSIU understood that in addition to the explosive gaseous mixture inside the boiler furnace, something must have triggered an internal deflagration of the explosive mixture inside the boiler furnace. The autoignition temperature[2] of MDO is about 260 ^{o}C which, is well within the range of a hot boiler furnace that had just been shut down[3].

Risk assessment

A risk assessment was carried out and signed by the chief engineer (as the risk assessment team leader) and all the engineering officers. A Risk Assessment Form, which was part of the Safety Management System of the vessel, had been completed on the day prior to the accident.

The electrician, who was one of the injured crew members, had not signed the risk assessment form since he was not part of the risk assessment team.

The assessed activity was the emergency operation of the auxiliary boiler. Two hazards had been identified, mainly 'flame failure' and 'low water inside the boiler'. The identified impact was recorded as damage to the boiler. As risk controls for both hazards, the crew members involved were expected to strictly follow the procedures for the 'Emergency Boiler Operation', which had been placed in the vicinity of the boiler control panel.

In the case of a flame failure, crew members were required to stop the fuel pump, whereas they were required to start the feed water pump manually in case of low water level but to stop the fuel pump if the water level could not be increased.

It was evident that the two identified hazards were actually related and limited to the defective sensors on the boiler control system. It was clear that potential hazards generated by, for instance, the actual operation of the boiler in the emergency mode, had not been identified.

Risk assessment is a very important tool; not only it is a requirement in terms of safety management systems, but it also guides the crew members when operating in situations in which crew members are not necessarily familiar with. However, as this case has indicated, comprehensive assessments require not only knowledge but also experience to identify potential hazards.

Risk identification is but an important crucial first step within a systemic process. Availability of data is crucial in this process and the safety investigation is aware that accidents similar to this one may have not been experienced by the crew members involved. Then, it is not necessarily possible for the risk assessment methodology employed on board to be validated and therefore ensure a thorough exercise. To this effect, the crew members did not have the necessary foresight to address all the hazards in a systematic way.

[2] Autoignition is the temperature at which MDO will ignite in the absence of an ignition source.

[3] This also necessitated that the generated explosive mixture would have been within the lower and upper explosive limits for MDO, which are about 0.6 % v/v and 7.5 % v/v respectively.

CONCLUSIONS

1. The boiler furnace contained an explosive mixture of fuel and air which had been ignited either by the residual heat inside or during a restart attempt by the two crew members;
2. The safety investigation did not exclude the possibility that MDO leaked inside the furnace after the boiler was shut down;
3. The boiler was operating on MDO and this would have led to an increased risk of an explosion inside the furnace;
4. The safety investigation did not exclude the possibility that either a post-shut down purge had not been carried out or its duration was not long enough to expel unwanted exhaust gases and / or (flammable) gases;
5. The autoignition temperature of MDO is about 260 ^{o}C, which is well within the range of a hot boiler furnace that had just been shut down;
6. The two identified hazards in the risk assessment exercise were actually related and limited to the defective sensors on the boiler control system;
7. Potential hazards generated by, for instance, the actual operation of the boiler in the emergency mode, had not been identified;
8. Accidents similar to this one may have not been experienced before by the crew members involved;
9. The crew members did not have the necessary foresight to address all the hazards in a systematic way.

SAFETY ACTIONS TAKEN DURING THE COURSE OF THE SAFETY INVESTIGATION[4]

During the course of the safety investigation, the Company issued a Safety Alert to all vessels within its fleet, in response to the boiler furnace explosion and injuries sustained by two crew members.

The Safety Alert addressed the safe operation of boilers during the course of fault finding tasks, the preparation of a work plan and risk assessment prior to the commencement of any work.

The Company has also taken the following safety actions:

- managerial controls by the Technical Superintendent and Fleet Managers with respect to the preparation of work plans and risk assessments;
- service engineers from the manufactures have been requested on board in order to carry out a complete assessment of the boiler functions and carry out the necessary adjustments to the boiler operational parameters;
- the master of the vessel has discussed the accident during the on board safety meeting; and
- the accident was also discussed during shore management meetings with all members of the engineering department.

RECOMMENDATIONS

In view of the safety actions taken by the Company, no recommendations have been issued by the MSIU.

[4] **Safety actions shall not create a presumption of blame and / or liability**.

SHIP PARTICULARS

Vessel Name:	*New Hampshire Trader*
Flag:	Malta
Classification Society:	DNV GL
IMO Number:	9571296
Type:	Container Ship
Registered Owner:	New Hampshire Trading Shipping Ltd.
Managers:	Columbia Shipmanagement Ltd.
Construction:	Steel
Length Overall:	212.54 m
Registered Length:	196.90 m
Gross Tonnage:	35,708
Minimum Safe Manning:	15
Authorised Cargo:	Containers

VOYAGE PARTICULARS

Port of Departure:	Dalian, People’s Republic of China
Port of Arrival:	Qingdao, People’s Republic of China
Type of Voyage:	Short International
Cargo Information:	19,051 mt of containerised cargo
Manning:	20

MARINE OCCURRENCE INFORMATION

Date and Time:	31 January 2018 at 18:07 (LT)
Classification of Occurrence:	Serious Marine Casualty
Location of Occurrence:	30 nautical miles from Qingdao Pilot Station
Place on Board	Engine-room
Injuries / Fatalities:	Two serious injuries
Damage / Environmental Impact:	Damage to equipment (boiler furnace)
Ship Operation:	In passage
Voyage Segment:	Transit
External & Internal Environment:	The weather was clear with a Northeasterly gentle breeze. The air and sea temperature were both 4 °C.
Persons on board:	20