PETROLEUMSTILSYNET

Investigation report

Report	
Report title Report of the investigation of an incident with a ram door blown off a BOP during a connection test on *Rowan Stavanger* 14 September 2020	Activity number Equinor (001025023) Valaris (414002011)

Security grading		
☑ Public	☐ Restricted	☐ Strictly confidential
☐ Not publicly available	☐ Confidential	

Involved	
Teams T-F, T-1	Date 2 March 2020
Members of the investigation team Amir Gergerechi Linn Iren Vestly Bergh Siv A Eeg Thom Fosselie	Investigation leader Amir Gergerechi

Contents

List of figures

List of tables

Abbreviations and explanation of terms

AoC	Acknowledgement of compliance
BOP	Blowout preventer
BSR	Blind shear ram
DOP	Detailed operation plan
Drill water	Water with additives
FAT	Factory acceptance test
High-pressure riser	Pipe connecting well to facility, permitting the return of drilling mud
HTO	Human, technology and organisation
LPR	Lower pipe ram (annulus ram)
MOC	Management of change
MPD	Managed pressure drilling
MPR	Middle pipe ram (annulus ram)
NOV	National Oilwell Varco
OJT	On-the-job training
PDO	Plan for development and operation
PosLock	System in the BOP to lock the BSR in closed position even with loss of hydraulic power
PSA	Petroleum Safety Authority Norway
RDS	Rig drilling superintendent
ROS	*Rowan Stavanger*
Secondary barrier	BOP
Stump	Dedicated location and set-up on the facility for testing a BOP without having to position it on a well
UPR	Upper pipe ram (annulus ram)

1 Summary

One of the ram doors on a blowout preventer (BOP) was blown out at 14.14 on 14 September 2020. This incident occurred on the *Rowan Stavanger* (ROS) jack-up facility in connection with work on well 15/3-A-08 on Gudrun. This field lies in the central section of Norway's North Sea sector, 55 kilometres north of the Sleipner A facility. Valaris is the drilling contractor for the well.

The incident occurred while testing the connection between the BOP and the high-pressure riser. During the high-pressure test, the BOP's blind shear ram (BSR) was blown out when the pressure reached 109 bar. Weighing about two tonnes, the ram first hit the railings in front of the BOP and then landed on top of a container standing alongside, which was used as a workshop for wireline operations outside the cordoned-off area. Nobody was inside the container or the cordoned-off area around the BOP when the incident occurred.

On 28 September 2020, the Petroleum Safety Authority Norway (PSA) decided to investigate the incident. The mandate for its investigation team included determining the course of events and assessing the direct and underlying causes with the emphasis on human, technical, organisational (HTO) and operational conditions from a barrier perspective. The mandate covered conditions up to the time of the incident.

The incident led to spills of drill water and hydraulic fluid to the weather deck on the Gudrun platform, but no environmentally harmful liquid escaped to the sea or gas to the air. Limited material damage was caused. Nobody was injured.

It was quickly established by BOP experts from the supplier that the direct cause of the incident was a failure to arm the anti-rotation bar in the lock mechanism for the BOP doors. None of these mechanisms were correctly locked in accordance with the recommendation from the supplier.

The investigation found a number of underlying causes for the incident on *Rowan Stavanger*. These related primarily to:

- design of the lock mechanism – human-machine interface
- expertise of and training for personnel
- procedures and governing documents
- management of change (MOC)
- roles, responsibilities and sharing of information in the organisation
- workload and inclusion of personnel on board
- contractual requirements and pressure on costs
- the operator's discharge of its see-to-it duty.

2 Background information

2.1 Gudrun field and the facility

Gudrun lies in the central part of Norway's North Sea sector, 55 kilometres north of Sleipner A, 13 kilometres east of Brae East in the UK sector and about 230 kilometres from Stavanger. The water depth is 109 metres. Gudrun was proven in 1975, and a plan for development and operation (PDO) was approved in 2010.

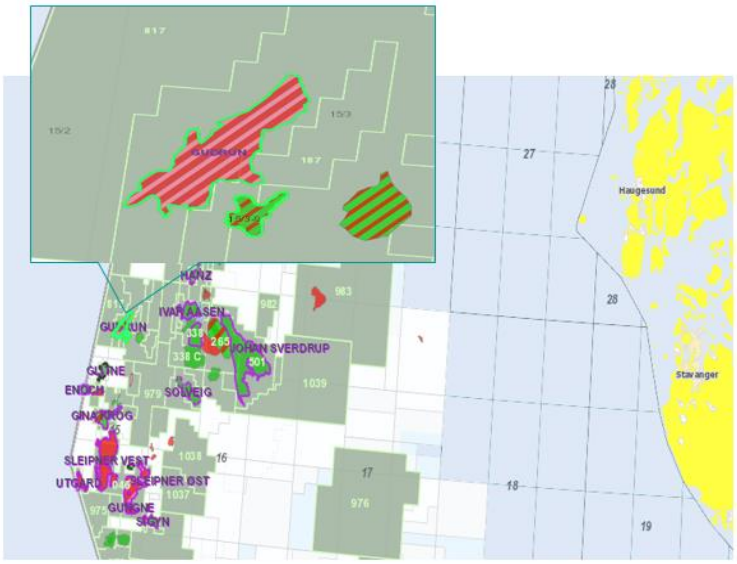


Figure 1: The Gudrun field in the North Sea. Source: Norwegian Petroleum Directorate

The field was developed with a fixed jacket-borne facility. This platform has living quarters and capacity for partial oil and gas processing. Gudrun is tied back to the Sleipner A facility with two pipelines, one for oil and the other for wet gas. The field came on stream in 2014.

Figure 2: The Gudrun platform. Source: Equinor

Gudrun produces oil from Draupne Formation sands and gas from the Hugin Formation using pressure depletion. The reservoir has high pressure and temperature. Managed pressure drilling (MPD) is used on the field, with wells drilled from the *Rowan Stavanger* jack-up.

2.2 *Rowan Stavanger* facility and organisation

Rowan Stavanger is a KFELS N-Class jack-up rig built in Singapore and operational from 2011. It flies the Marshall Islands flag. The rig received an acknowledgement of compliance (AoC) from the PSA in 2012 and has been on contract for Equinor on Gudrun since January 2020. It is operated by Valaris PLC.

This company was created by the merger of Ensco PLC and Rowan Companies PLC in 2019. Headquartered in Houston, Valaris is one of the world's largest rig owners.

Valaris Norge is the arm of Valaris responsible for operations on the Norwegian continental shelf. Its operations organisation for Norway has its offices in Stavanger. The company is in the final stages of converting to a management system tailored to the international business conducted by Valaris.

Rowan Stavanger is one of three rigs operating for Valaris in Norway.

Figure 3: The Rowan Stavanger *jack-up facility. Source: Valaris*

2.3 Valaris operations organisation on *Rowan Stavanger*

2.3.1 Organogram Valaris Norge

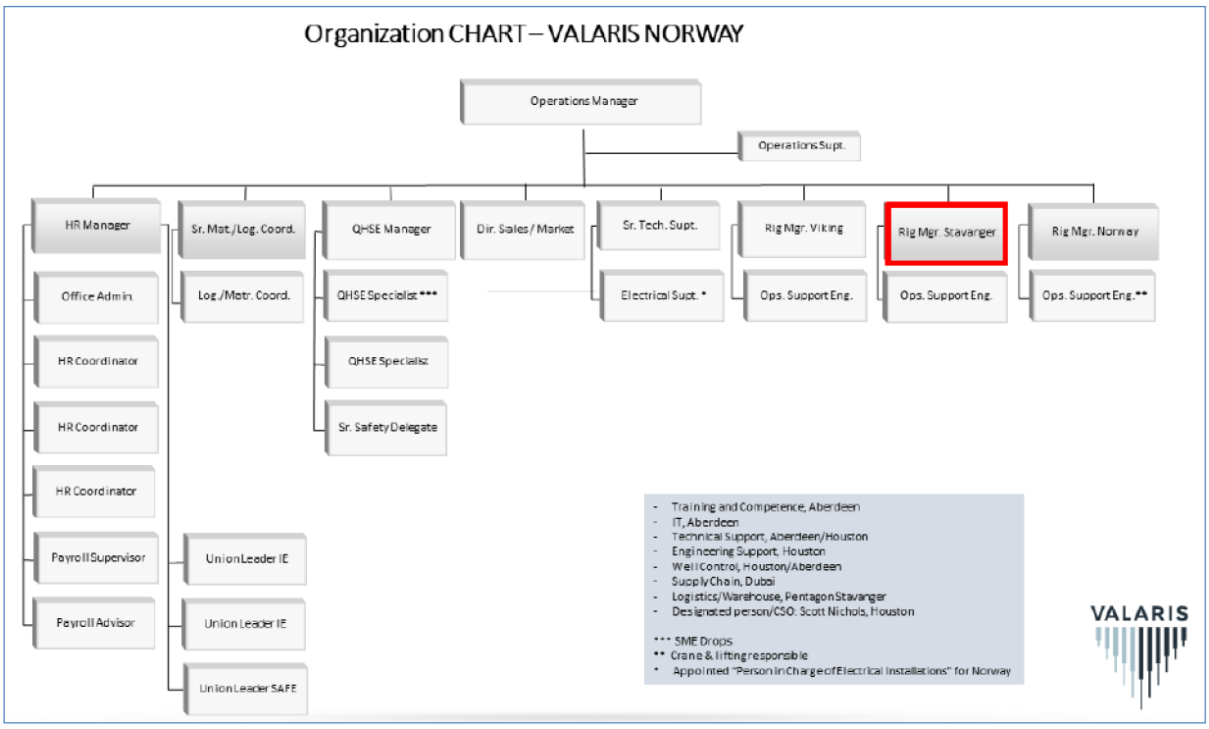


Figure 4: Organogram Valaris Norge.

2.3.2 Organogram *Rowan Stavanger*

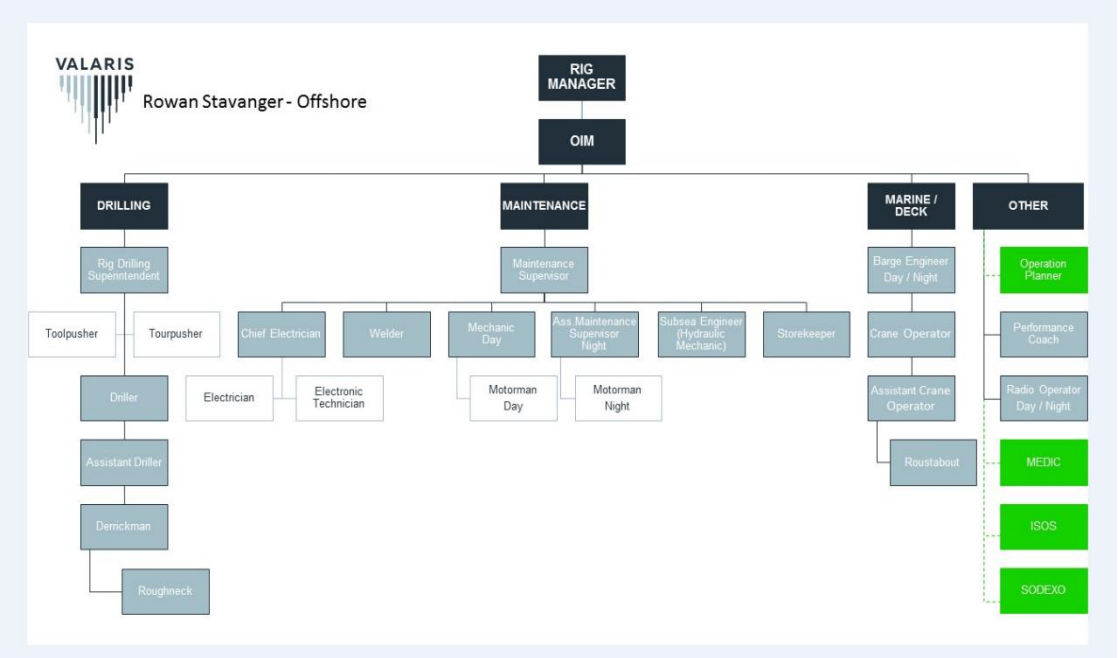


Figure 5: Organogram Rowan Stavanger.

2.4 Equinor's contract requirement for subsea engineers on *Rowan Stavanger*

It emerged during the investigation that Equinor had stipulated in contract negotiations with Rowan Norway (Valaris) that *Rowan Stavanger* should have a subsea engineer. Valaris therefore introduced a new position of subsea engineer on the facility. Work on the BOP had previously been conducted by personnel from the drilling and maintenance department (mechanics or hydraulic engineers). Valaris chose to bring in three subsea engineers on temporary contracts from three different hire companies on a fixed two-four rotation. Information received reveals that subsea engineers are not usually employed on jack-up facilities. But they are normal on a semi-submersible facility, where the BOP is placed on the seabed and associated control systems are regarded as more complex.

2.5 Equipment involved

2.5.1 NOV NXT BOP

BOP

The BOP on *Rowan Stavanger* is an NXT type manufactured by National Oilwell Varco (NOV). This design differs from other BOPs in that all rams except the annular ram are equipped with doors. These doors are operated hydraulically and make handling during maintenance more efficient. The BOP comprises two Shaffer NXT double rams with an annular ram on top.

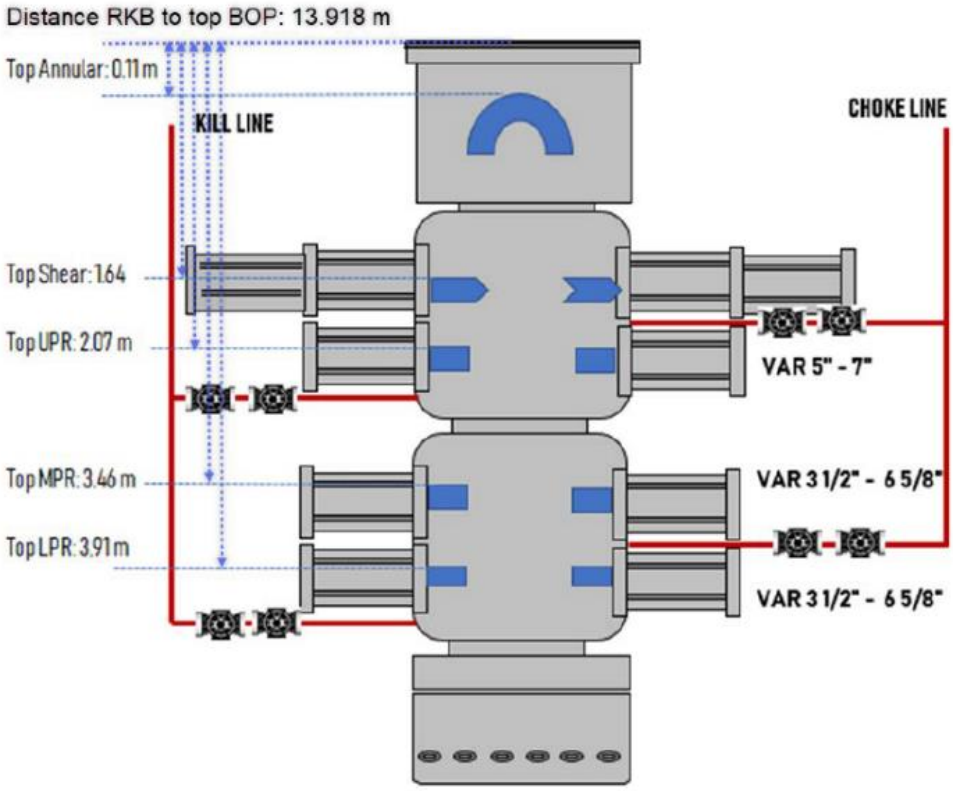


Figure 6: Diagram of the Rowan Stavanger *BOP. Source: consent application*

As figure 6 shows, the BOP has five main rams. The bottom three of these – the lower (LPR), middle (MPR) and upper (UPR) rams are replaceable. The fourth ram, above the UPR, is the BSR.

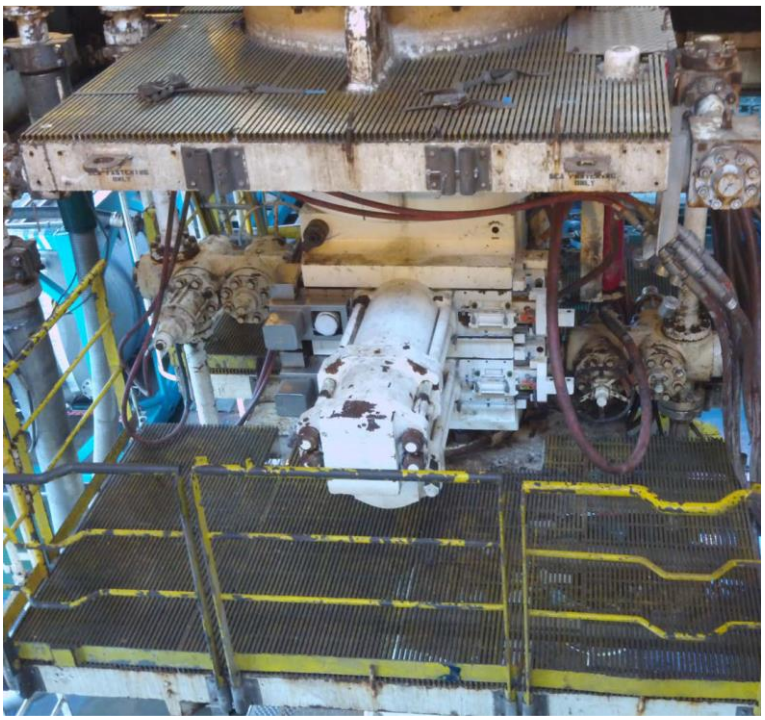


Figure 7 Access platform for the NXT BOP. Source: Valaris

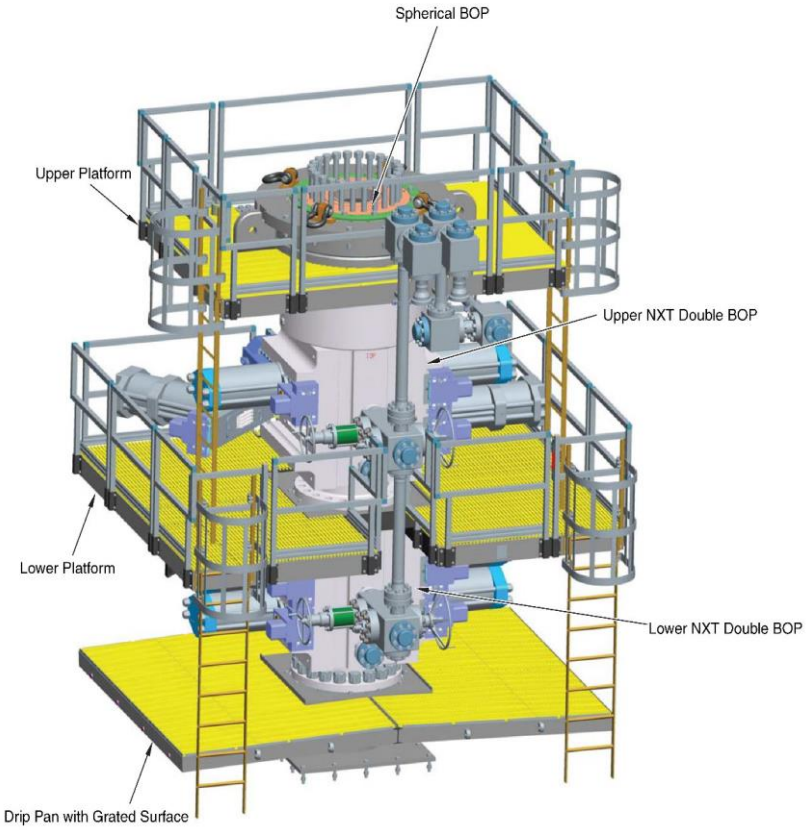


Figure 8 Diagram of the access platform. Source: Valaris

BOP ram door locking system

Original 2010 locking-mechanism design

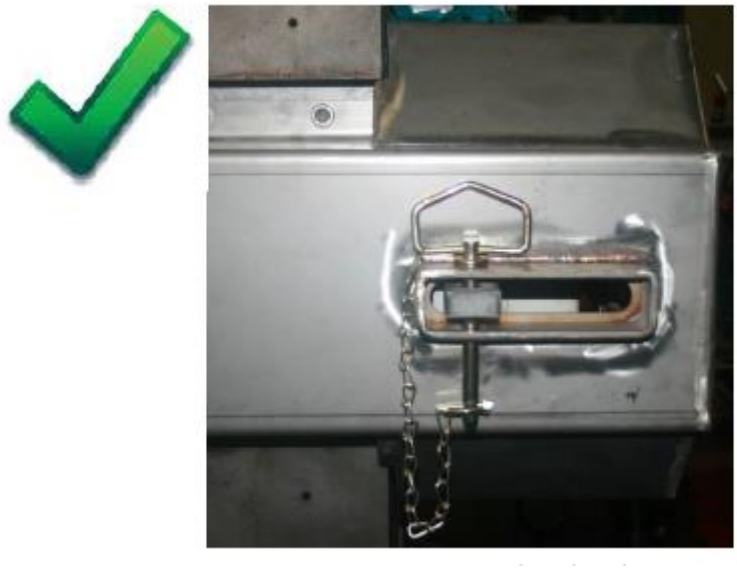


Figure 9: Photos from the NOV safety report show the correct installation of the safety pin.

Figure 10: Incorrect installation.

Change in locking-mechanism design, 19 April 2012

On 19 April 2012, NOV issued a product bulletin which provided information on a new design for the lock mechanism on the NXT BOP.

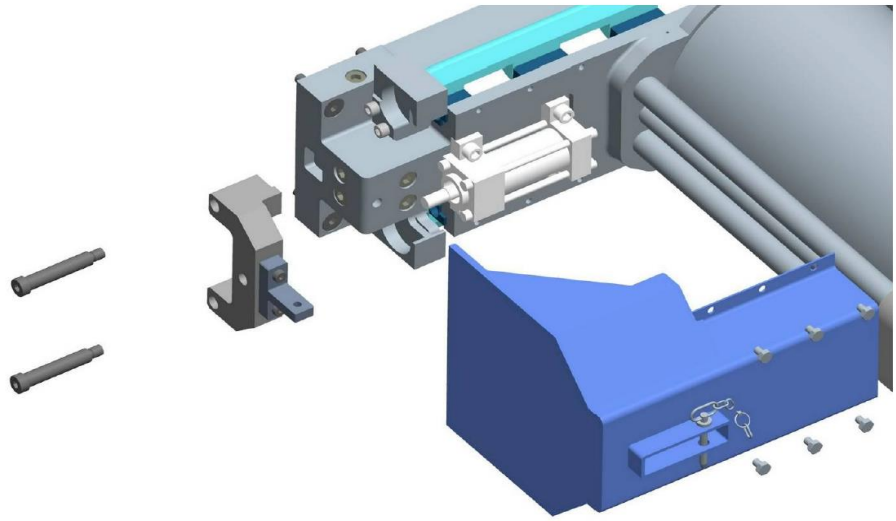


Figure 11: The original design.

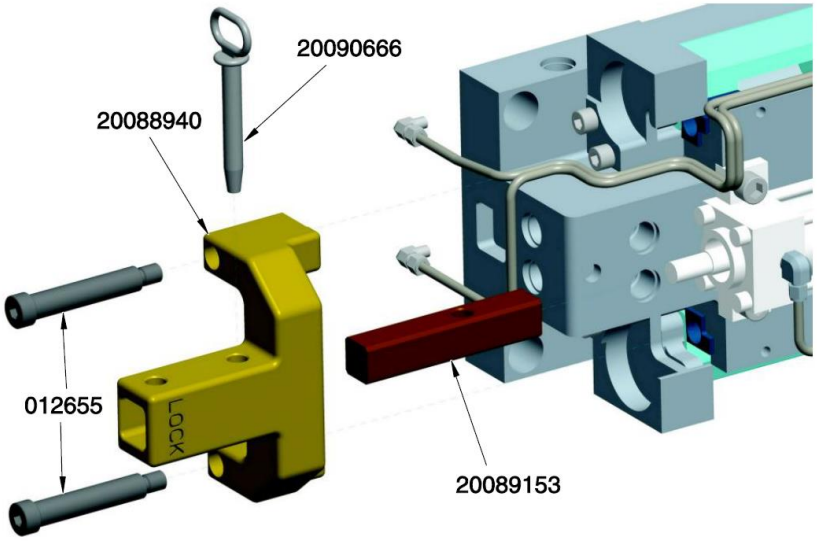


Figure 12: The changes to the design with components 20088940, 20089153 and 20090666.

Upgrade of locking-mechanism indicator, 22 September 2014

After an incident involving incorrect use of the locking system, NOV issued a product bulletin on 22 September 2014 to provide information on a new upgrade of the anti-rotation locking bar. Part of the 2012 change, this bar (P/N 20089153) needed to be replaced with a longer version (P/N 10805038-001).

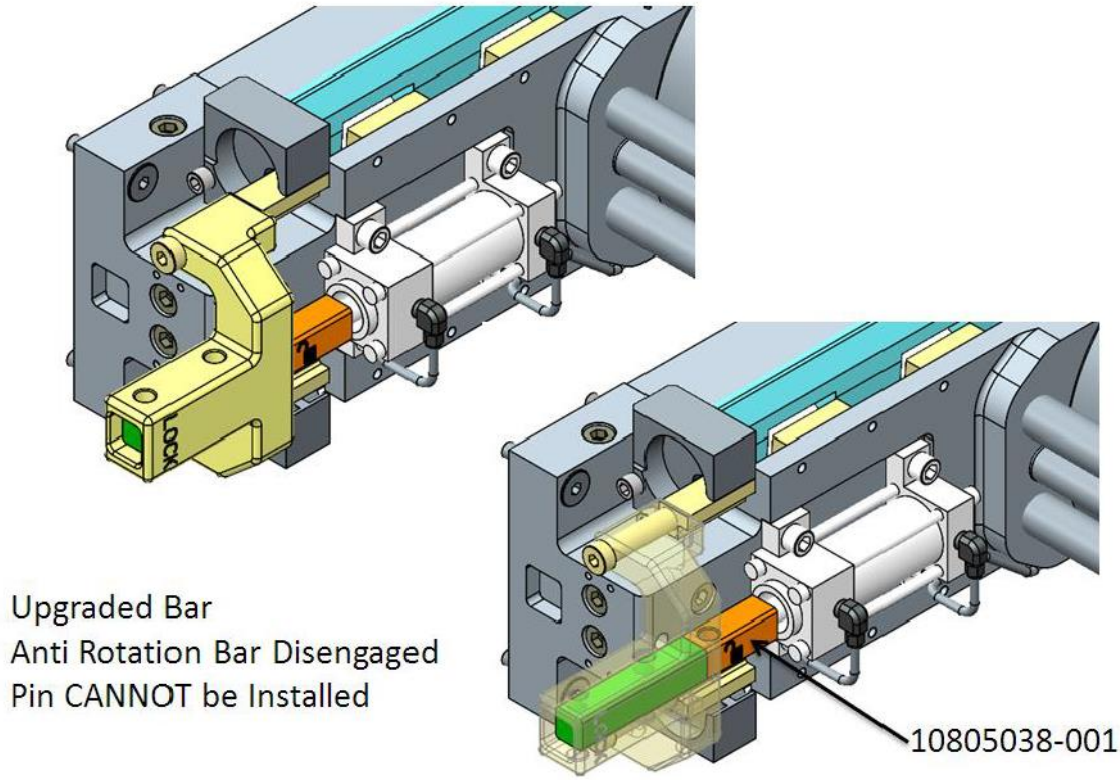


Figure 13 Illustration from safety report D4511043808-PIB-001 Rev 01 showing changes to the design which involved a lengthened component with product number 10805038-001.

After yet another incident of incorrect use of the door-locking mechanism on the NXT BOP, a safety bulletin (no 1000012002-SA) was issued by NOV on 30 March 2017 with a reminder of the correct way to operate the anti-rotation bar.

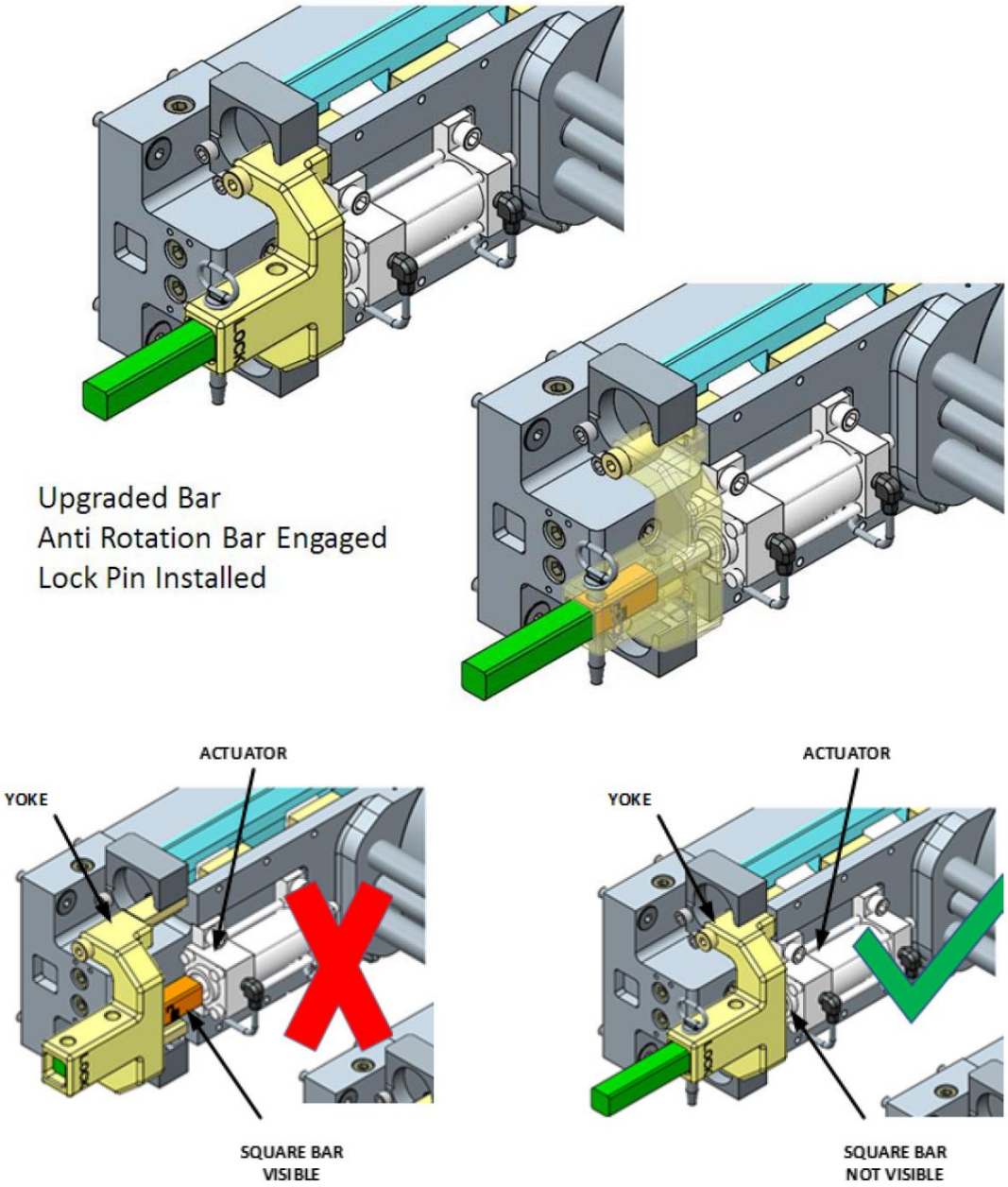
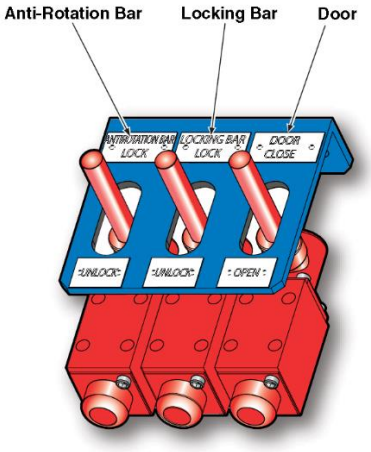


Figure 14: Images from safety bulletin 1000012002-SA issued by NOV showing the secured door with the anti-rotation bar activated and the lock pin in the correct position.

Opening and closing of ram doors



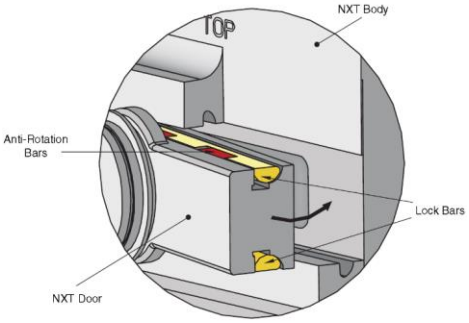


Figure 15 Control panel for the ram door system.

Ram doors in open position with the lock bars in yellow and the anti-rotation bar in red.

BOP ram door in closed position with lock bar being activated.

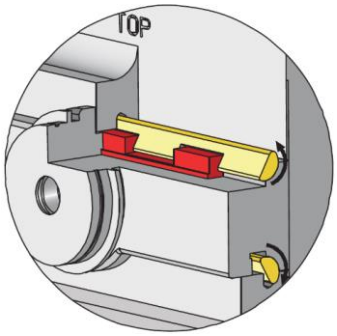
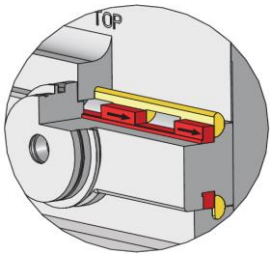


Figure 16 Indicator that the lock bar is in position..



BOP ram door with lock and anti-rotation bar activated.

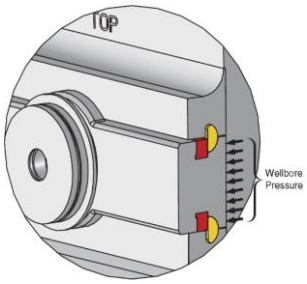


Figure 17 Anti-rotation bar in the correct position. The colours were part of the 2014 upgrade.

2.6 Position before the incident

Maintenance was carried out on the BOP when preparing the facility to drill the next section. All eight of its doors were then opened. Interviews revealed that the level of activity was high, with work in parallel on rigging up and readying equipment (MPD and BOP maintenance) to start drilling. Plans called for a BOP test after maintenance was completed. According to interviews, the BOP test was carried out on the stump on 12 September 2020 without reported problems. All the rams were tested except for the BSR, and it was decided to test this when the connection test (BOP and high-pressure riser) was carried out. The BOP was moved on 13 September from the stump to the well centre (top of the high-pressure riser) A change of subsea engineers took place on 14 September, with the one who had participated in BOP maintenance and testing leaving the facility at about 11.54. The replacement engineer arrived on *Rowan Stavanger* and, according to interviews, conducted an inspection of the BOP area without observing any irregularities (did not notice that the BOP door locks were in the wrong position).

3 The PSA investigation

The PSA received written notice from Equinor on 14 September of an incident with a BSR door blown out of the BOP during a connection test on *Rowan Stavanger*. It was decided on 28 September that the PSA would investigate the incident. The main purpose of this investigation has been to contribute to learning and to prevent recurrence. The PSA investigation team arrived on *Rowan Stavanger* at about 10.00 on 22 September after normalisation work had been completed.

Composition of the investigation team.

Name	Position	Discipline	Inspection offshore
Amir Gergerechi	Principal engineer/ investigation leader	Drilling and well technology	X
Thom Fosselie	Principal engineer	HSE management	X
Siv Adelheid Eeg	Principal engineer	Drilling and well technology	
Linn Iren Vestly Bergh	Senior adviser	Occupational health and safety	X

3.1 Method

The investigation has been conducted through interviews with relevant personnel in the land and offshore organisations at both Valaris and Equinor. An inspection was also carried out on *Rowan Stavanger* along with meetings and a review of relevant documents/logs. In addition, the Valaris and Equinor investigation report was reviewed.

Documents requested and received in connection with the investigation are listed in appendix B.

3.2 Mandate for the investigation

The following mandate was adopted for the investigation.

- Establish contact meetings with Valaris and Equinor
- Describe the course of events
- Discuss barriers which have functioned
- Assess and discuss the description of underlying causes
- Assess actual and potential consequences
- Actual harm caused to people, material assets and the environment
- The incident's potential to harm people, material assets and the environment
- Discuss and describe possible uncertainties/unclear points
- Identify nonconformities and improvement points related to the regulations (and internal requirements)
- Prepare a report and a covering letter (possibly with proposals for the use of reactions) in accordance with the template
- Assess reports from the players
- Recommend – and contribute to – further follow-up by the PSA

4 Course of events

To obtain a comprehensive understanding of the course of events, it is appropriate to look at historical developments from the time the new BOP design was introduced in 1999. The description of the course of events is based on interviews, documents received and a meeting with the manufacturer (NOV).

4.1 History

Date		Description	Comments
1999		Shaffer introduces NXT as the first bolt-free BOP	
4 Jun 2010		Two incidents with NXT BOP during test (location of these incidents not known to the	Safety bulletin (D451000167-PIB-001) issued by NOV on

Date		Description	Comments
		team)	correct use of lock mechanism. The door-locking mechanism had not been activated and the safety pin was incorrectly installed
17 Jun 11		*Rowan Stavanger* receives AoC from the PSA	
28 Mar 12		PSA gives Talisman Energy Norge consent to use *Rowan Stavanger* for production drilling on the Rev field	An NXT BOP is used
19 Apr 12		Incident with an NXT BOP on *Maersk Guardian*	Safety bulletin (D4510655285-PIB-001-Rev 01) issued by NOV. Door-locking mechanism not activated, door blew off at 336 bar
10 Sep 14		Incident with NXT BOP on *Ensco 102*	Anti-rotation bar was not armed, although the safety pin was installed in the lock position (only installed in the yoke, but not through the hole in the green indicator). Door blew off at 214 bar
Mar 17		Incident with NXT BOP, BP	Anti-rotation bar was not in correct position, door blew off the BOP during pressure testing
2018		*Rowan Stavanger* contracted by Equinor to drill several wells,	Requirement in contract from Equinor to have

Date		Description	Comments
		including on the Gudrun field	subsea engineers on board
Apr 19		Rowan merged with Ensco as EnscoRowan	
Jul 19		EnscoRowan changed name Valaris	
27 Aug 19		PSA gives Equinor consent to use *Rowan Stavanger* for production drilling on Gudrun	
30 Oct 19		Incident with NXT BOP, Altens, Aberdeen (workshop)	Annulus ram blew out of the BOP during pressure testing. Door blew off at 714 bar
2019		Valaris decided to appoint subsea personnel, and changed the personnel composition on *Rowan Stavanger*	Management of change (MOC) process lacking
		Valaris hires in three subsea engineers from three different companies	No training and expertise matrix for subsea personnel
2019-20		Subsea personnel had been on board for about four-five tours each	
26-29 May 20		Equinor verified the pressure control system on *Rowan Stavanger*. Verification report TPD D&W MU.2VCO_000388	Five of 16 findings were in the red category. Based on these observations, the conclusion of the verification was set at red

4.2 Course of events

Date	Time	Incident	Comments
Sep 20		Maintenance work on BOP, all doors opened for inspection	High level of activity, work on BOP was to be completed
Sep 20		Subsea engineer asked for NOV engineer to be retained on board in order to help with the PosLock system for closing and locking ram doors	Refused
11 Sep 20		BOP doors shut by subsea engineer and mechanics	Subsea engineer used manual from the supplier for closing and locking ram doors
12 Sep 20	03.30	BOP test on stump: 690 bar body test 3 x pipe ram test to 570 bar 4 x outer HCR test to 690 bar	Drilling superintendent (RDS) did not verify lock mechanism as specified in the procedure, but the test was conducted without problems
13 Sep 20		Moved BOP to well centre	
13 Sep 20		Connected BOP to high-pressure riser	
14 Sep 20		Crew change for subsea engineers	
14 Sep 20		BOP connection test, including BSR test, conducted in parallel (low-pressure test 20 bar with closed BSR)	Low-pressure test at 20 bar for five minutes conducted without problems
14 Sep 20		BOP connection and BSR tests conducted, this time with high pressure	Pressure was to increase from 20 to 570 bar
14 Sep 20		BOP BSR blew out	Pressure was at 108 bar

14 Sep 20		The ram was blown a distance of four metres and landed on the roof of a logging container	

5 Potential of the incident

5.1 Actual consequences

The incident caused a spill of drill water and hydraulic fluid to the weather deck on the Gudrun facility. Operations on *Rowan Stavanger* were delayed, but material damage to the BOP and the facility was limited. According to Equinor, operations on *Rowan Stavanger* were delayed by 11 days.

5.2 Potential consequences

The investigation team's assessment is that the incident could have led to the loss of both primary and secondary barriers in the well if the lower pipe ram (LPR – see figure 6) had blown out during MPD. This is because, during MPD operations, the mud weight against the formation pressure is set lower than expected and the remaining pressure differential is regulated with backpressure. Losing the LPR on the BOP could have caused a loss of well control with a big potential for harm to people, the environment and the facility.

6 Direct and underlying causes

6.1 Direct cause

The direct cause of the incident was that the anti-rotation bar was in the wrong position after closing the BOP doors. The incident occurred when the BSR test was to be carried out in combination with the BOP pressure test.

6.2 Underlying causes

A number of underlying causes have been identified for the incident on *Rowan Stavanger*. These primarily related to:

- design of the lock mechanism – human-machine interface
- expertise of and training for personnel
- procedures and governing documents
- management of change (MOC)
- roles, responsibilities and sharing of information in the organisation
- workload and inclusion of personnel on board
- contractual requirements and pressure on costs
- the operator's discharge of its see-to-it duty.

6.2.1 Design of the lock mechanism – human-machine interface

Rowan Stavanger has an NXT-type BOP. This design differs from other BOPs in that all rams except the annular ram are equipped with doors. These are operated hydraulically and make handling during maintenance more efficient.

Interviews and the document review reveal that the design of the NXT BOP provided little information in a manner which gave executing personnel the right data to form a picture of how the lock mechanism should be operated correctly. The following examples illustrate this.

- The lock system failed to give a clear indication that the anti-rotation bar was in the right position. The ram-door locking system on the NXT BOP had no fail-safe mode, which meant the bar was placed in the wrong position and the lock pin was inserted in the wrong hole.
- A lack of transparency meant the system contributed little to the actions needed to install the lock correctly. The pin used to secure the anti-rotation mechanism, for example, could be inserted even though the bar was in the wrong position.
- The system failed to present the information needed to take good decisions. The colours used to show the bar's position in the locking system were easy to misunderstand. Interviews revealed that this was case with the meaning of the colours green and orange. Personnel involved assumed that orange meant the bar was in the locked position, but this was incorrect.

These factors contributed to a lack of information needed by personnel to understand the position and do their job properly. The complexity of and weaknesses in the design reduced opportunities to interpret information and foresee necessary actions. Correct use of the NXT BOP depended to a great extent on specific training and experience.

Based on documents received, a total of six earlier incidents related to the NXT BOP ram-door locking system and anti-rotation bar have been registered since 2010. These recurrent incidents contributed to the system being modified in 2012 and 2014. After the latest modification in 2014, further incidents were nevertheless reported in relation to this equipment.

Incidents even after the modifications make it appropriate to ask how far knowledge of human aspects has been incorporated in developing and modifying the NXT BOP. The modifications made in 2012 and 2014 with regard to colour-coding of the ram-door lock mechanism on the NXT BOP and changes to the lock pin could have introduced new error risks. The investigation team believes that attempts at improvement through upgrading the lock mechanism on the NXT BOP were inadequately evaluated in terms of the human-machine interface.

Neither management nor executing personnel were aware to any extent of possible problems related to the lock mechanism's complexity. Interviews revealed that risk and uncertainty related to operating the lock mechanism were inadequately assessed

and handled ahead of doing the work. It appears that Equinor, Valaris and NOV all paid insufficient attention to risk associated with the NXT BOP design.

During an interview with NOV, the investigation team was informed that the manufacturer lacked a complete overview of incidents involving the NXT BOP. NOV explained that companies owning the equipment did not always report incidents to the manufacturer.

Paying inadequate attention to challenges with the human-machine interface and an inadequate overview of incidents were not conducive to creating good conditions for safe and robust operation.

6.2.2 Expertise of and training for personnel

The BOP doors are locked manually, which calls for equipment-specific expertise and experience. It emerged from the investigation that neither supervisory nor executing personnel in the *Rowan Stavanger* organisation had received relevant and specific training with the ram-door locking system for the NXT BOP. Personnel were also unaware of design weaknesses in and earlier incidents with this BOP type.

The investigation found that the subsea engineers on temporary contracts lacked knowledge of and expertise about the NXT BOP. Interviews revealed that no expertise matrix had been established for subsea engineers on temporary contracts, and no form of familiarisation with systems and equipment was provided for new temporary hires. No documents were presented to show that Equinor or Valaris had verified the equipment-specific expertise of the subsea engineers.

Valaris had no expertise requirements of training for personnel who were meant to support the subsea engineer in locking the ram doors. In addition, personnel who were to verify locking the doors – such as the RDS – lacked expertise about the NXT BOP locking system. Training with the BOP was particularly important, given that the NXT model had been modified twice in the past 10 years. The user manual utilised during maintenance had not been updated to take account of these changes.

Lack of knowledge about and overview of training could have contributed to setting incorrect priorities and taking the wrong decisions ahead of the incident.

6.2.3 Procedures and governing documents

The investigation found that governing documents had not been updated and were deficient.

- Work instruction *WIT-120/E76/N-CLASS-DR-BOP-099*. The images included referred to an older design of the lock mechanism from 2012.
- User manual *NXT Ram BOP, 18¾-15M with UltraLock II™ (B) and 22" PosLock® Operators*. The manual used dated from 2010 and lacked accurate information on the latest design changes to the lock mechanism in 2012 and 2014.

Failure to comply with procedures ahead of the incident was also identified.

- Work instruction *BOP - Pressure Test - Setback Area (Test Stump), WI-R91-DR-BOP-019* requires work permits (WPs), which were not obtained.
- Work instruction *BOP - Pressure Test - Setback Area (Test Stump), WI-R91-DR-BOP-019* required the person responsible for the WP to verify correct locking of doors. This was not done.

Personnel used the manual from the manufacturer for closing and locking the ram doors in the NXT BOP. Interviews revealed that the manual from the year of manufacture (2010) was the only version available in the maintenance file offshore. Interviews and the document review with NOV also showed that the updated manual for the lock mechanism from 2015 was not precise about the colour coding. See the 2014 design upgrade. The manual did not refer to the green and orange colours.

The subsea engineer involved in shutting the BOP doors had made several unsuccessful attempts on their previous tour to find work instructions for the NXT BOP in the Valaris system. This had been reported to the responsible person in Valaris.

The investigation has found that the relevant work instructions were not updated after the last modifications to the ram-door locking system. Interviews revealed that no nonconformity had been entered either in governing documents or in the Valaris nonconformity system. Nor has the investigation found that the system contained proposals for updating the relevant work instructions. It emerged that NOV does not issue an updated manual as part of the delivery after modifications. According to NOV, companies which have purchased the equipment must themselves request and pay for updated manuals.

Several changes were made to the Valaris management system in 2019-20. The investigation found that the maintenance system was replaced in connection with the international merger of Rowan and Ensco. Interviews revealed that this meant documentation and certificates lay unsorted in a number of folders, and personnel spent a lot of time finding documents.

As part of Valaris, Rowan Norge adopted new common management systems for operation and maintenance in 2020. The investigation has found that updating the management system has presented operational and maintenance challenges on *Rowan Stavanger*. It was reported in interviews that quality assurance of the management system is largely left to the offshore organisation. This meant that necessary changes were not made to governing documents.

When introducing new management systems, templates for governing documents, procedures and work descriptions have also changed. Interviews with offshore personnel revealed that changing or updating procedures has been challenging because the process involves the Houston head office to a greater extent than before.

6.2.4 Management of change (MOC)

Interviews and the document review reveal that Valaris had failed to pursue a systematic and managed process for changing crew composition on *Rowan Stavange*r. The requirement from the operator for subsea engineers, which followed from a new contract, was handled without assessing the consequences of errors related to the NXT BOP and the expertise of new subsea engineers on temporary contracts.

Introducing a new subsea post on board has highlighted ambiguities around ownership of and responsibility for BOP maintenance. Such work is the responsibility of the maintenance supervisor (MS), who admitted in interviews to little expertise with BOPs. The RDS as owner of the equipment is not directly involved in its actual maintenance. Interviews have revealed that the transition from completing maintenance and delivering the BOP to the drilling team has involved ambiguities in responsibility and ownership on board. The offshore organisation has largely left it to the subsea engineer to control maintenance and make preparations for BOP testing.

Interviews revealed that management-system changes are often initiated from the Houston head office and introduced without a process for employee involvement and quality assurance. Personnel therefore found that the systems did not function well at local level.

The investigation has found that MOC has been deficient throughout the chain of changes, and that a clear link exists between causes of the incident and the changes which have been made.

6.2.5 Roles, responsibilities and sharing of information in the organisation

According to the Valaris organogram, the maintenance supervisor on *Rowan Stavanger* had reporting responsibility for the subsea engineers. Introducing a new post meant that the maintenance supervisors were given resource responsibility for the subsea engineers on board.

It emerged from the investigation that roles and responsibilities related to the subsea engineer, maintenance supervisor and RDS were not clearly understood. Interviews revealed that no clear understanding existed over who the subsea engineer reported to and who had responsibility for what equipment. Interviews revealed that subsea personnel reported to various with regard to BOP maintenance.

Furthermore, interviews revealed that certain maintenance supervisors thought that safety-critical equipment like the BOP belonged to the drilling team rather than the maintenance department. The maintenance supervisors knew little about the NXT BOP system, and had little ownership of the BOP. That could have contributed to the failure to update rig-specific procedures and equipment manuals.

It emerged from interviews that *Rowan Stavanger* received little technical support from the land organisation, and personnel felt that the offshore organisation was left

in many cases to its own devices. *Rowan Stavanger* had no position responsible for coordinating maintenance with the land team,.

Information-sharing in the organisation before the incident was deficient. It is unclear how safety-critical information was adequately addressed and communicated to relevant people in the organisation. Little information was conveyed through traceable reporting systems. Bulletins, for example, were distributed by e-mail without follow-up of whether the information was received and acted on. Important information on earlier incidents with ram doors on the NXT BOP was not adequately communicated across the organisation. The investigation found that design changes were not reflected in relevant procedures, manuals or internal training. That could have contributed to inadequate shared understanding of risk and poor decisions.

6.2.6 Workload and inclusion of personnel on board

Preparing the facility to drill the next section of well 15/3-A-08 was a hectic period with a high level of activity. At the same time, personnel from other companies were working to rig up the MPD system, which has an interface with the rig's own systems. Plans also called for maintenance work on the BOP as well as class inspection of the BSR by NOV. Its inspector was only there to certify the BSR, and had returned to land before the BOP doors were shut.

Before the incident, personnel experienced a high workload and pressure of time while readying the BOP for drilling. Interviews revealed that a single subsea engineer was solely responsible for BOP maintenance. Ahead of the incident, this person asked the management to provide support with the PosLock system by extending the presence offshore of the NOV inspector, who was still on board. The latter confirmed in an interview with the investigation team that he was asked to do this by the subsea engineer. The request was refused and the subsea engineer had to do the job alone. Nobody, either offshore or on land, could explain who had turned down the request and on what grounds. Furthermore, interviews revealed that few others on board knew anything about the NXT BOP and that this contributed to the failure to provide the subsea engineer with sufficient support.

Several interviewees reported that the subsea engineer was left to their own devices over work on the BOP. The subsea engineers, who were temporary hires, never worked together on *Rowan Stavanger* and were therefore unable to discuss their assignments in detail. Coming from three different companies, they did not know each other particularly well. That contributed to weak collaboration between them. Furthermore, interviews revealed that the subsea engineer was only included to a limited extent in important local processes such as the detailed operations plan (DOP) and safety work on board.

Interviews and the document review revealed that a verification of the well control system on board was conducted by Equinor in March 2020. This yielded 16 findings, including five classed as red (critical condition, lack of conformity with regulatory or

internal requirements, need for immediate action, management at higher levels to be informed). At the time of the incident, the verification findings had passed the deadline for action without corrective measures being taken. Interviews revealed that considering and correcting nonconformities was largely left to the offshore organisation. This was perceived as a burden for personnel. Crew offshore also felt that support from the land organisation was inadequate.

Work on the NXT BOP was poorly organise, so that executing personnel were exposed to undesirable work loads. Lack of knowledge, inadequate support, parallel activities and a heavy workload contributed to exposures posing a health hazard for individuals, which could have influenced assessments of the complexity in the circumstances and reduced attention. This was reinforced by the company's failure to have appropriate procedures available for handling the BOP lock mechanism in order to ensure prudent planning and execution of the work assignment.

6.2.7 Contractual requirements and pressure on costs

Contractual requirements are an important operating parameter, which can potentially influence decisions and priorities. Interviews revealed that such terms and pressure on costs may have contributed to the failure to take the necessary action on *Rowan Stavanger* to ensure prudent conditions on board ahead of the incident.

Equinor's requirement for a subsea-engineer position was basically meant to apply to semi-submersibles where the BOP sits on the seabed. It was incorporated in the contract for *Rowan Stavanger*, which has the BOP on the surface. The investigation found that Equinor used the same semi-submersible template without making assessing the inclusion of this requirement in the contract for *Rowan Stavanger* on Gudrun. That could have led to a lack of clarity over responsibilities, inadequate risk understanding and uncertainty over rig-specific equipment for personnel on *Rowan Stavange*r.

The investigation found that follow-up of the requirement for a subsea engineer on *Rowan Stavanger* by Valaris was deficient. It had done little to make provision for and provide good/realistic conditions for these temporary hires to do their job in the best possible way. Interviews revealed that nobody from the land organisation had been tasked with following up the temporary hires directly in relation to their assignments on board. The possible consequences of the decision to use three hire companies and the process for including the temporary hires appear to have received little consideration.

Interviews revealed that a number of those on board felt they had a high workload and were under pressure to deliver efficient operations. Pressure on time may have influenced work on readying the BOP in order to avoid postponing operations. Executing personnel felt under pressure to complete the maintenance work so that the BOP could be pressure-tested before moving it to the well centre and starting to drill. Excessive concentration on efficiency and costs may thereby have helped to

reduce the ability of Valaris to ensure prudent planning and execution of work in the organisation.

Interviews with management on land revealed that *Rowan Stavanger* has made a loss from the contract to drill wells on Gudrun. The investigation team was told that *Rowan Stavanger* receives a reduced rate for downtime and that the time required for BOP maintenance had been underestimated.

6.2.8 The operator's discharge of its see-to-it duty

Equinor failed to conduct adequate follow-up of correcting nonconformities and handling of measures following an internal verification: *Well control system and BOP safety function verification* Rowan Stavanger *26-29 May 2020*.

Interviews revealed that follow-up meetings had been held to review findings from verification of the well control system on 26-29 May 2020. During the investigation, however, it emerged that the nonconformities had still not been corrected. It also emerged that no overall assessment had been made of whether further drilling would be prudent. Drilling operations continued on *Rowan Stavanger* despite the failure to correct nonconformities.

Furthermore, it emerged that Equinor had done little to follow up how Valaris implemented its requirement for a subsea-engineer post in *Rowan Stavanger*'s offshore organisation, including possible assessments of the decision to bring in subsea engineers on temporary contracts from hire companies.

7 Observations

The PSA's observations fall generally into two categories.

- Nonconformities: this category embraces observations where the PSA has identified breaches of the regulations.
- Improvement points: these relate to observations where deficiencies are seen, but insufficient information is available to establish a breach of the regulations.

7.1 Nonconformity: Installations, systems and equipment

The lock mechanism on the BOP ram doors were not designed in a way which reduced the threat of errors with significance for safety.

Grounds

Interviews and the document review revealed that the design of the NXT BOP failed to provide adequate information in such a way that executing personnel had the right data to understand how the lock mechanism should be correctly installed.

- The lock system failed to give a clear indication that the anti-rotation bar was in the right position. The ram-door locking system on the NXT BOP had no

fail-safe mode, which meant the bar was placed in the wrong position and the lock pin was inserted in the wrong hole.
- A lack of transparency meant the system contributed little to the actions needed to install the lock correctly. The pin used to secure the anti-rotation mechanism, for example, could be inserted even though the bar was in the wrong position.
- The system failed to present the information needed to take good decisions. The colours used to show the bar's position in the locking system were easy to misunderstand. Interviews revealed that this was the case with the meaning of the green colour, which was thought to mean open rather than closed.

Requirement

Section 10 of the facilities regulations on installations, systems and equipment

7.2 Nonconformity: Lack of expertise on facility-specific equipment (NXT BOP)

Valaris failed to ensure that personnel had the equipment-specific expertise on the NXT BOP required to execute activities in accordance with the HSE legislation, including the handing of hazards and accidents.

Grounds

- It emerged from the investigation that neither supervisory nor executive personnel had received relevant and specific training with the ram-door locking system for the NXT BOP. Personnel were also unaware of design weaknesses in and earlier incidents with the same BOP type.
- Interviews revealed that no expertise matrix had been established for new subsea engineers. In addition, the RDS – who was to verify locking the ram doors – lacked specific expertise on the NXT BOP locking system. Nor was any form of familiarisation with systems and equipment provided for new temporary hires.

Requirement

Section 21 of the activities regulations on competence

7.3 Nonconformity: Inadequate procedures and compliance

Valaris had failed to ensure that maintenance procedures for the BOP were formulated or applied in a way which fulfilled their intended functions.

Grounds

Governing documents had not been updated and were deficient.
- Work instruction *WIT-120/E76/N-CLASS-DR-BOP-099*. The images included referred to an older design of the lock mechanism from 2012.
- User manual *NXT Ram BOP, 18¾-15M with UltraLock II™ (B) and 22" PosLock® Operators*. The manual used dated from 2010 and lacked accurate information on the latest design changes to the lock mechanism from 2012 and 2014.

Failure to comply with procedures ahead of the incident was also identified.

- Work instruction *BOP - Pressure Test - Setback Area (Test Stump), WI-R91-DR-BOP-019* requires work permits (WPs), which were not obtained.
- Work instruction *BOP - Pressure Test - Setback Area (Test Stump), WI-R91-DR-BOP-019* required the person responsible for the WP to verify correct locking of doors. This was not done.

The investigation found that a confirmatory check that the ram doors were correctly closed and locked before pressure testing of the BOP on the stump was not done. Nor were the ram doors checked before the connector test on the well.

To sum up, it can be said that inadequate formulation of and compliance with procedures have contributed to the incident. See section 6.2.3

Requirement

Section 24 of the activities regulations on procedures

7.4 Nonconformity: Lack of management of change (MOC) process

Valaris had not ensured that issues related to HSE were comprehensively and adequately addressed when changing crew composition on *Rowan Stavanger*.

Grounds

- Requirements from the operator had been met without assessing the consequences of errors related to the NXT BOP and the expertise of new subsea engineers on temporary contracts.
- Valaris went through a number of organisational changes in 2019-20 during the integration of the merged company. *Rowan Stavanger* began a new contract for Equinor on Gudrun and also acquired a new subsea engineer post on board.

The investigation has found that MOC was deficient throughout the whole chain of changes, and that a clear relationship exists between the causes of the incident and the changes made (see section 6.2.4).

Requirement

Section 11 of the management regulations on the basis for making decisions and decision criteria

7.5 Nonconformity: Unclear roles and responsibilities

Roles and responsibilities were not adequately clarified and understood by management and executing personnel on *Rowan Stavanger*.

Grounds

- Interviews revealed difference in understanding about who the subsea engineers reported to and who was responsible for what equipment. It

emerged that personnel reported to different supervisors on BOP maintenance.

- Interviews revealed that certain maintenance supervisors thought that safety-critical equipment like the BOP belonged to the drilling team and not the maintenance department.
- The maintenance supervisors knew little about the NXT BOP system, and had little ownership of the BOP.

Requirement

Section 6, paragraph 2 of the management regulations on management of health, safety and the environment

7.6 Nonconformity: Inadequate information-sharing

Valaris had not communicated the necessary information to relevant users which would enable them to plan and execute activities and to improve HSE.

Grounds

- Critical information, such as bulletins related to design changes, were distributed by e-mail without follow-up of whether the information was received and acted on by recipients. The investigation found that design changes were not reflected in relevant procedures, manuals or internal training.
- Safety-critical information was not communicated through traceable reporting and/or nonconformity systems. *Rowan Stavanger* had no arrangement which ensured that all maintenance supervisors were informed about safety bulletins.
- Management or executing personnel had little idea about possible issues related to the complexity of the lock mechanism. Interviews revealed that risk and uncertainties related to operating the mechanism had not been adequately assessed and handled before executing work. Failures in internal communication of information could have contributed to inadequate understanding of risk and poor decisions.
- Valaris had done little to ensure that risk data about the NXT BOP were utilised in executing and following up activities in various phases of the business, and to implement corrective and preventive measures.

Requirements

Section 15 of the management regulations on information

Section 19 of the management regulations on collection, processing and use of data

7.7 Nonconformity: Inadequate organisation of work

Valaris had not ensured that the work was organised in such a way that strains which could be injurious to health were avoided and that the likelihood of mistakes which could lead to hazards or accidents was reduced.

Grounds

- Organisation of the work on board took little account of opportunities for and restrictions on personnel to do their jobs in good way. Interviews and the document review reveal that executing personnel experienced an increased workload before the incident and that planning for maintaining and testing the BOP was inadequate. A single subsea engineer was solely responsible for BOP maintenance. The one on board during the incident had asked for the NOV inspector to be retained on board in order to provide assistance with the PosLock system, but this was refused. Interviews revealed that others on board generally knew little about the NXT BOP, which contributed to inadequate support for the subsea engineer. A number of those interviewed said that the subsea engineers were left to their own devices with regard to work on the BOP.
- Lack of knowledge about the BOP, inadequate technical support, parallel activities, heavy pressure of work and a big scope of work contributed to strains which could be injurious to health, and which may have influenced assessments of the complexity of the conditions and reduced the attention paid to BOP maintenance. This could have contributed to offshore personnel taking unfortunate decisions ahead of the incident. A heavy workload combined with lack of support and training was reinforced by the company's failure to have appropriate procedures available for handling the BOP lock mechanism in order to ensure prudent planning and execution of the work.

Requirements

Sections 33 and 35 of the activities regulations on organisation of work and on psychosocial aspects respectively

7.8 Nonconformity: Shortcomings in discharging the operator's see-to-it duty

Equinor has not seen to it that Valaris complies with the requirements in the HSE regulations.

Grounds

- When Equinor instructed Valaris to change manning, it ignored the risk associated with the NXT BOP design. The company failed to follow up adequately that nonconformities were corrected and measures implemented after its *Well control system and BOP safety function verification Rowan Stavanger 26-29 May 2020*.

Equinor failed to follow up

- its requirement for a change of manning in the maintenance department through the introduction of a subsea-engineer post offshore
- expertise of new personnel
- available procedures and manuals
- the expertise matrix for OJT of subsea engineers offshore.

Requirements

Sections 7, paragraph 2, and 18 of the framework regulations on responsibilities pursuant to these regulations and on qualifications and follow-up of other participants respectively

8 Barriers which have functioned

Tests with the BOP before use in the operation:

- BOP connection and BSR testing was conducted before the actual operation began.

The BOP test ahead of the connection test failed to uncover a fault and thereby gave a false positive result.

Cordoning-off the area:

- No people were in the area.

Cordons were established for the connector test, but the BOP door landed on a container roof outside the cordoned-off area.

The investigation has found that very few organisational, operational or technical barriers related to the incident functioned.

9 Discussion of uncertainties

- Uncertainties exist over how far the Covid-19 pandemic has influenced the work performance of personnel involved because of infection controls and restrictions. Certain interviewees reported that they had been away from their families for several months because of the quarantine rules.
- Uncertainty exists over how much pressure the locking bar in the door lock mechanism can withstand without rotating back into the open position because the anti-rotation mechanism fails to activate. According to NOV, more detailed investigations are needed to answer this.
- The investigation team is uncertain about the possible effects of carrying out upgrades proposed by the manufacturer in 2014 using Rowan personnel, and without participation from the manufacturer.

10 Assessment of investigation reports by the players

10.1 Valaris investigation report

The *BOP Pressure Test Incident VALARIS Stavanger final report* was received by the PSA on 3 November 2020. It was completed in the company on 20 October 2020. The report has no input from personnel with expertise on human and organisational factors and from NOV as the BOP supplier.

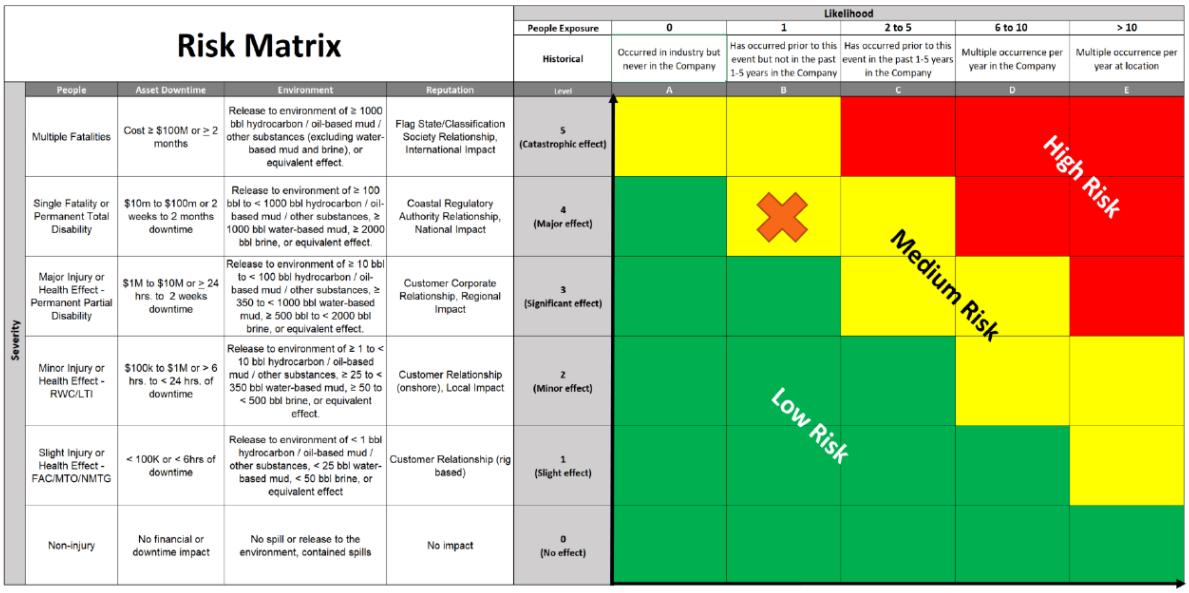
To a great extent, the Valaris report emphasises human error as the underlying cause of the incident. It does not address to the same extent how the incident related to latent conditions (organisational, operating parameters and local operational conditions) in the organisation. Experience from the PSA's investigations and technical reports shows that human error occurs at the interface between the individual and conditions in the organisation. Errors often arise within a broader organisational framework and relate to both local operational, technical and organisational conditions and operating parameters.

The potential of the incident is assessed as yellow (1B-4, see table 1). This assessment is based on the level of seriousness and frequency (whether such an incident has occurred earlier in the company). Based on the matrix, it is therefore impossible to assess other conditions and uncertainties relevant to the potential of the incident. The PSA team would question the assessment of the level of seriousness established where the consequences for the environment and injury to personnel are concerned. Had the LPR (see figure 3) blown out during the MPD operation/drilling in the reservoir, the level of seriousness in relation to harm to personnel, facility and the environment would have been higher than is suggested in the report.

Valaris does not discuss the parameters set by the applicable contract in its report.

The Valaris report does not discuss whether the Covid-19 position could have had an indirect effect on the incident on *Rowan Stavanger*.

Table 1 Valaris risk matrix.



10.2 Equinor investigation report

Equinor's report – *A 2020-16 TPD L2- 2020-001246_COA granskings-rapport BOP på* Rowan Stavanger – was received by the PSA on 23 November 2020. It was completed in the company on 13 November 2020. The report comes across as structured and gives a well-ordered and detailed description of consequences. According to the description in the report, the safety delegate service has participated in the investigation team. The latter has not included a permanent participant with expertise on human and organisational factors

Equinor's investigation report notes that significant challenges were presented by the NXT BOP design, but takes little responsibility for and ownership of this risk, and has not included this subject among its own learning points.

The report recommends a review of the rig intake process through the see-to-it duty and the factory acceptance test (FAT) process with a view to securing the right expertise.

Equinor's investigation team has classified the incident as an HSE incident – accident, with the highest actual level of seriousness: Actual green 5 – uncontrolled discharge, and Actual green 4 – costs/losses. The highest level of seriousness under slightly different circumstances is classified as Possible red 2 – failure of safety functions and barriers.

Table 2 Classification of incident in relation to internal guidelines GL0455. Source: Equinor

Konsekvenskategori	Faktisk alvorlighetsgrad	Potensiell alvorlighetsgrad
Personskade	Ingen	Ikke klassifisert på grunn av lav sannsynlighet
Arbeidsrelatert sykdom	Ingen rapportert så langt	
Ukontrollerte utslipp	5 - "Enkeltutslipp til omgivelsene med neglisjerbar miljøpåvirkning"	5 - "Enkeltutslipp til omgivelsene med neglisjerbar miljøpåvirkning"
Olje- / gasslekkasje	None	Ikke klassifisert på grunn av lav sannsynlighet
Brann / eksplosjon	None	Ikke klassifisert på grunn av lav sannsynlighet
Svekking / bortfall av sikkerhetsfunksjoner og barrierer		2 – "Truer store deler av installasjonen / anlegget "
Tap av produksjon	None	Ikke klassifisert på grunn av lav sannsynlighet
Kostnader / tap	4 – ">500 000 NOK"	4 – ">500 000 NOK"

Equinor does not discuss operating parameters in the applicable contract. Nor does the investigation team discuss whether the Covid-19 position could have had an indirect effect on the incident on *Rowan Stavanger*.

11 Appendices

A: Cause and effect analysis

B: Documents used in the investigation

C: Overview of personnel interviewed