THE COMMONWEALTH OF THE BAHAMAS

Norbe VIII

IMO Number: 9562568
Official Number: 8001689

Report of the marine safety investigation into a boiler explosion leading to three fatalities on a drill ship on 09 June 2017

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1 GLOSSARY OF ABBREVIATIONS AND ACRONYMS

APRI	Preliminary analysis of risks and impacts
BMA	Bahamas Maritime Authority
°C	Degrees Celsius
IMI	Instituto de Metrologia Industrial Ltd
ISM	International Safety Management
m	Meters
PJP	Pre-job planning
PMS	Planned Maintenance System
PPE	Personal Protective Equipment
PTW	Permit to work
UTC	Universal Coordinated Time

Times: All times used in this report are local (UTC -3) unless otherwise stated.

2 SUMMARY

At 07:38 on 09 June 2017, whilst the vessel was holding position in the Marlin Oil Field, off the coast of Brazil, one of Norbe VIII's auxiliary boilers exploded, filling the boiler room with steam. The two shore-based service technicians and the ship's engineer who were working in the boiler room received severe burns and respiratory injuries and later died. Another member of the crew, who was working outside the space, was injured but recovered.

The explosion was caused by over-pressurisation of the boiler's water chamber that led to internal structural failure and ingress of pressurised hot water into the boiler's furnace. The resultant steam expansion ruptured the furnace base and firehole, leading to the escape of high-pressure steam.

The boiler's pressure safety valves, which should have automatically opened to release the excess pressure, had been isolated that day, due to an incorrect but shared mental model that they were opening below their set pressure.

The investigation found that the vessel's safety management system was rendered ineffective prior to the service operation starting, when the procedural barriers identified in the work order were ignored. Further, the service technicians were not appropriately qualified to conduct the boiler service and that the vessel's senior engineers did not provide sufficient oversight of the service operation.

Additionally, the boiler's pressure sensors were not operating as required and the boiler maintenance and preservation regime did not comply with the Company's, manufacturer's or Brazilian rules.

There was no marine pollution as a result of the boiler explosion.

3 DETAILS OF VESSEL AND OTHER MATTERS

3.1 Details of vessel

The Norbe VIII is a drill ship which has been registered under the flag of The Commonwealth of The Bahamas since 2011.

The vessel has the following principal particulars:

Call sign	C6YB4
IMO number	9562568
MMSI number	311 028 400
Built	Geoje, South Korea 2011
Length overall	220.9 metres
Breadth	42.0 metres
Depth moulded	19.0 metres
Propulsion power	42,000 kW
Gross registered tonnage	67821tons
Net registered tonnage	20346 tons
Class Notation (DNV GL)	1A1 Ship-shaped Drilling unit BIS DPS (3) E0

3.2 Vessel Certification

The vessel is owned by Odebrecht Drilling Norbe Eight GmbH and, at the time of the incident, technical and safety management was performed by Odebrecht Óleo & Gás S.A., now renamed Ocyan S.A.

At the time of the incident, the vessel complied with all statutory and international requirements. The ship held valid statutory certification required under international conventions including the Code for the construction and equipment of mobile offshore drilling units, 2009.

The vessel's managers held a Document of Compliance under the International Safety Management Code by the Bahamas Recognised Organisation DNV GL, issued on 25 January 2017.

The vessel was last subject to a Bahamas Maritime Authority Annual Inspection whilst operating offshore on 08 June 2016 when four deficiencies were identified, these were not relevant to the circumstances of the casualty.

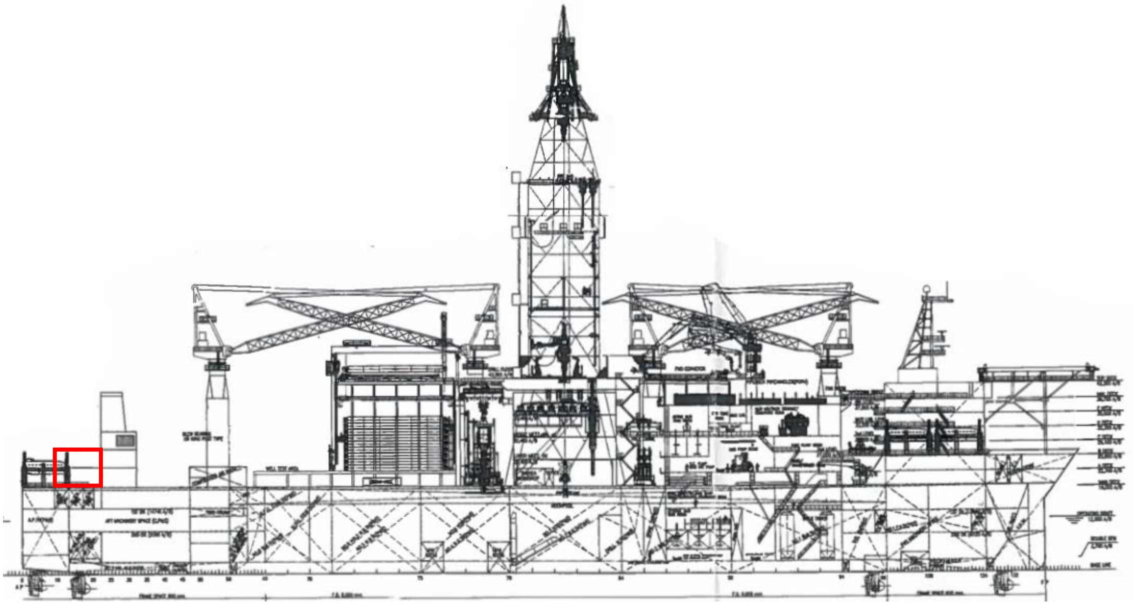

Figure 1: Norbe VIII general arrangement, auxiliary boiler room in red

3.3 Auxiliary boilers

The vessel's two auxiliary boilers were model PA 0201P32, manufactured by KangRim Heavy Industries. Co. Ltd of South Korea, in 2008. The boilers were solely used for well test operations and were not considered to be part of the vessel's machinery by the vessel's Classification Society, DNV GL. The auxiliary boiler room was located at the stern of the vessel, on main deck level (marked in red, on figure 1).

The boilers were of vertical water tube design and had a working pressure of 7.0 bar and a permissible maximum working pressure of 9.18 bar. Each boiler was fitted with two pressure safety valves, each working independently of the other and designed to be set to open automatically at a pressure equal to or lower than the boiler's maximum working pressure.

The boilers were divided into two chambers, the water chamber where superheated water[1] is stored and converted to steam and the furnace where diesel is burned to create exhaust gas. Heat exchangers (with water on the cold side and exhaust gas on the hot side) are used for steam generation.

[1] Superheated water is liquid water under pressure at temperatures higher than 100°C

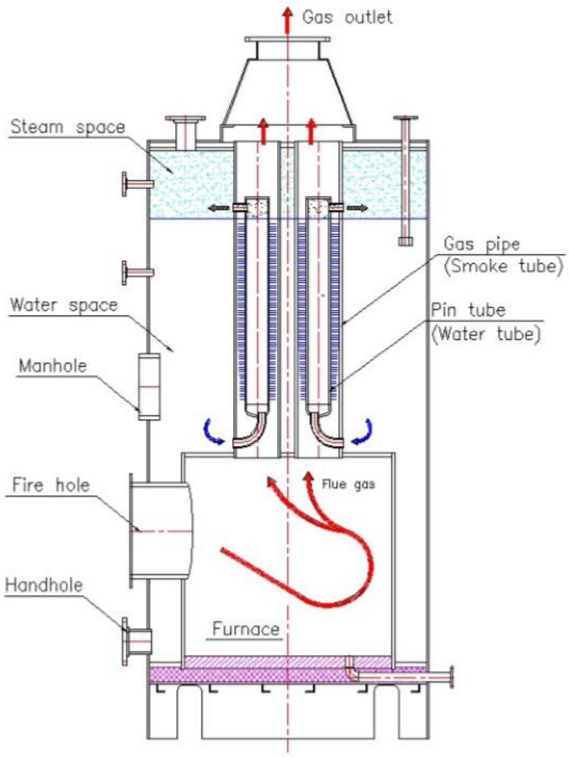

Figure 2: Boiler cross-section

3.4 Environment

At the time of the incident, the vessel was holding position using dynamic positioning at the Marlin Oil Field, off the coast of Brazil, in position 22°20.4’S 040°04.6’W.

The wind was northerly at 32 knots with good visibility and a clear sky. The current was setting to the south at two knots. The incident occurred during daylight. The environmental conditions did not contribute to the incident.

3.5 Victims

The Second Assistant Engineer was a 33-year-old Brazilian national who held an Officer in Charge of an Engineering Watch certificate of competency, issued by the Bahamas on 31 July 2013.

Service Technician A was a 44-year-old Brazilian national and held a certificate in safety training in boiler operation[2], issued by Instituto de Metrologia Industrial Ltd on 10 October 2016.

Service Technician B was a 28-year-old Brazilian national and held a certificate in safety training in boiler operation, issued by Instituto de Metrologia Industrial Ltd on 06 March 2017.

[2] Translated from Portuguese: Treinamento de Segurança na Operação de Unidades de Processo

4 NARRATIVE OF EVENTS

4.1 Events prior to the explosion

On 7 June 2017, two service technicians employed by the Instituto de Metrologia Industrial Ltd. (IMI) joined the Norbe VIII by helicopter, in order to carry out annual servicing of the vessel's two auxiliary boilers. That evening, the ship's duty engineers were requested to warm-up the boilers and start preparations for servicing.

At approximately 23:20, after identifying a leak on boiler #1's sight glass and replacing the associated gasket, the boilers were re-started. Shortly afterwards the pressure safety valves opened, seemingly at 1.9 bar for boiler #1 and 5.9 bar for boiler #2 - well below the boilers' working pressure of 7.0 bar. Over the course of the next four hours, the boilers were stopped and restarted a further three times with the pressure safety valves reportedly operating abnormally each time.

The following morning, 8 June 2017, the Chief Engineer was informed that the boilers were not ready for servicing due to the apparent issues with the pressure safety valves. The Chief and First Engineers, along with the service technicians, then started the boilers to check the operation of the pressure safety valves which still appeared to be opening below the boilers' working pressure.[3]

At around 12:00, the boilers were shut down and left to cool, in order to allow the technicians to overhaul the pressure safety valves. The technicians were later seen calibrating manometers and the boilers were left isolated until the next day shift.

At the pre-work meeting, at 06:00 on 09 June 2017, overhauling the pressure safety valves was discussed and the service technicians, along with one of the ship's Second Assistant Engineer's, proceeded to the boiler room.

4.2 The explosion

Shortly after 07:00, the boilers were started and almost immediately triggered alarms on the engine room monitoring system. Over 20 alarms were acknowledged over the course of the next 36 minutes.

At 07:38 on 09 June 2017, boiler #1 catastrophically failed, filling the boiler compartment with steam.

The two service technicians and ship's Second Assistant Engineer who were in the boiler room received severe burns and respiratory injuries. Another member of the crew, a welder who was working on deck outside the boiler room, was injured as the boiler room's weathertight door was blown open and the pressure vented to atmosphere.

[3] Reported to be 3.5 bar for boiler #1 and 5.9 bar for boiler #2.

4.3 Actions post-explosion

The explosion was immediately detected on the ship's fire detection panel and shortly afterwards the rescue and medical team were directed to the scene.

At 07:48 the ship's general alarm was sounded and the fire fighting team mobilised. It was confirmed that there was no fire and the injured personnel were taken to the ship's hospital.

At 09:52 the first of two medivac helicopters arrived, and the four injured personnel were evacuated over the course of the next three hours.

The two service technicians and ship's Second Assistant Engineer died of the injuries sustained in the incident.

5 ANALYSIS

5.1 Failure mode

During the explosion, the boiler's burner unit was ejected from the boiler with significant force. Internal inspection of the failed boiler identified significant deformation of the wall between the water space and the furnace as well as deformation to the furnace bottom plate and cracks in several places.

Figure 3: Deformation of internal wall

Figure 4: Furnace bottom plate (insulation removed)

The pattern of damage suggested either a steam explosion due to structural failure or flashback in the furnace space due to build-up of unburnt fuel.

To determine the most likely mode of failure, DNV GL were commissioned to simulate the explosion and resulting pressure development in the boiler compartment. This was done in two stages - modelling to estimate the internal pressure required to cause the observed deformation of the boiler and then modelling of the pressure release and resulting pressure development in the boiler room.

The simulations showed that water chamber pressure of approximately 30 bar was required to cause the observed deformation of the internal wall. Flashback in the furnace was considered unlikely to increase the waterside pressure to this level.

The simulations also showed that after the failure of the internal wall, water entering the furnace would be vaporised and create pressure in the furnace until the furnace bottom and / or fire hole ruptured. The damage to the furnace bottom indicated this ruptured at approximately 15 bar which would also be enough to eject the burner unit with the force seen.

Further analysis was completed to test these conclusions. Stress Engineering Services was commissioned to model the pattern of failure due to overheating in the furnace and for excess pressure in the water space.

Numerical analysis for overheating of the furnace suggested that, even with pressure in the water space constant at the boiler's maximum operating pressure, structural collapse due to overheating of the furnace was unlikely.

Finite element analysis suggested that the maximum stress in the boiler due to over-pressurisation would occur at the interface between the upper combustion chamber and riser pipes with buckling occurring opposite the firehole, in line with the observed damage. The model suggested structural failure at a pressure of 34.5 bar, in line with DNV GL's simulations.

5.2 Pressure management

Each boiler was fitted with two pressure safety valves, each independent of the other and designed to be set to open automatically at a pressure equal to, or lower than, the boiler's maximum working pressure. Each valve was additionally fitted with a pulley system to manually open the valves if required.

Post-incident scene investigation identified that the manual activation mechanism had been removed from the pressure safety valves on boiler #1. In addition, the pressure safety valves no longer had their anti-tamper seals[4] in place and were wound significantly tighter than those observed on boiler #2.

[4] Valve set pressure is adjusted under test bench conditions. To ensure that non-qualified persons do not adjust the set pressure, valves are fitted with a seal identifying the set pressure, facility performing the adjustment and date.

Figure 5: Pressure safety valves – boiler #1 – note compression of spring, ringed in red

Figure 6: Pressure safety valves – boiler #2, seals ringed in green (source: Brazilian Navy)

To determine the effect of the apparent adjustment of the pressure safety valves, Shimmer Inspection were commissioned to inspect and test both sets of pressure safety valves along with other boiler equipment.

Inspection of the valves from both boilers found corrosion and foreign material deposits inside the valves. It was confirmed that both valves from boiler #1 had been adjusted so that their springs were fully compressed.

Pressure testing identified that, in this condition, the valves would partially open[5] at a pressure of around 24 bar but would not fully open, even when subjected to test bench pressures in excess of 35 bar.

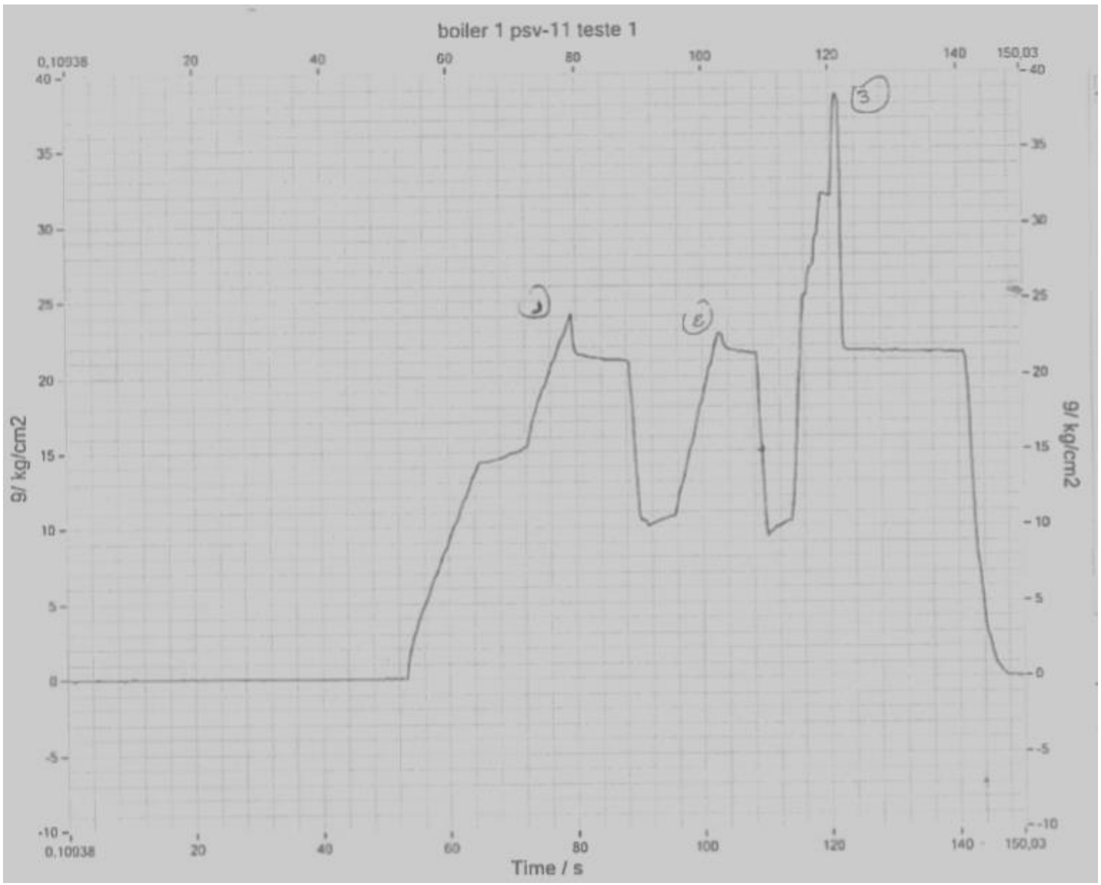

Figure 7: Example pressure test – boiler #1, pressure safety valve 1, as found condition

When adjusted to a set pressure of 9 bar, boiler #1's pressure safety valves partially opened at set pressure but could not be made to fully open, even at a pressure in excess of 35 bar.

Tests on the pressure safety valves of boiler #2 yielded similar results.

[5] Partial opening, also known as simmering, occurs when a valve opens slightly, discharging only a small percentage of its rated capacity. Spring-operated safety valves may partially open at 90% of the set pressure, this is not considered open.

5.3 Pressure monitoring

The engine room monitoring system included pressure monitoring of the auxiliary boilers. According to the history extracted from the system, boiler #1 was started eight times in the 36 hours prior to the incident, with measured steam pressure (figure 8, green line) never reaching the boiler's design operating pressure.

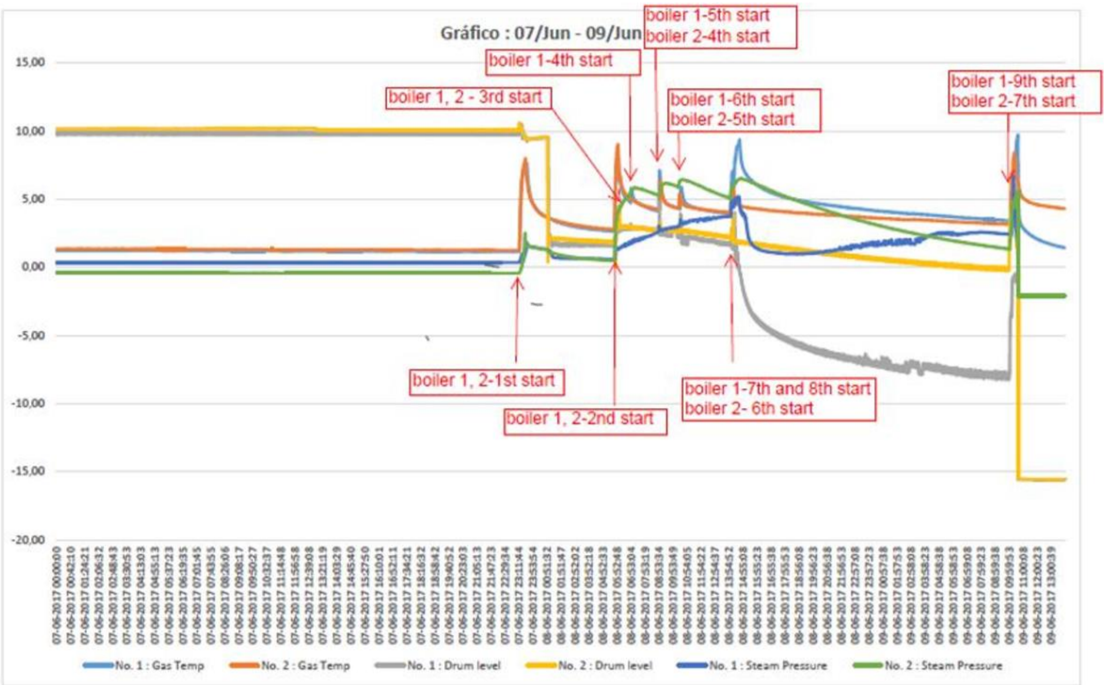

Figure 8: Boiler level, pressure and temperature records 07-09 June 2017

The pressure trace over this period is similar to those seen in test bench conditions, where the pressure safety valves partially opened.

Post-incident scene investigation identified that the feed to the pressure sensor was restricted by the partial closure of the system's isolation valves. Additionally, testing of both boilers' pressure sensors by Shimmer Inspection found that the instruments were not operating as required[6].

There is nothing to suggest that at any point during the preparation or servicing of the boilers, the validity of the pressure sensor output was questioned by the vessel's engineers or service technicians.

[6] Boiler #1 "O instrumento encontra-se fora dos paramentro de indice de class" / "the instrument is operating outside the Class index perimeters".

5.4 Safety management

For annual servicing of the boilers, the work order (figure 9) identified nine safety instructions to be followed and referenced several sections of the vessel's quality health and safety management system:

- MB-QHSE-PR-009 required the creation of pre-job plans
- MB-QHSE-PR-003 required the completion of a "preliminary risks and impacts analysis"
- MB-QHSE-PR-024 required issue of a permit to work

Work Order Details

14-46368: PMD-0365 DAYS-WELL TEST BOILER-ENGINEERING

Task IDs

Task ID	Description	Status	Measurement Point	Value
10	SAFETY INSTRUCTIONS	CLOSE		0

Activity Details

SAFETY INSTRUCTIONS:
INTRUÇÕES DE SEGURANÇA:

1- PERFORM PRE-JOB PLANNING (PJP) AS PER PROCEDURE MB-QHSE-PR-009.
REALIZAR O PLANEJAMENTO DA TAREFA (PJP) DE ACORDO COM O PROCEDIMENTO MB-QHSE-PR-009.
2- PERFORM PRELIMINARY ANALYSIS OF RISKS AND IMPACTS (APRI) AS PER PROCEDURE MB-QHSE-PR-003.
REALIZAR ANALISE PRELIMINAR DE RISCOS E IMPACTOS (APRI) DE ACORDO COM O PROCEDIMENTO MB-QHSE-PR-003.
3- ISSUE THE PERMIT TO WORK (PTW) IF JOB REQUIRE AS PER PROCEDURE MB-QHSE-PR-024.
EMITIR PERMISSÃO PARA TRABALHO (PTW) SE FOR REQUERIDO PELO TRABALHO DE ACORDO COM O PROCEDIMENTO MB-QHSE-PR-024.
4- ISSUE THE BLOCKING OF HAZARDOUS ENERGIS (LOTO) AS PER PROCEDURE MB-QHSE-PR-033.
EMITIR BLOQUEIO DE ENERGIAS PERIGOSAS (LOTO) DE ACORDO COM O PROCEDIMENTO MB-QHSE-PR-033.
5- THE COMPLETE PPE IS MANDATORY.
É OBRIGATORIO O USO DO EPI COMPLETO.
6- WHEN WORK BE CARIED OUT AT HEIGHTS OBSERVE THE REQUIREMENTS IN THE PROCEDURE MB-QHSE-PR-028.
QUANDO O TRABALHO FOR REALIZADO EM ALTURA OBSERVE OS REQUERIMENTOS DESCRITOS NO PROCEDIMENTO PÉS MB-QHSE-PR-028.
7- INSPECT THE WORK AREA AND INFORM THE PEOPLE OR DEPARTMENT (S) AFFECTED BY TASK AND GENERAL HOUSEKEEPING AFTER JOB COMPLETE.
INSPECIONAR A ÁREA TRABALHO E INFORMAR AOS AS PESSOAS OU DEPARTAMENTO (S) AFETADOS PELA TAREFA E LIMPEZA E ARRUMAÇÃO APÓS A CONCLUSÃO DA TAREFA.
8- PERSONNEL PERFORMING THIS MAINTENANCE SHALL BE FAMILIAR WITH MANUFACTURER'S OPERATIONAL AND MAINTENANCE INSTRUCTIONS BEFORE BEGINNING.
O PESSOAL ENVOLVIDO NA EXECUÇÃO DA TAREFA DEVE ESTAR FAMILIARIZADO COM AS INSTRUÇÕES OPERACIONAIS E DE MANUTENÇÃO DO FABRICANTE ANTES DO INÍCIO.
9- IF APPLICABLE PERFORM THE MANAGEMENT OF CHANGE (MOC) AS PER PROCEDURE MB-QHSE-PR-015.
SE APLICÁVEL REALIZE O GERENCIMANETO DE MUDANÇA (MOC) DE ACORDO COM O PROCEDIMENTO MB-QHSE-PR-015."

Task ID	Description	Status	Measurement Point	Value
20	OVERHAUL SEQUENCE	CLOSE		0

OVERHAUL SEQUENCE:

WELL TEST BOILER

THIRD PARTY BOILER INSPECTION

1. THIRD PARTY COMPANY TO CARRY OUT FULL INSPECTION TO THE STEAM BOILER AND ALL RELATED EQUIPMENT ACCORDING TO NR13*.
2. FILE INSPECTION RECORDS IN STAR IPS AND BOILER DATA BOOK HAS TO BE SIGNED.
NOTE: *NR-13 - BOILER AND PRESSURE VESEL
13.5 BOLIER SAFETY INSPECTION
13.5.3 THE PERIODIC SAFETY INSPECTION, INCORPORATED BY INTERNAL AND EXTERNAL EXAMES, MUST BE CARRIED OUT ON THE FOLLOWING MAXIMO SCHEDULES:
A) 12 (TWELVE) MONTHS FOR BOILERS OF CATEGORIES "A", "B" E "C";

Figure 9: Work order – annual boiler service

There is no evidence that any of these tasks were completed nor any evidence of the vessel planning for, or managing, the servicing operation.

5.5 Manufacturer's instruction

The boilers' manual provides instruction for operation and maintenance of the boilers. Guidance on preparation for service includes:

> Before heating is begun it must be checked if the gas openings are open (danger of explosion), accurately adjusted and ready for service, and that the water in the boiler is between the lowest and normal water level.

It reinforces the importance of pressure management when setting up the boiler:

> Before the boiler is connected it is necessary that the safety valves are adjusted so that they can begin to function at the prescribed pressure. Alteration of the adjustment is to be carried out only by an expert from the local classification society.

And states that the boiler should be taken out of service if the safety valve is not functioning:

> The boiler must be taken out of service immediately and the superior informed as soon as possible if you have a suspicion that something dangerous is arising. The applies especially when… the safety valve cannot function.

5.6 Use and maintenance

As well as the annual servicing by shore technicians, the boilers were subject to monthly and six-monthly planned maintenance schedules[7], conducted by the vessel's engineers.

Six-monthly maintenance consisted of visual inspection of the boiler main control panel, remote start/stop of the fuel oil pumps and megger test of all electronic motors.

The monthly maintenance detailed only the boiler preservation procedure. This included instruction on preservation methods when boilers were in lay-up for short periods and periods of more than one month. For periods of more than one month, boilers could be in a state of "dry", "nitrogen" or "wet" preservation with a note that wet preservation could be used "for a short period (1-3 months) of lay up".

The boilers were solely used for well test operations and, due to the vessel's current tasking, the boilers were not in regular operation and had not been operated, except for maintenance tasks, for the entire period since the last annual service, in May 2016. The boiler was kept in wet preservation for this period. A note in the work order from 2014 states: "Dry preservation and nytrogen [sic] preservation is not possible". There is no further information to suggest why this was the case.

Tesalab Tecnologia em Serviços Ambientais was commissioned to conduct chemical analysis of boiler water. The samples, collected from the cascade tank and boiler #2 were found to be outside of the manufacturer's specifications for pH, sulphites, P-alkalinity and other measures.

Whilst prolonged wet storage and out of specification boiler water significantly increases the risk of corrosion, post-incident inspection identified flash rust on internal surfaces but no evidence of pitting. Review of records identifies non-scheduled maintenance was conducted in 2015 to remedy corrosion (pitting up to 0.7mm) and the water drum was repainted in 2016 and January 2017.

5.7 Brazilian Regulations

Brazilian Regulatory Standards (known as NR) regulate and provide guidance on mandatory procedures related to occupational safety. NR 13 covers boilers and pressure vessels and sets the minimum requirements for managing the integrity of steam boilers including inspection, operation and maintenance activities.

[7] There are no planned maintenance tasks prescribed in the manufacturer's manual, only operational advice, associated daily tasks and detail on repair of the pin tube element.

Amongst other safety items, the regulation's general provisions (NR13.3.1) state: "it constitutes serious and imminent risk not to comply with any item prescribed in this [regulation] …especially…blocking [safety devices] intentionally without proper technique." It also prescribes setting the safety valve below the PMTA and the need to inspect and test safety valves monthly.

NR13 Annex I provides guidance on personnel training including the syllabus and practical training required for the safety training in boiler operation certificate. For category B boilers, such as the well test boiler on Norbe VIII, the practical element is a minimum of 60[8] hours supervised operation and 40 hours of taught elements. The entry qualification is completion of primary education.

NR13.3.2 prescribes a Qualified Professional as "one who has legal competence to practice engineering in the activities related to the design of construction, monitoring of operation and the maintenance, inspection and supervision of boilers…" in accordance with the current professional regulations in force in Brazil.

The Brazilian Navy's investigation into the casualty found that the safety training in boiler operation certificate did not suffice for the service engineers to be considered "qualified professionals" as per section 13.3.2 of the regulations.

[8] Category A: 80 hours, Category C: 40 hours

6 CONCLUSIONS

Norbe VIII's auxiliary (well test) boiler #1 exploded due to over-pressurisation of the boiler's water chamber that led to internal structural failure. This failure allowed ingress of superheated water into the boiler's furnace where it became steam and expanded rapidly. The resultant pressure ruptured the furnace base and firehole, leading to the escape of high-pressure steam which fatally injured the three persons working in the boiler room.

The boiler's pressure safety valves had been adjusted in situ by the service engineers to the point that they were essentially isolated, due to an incorrect but shared mental model that they were opening below their set pressure.

The boiler's pressure sensors were not operating as required.

The service engineers were not appropriately qualified to conduct the servicing operation under Brazilian Regulatory Standards.

The vessel's management did not provide sufficient oversight of the service operation and failed to follow the fundamental safety management tasks prescribed in the work order and safety management system.

The vessel's engineer that was tasked with assisting the service technicians did not adequately challenge the unsafe behaviour of the service technicians.

With respect to the pressure safety valves, the boiler's planned maintenance regime did not conform with Brazilian Regulatory Standards.

The boiler had not been used operationally for over a year and was not preserved in line with company instructions.

Boiler water was not managed as required by the manufacturer.

7 LESSONS TO BE LEARNED

The vessel's safety management system was rendered ineffective prior to the service operation starting, when the procedural barriers identified in the work order were ignored.

- An effective pre-job plan would have defined the task to be completed and the safe working practices to be utilised, compensating for the lack of detail in the work order.
- An effective and well communicated preliminary analysis of risks and impacts would have highlighted to the Second Assistant Engineer the potential events and conditions that could cause harm, as well as the barriers needed to control the risk of harm.
- A permit to work would have ensured that the vessel's engineering management maintained control and oversight of the operation.

A hypothesis that the pressure safety valves were opening below their set pressure was created at the outset and never challenged. Senior engineers identifying that the pressure safety valves needed "troubleshooting" may have set this mental model in all those involved in the task.

Further opening of the valves may therefore have been interpreted through a lens of confirmation bias, meaning that the accuracy of the pressure sensors was never questioned as everyone believed they knew the problem.

The service technicians' lack of experience may have resulted in the unsafe action of adjustment of the pressure safety valves on a pressurised boiler. Adequate supervision by a Qualified Professional may have prevented their deviation from established safe practices.

The Second Assistant Engineer was involved in drafting the boiler's operation procedure and was aware of the potential risks and essential control measures. Despite this, he failed to challenge the adjustment of the pressure safety valves. If the task had been appropriately planned, risk assessed and controlled, it is unlikely that this would have been the case.

The auxiliary boilers were not preserved or maintained as required. If the boilers had been placed in dry preservation the maintenance regime could have been suspended until re-activation and the activity avoided.

8 ACTION TAKEN

Ocyan S/A has taken the following actions:

Conducted an investigation into the causes of the accident.

Created an inspection procedure for tube boilers (type KANGRIM PA0201P32) that:

- Mandates Chief / First Engineer oversight of boiler operation and maintenance and issue of a permit to work.
- Prescribes minimum qualification of service technicians.
- Confirms that testing of safety valves is not in the scope of periodic safety inspections and that they must be bench tested.
- Reinforces that alteration of boilers and /or safety valves must be subject to a management of change process.

Revised and updated the maintenance procedure for tube boilers (type KANGRIM PA0201P32) to:

- Mandate Chief / First Engineer oversight of boiler operation and maintenance.
- Highlight risks associated with boiler maintenance and operation.
- Include monthly testing of the pressure safety valve manual lever.
- Provide full guidance on tasks to be completed for annual maintenance.
- Improve record keeping.

Revised and updated the operation procedure for tube boilers (type KANGRIM PA0201P32).

Removed the boilers from the vessel.

9 RECOMMENDATIONS

Ocyan S/A are recommended to:

- Consider bringing supervision of the maintenance and testing of auxiliary boilers into the vessel's Classification Society inspection regime.
- Facilitate dry-storage of equipment that is out of use for extended periods.

Instituto de Metrologia Industrial Ltda. are recommended to:

- Adopt a formal procedure to identify the hazards and control measures for each task.
- Adopt a documented safe system of work to mitigate risks.
- Provide workers with guidance material for the safe completion of tasks.
- Ensure personnel are qualified for nominated task.