PETROLEUMSTILSYNET

Investigation report

Report	
Report title Report of the investigation into a gas leak on Aasta Hansteen, 8 April 2019	Activity number 001218029

Security grading		
☐ Public	☐ Restricted	☐ Public
☐ Not publicly available	☐ Confidential	☐ Not publicly available

Involved	
Team T-1	Approved by/date Kjell Marius Auflem 24 March 2020
Members of the investigation team Bente Hallan, Kristi Wiger and Eivind Sande	Investigation leader Eivind Sande

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1 Summary

A gas leak occurred on the Aasta Hansteen facility operated by Equinor on 8 April 2019. It came from a rupture disc in the flare system and arose after an operational disruption which required production flaring. The Petroleum Safety Authority Norway (PSA) decided on 9 April 2019 to investigate the incident.

The flare system is a safety system intended to ensure safe handling of hydrocarbons in the process plant in the event of incidents which call for depressurisation and emergency shutdown of the plant. This reduces the risk for and probability of escalation. Incidents which weaken or disable the flare system are therefore especially concerning.

Aasta Hansteen is designed with a closed high-pressure flare system. When flaring is required, a quick-opening valve operates so that gas can flow from the flare tip and burn. A 30-inch rupture disc is installed in parallel with the flare valve to ensure free passage for the gas if the valve fails to open as it should.

During the incident of 8 April 2019, the rupture disc burst (opened). Parts of the disc were pulled out of its holder and into the flare line. This caused an external gas leak from the disc holder, assessed to be greater than 0.1 kilograms per second (kg/s).

The gas leak was observed by personnel in the area and detected by the gas detection system. That activated a general alarm, production shutdown, deluge and depressurisation.

Detection of the leak occurred at 13.29. The personnel on board (POB) check was confirmed at 13.40. Deluge was halted at 14.15, when no detectors registered gas. Demobilisation and normalisation began at 14.50.

Production was shut down for 10.5 days as a result of the incident.

Two nonconformities have been registered, related to the following conditions:

- deficiencies in the requirements for the flare valve
- deficiencies in the installation of the rupture disc with holder.

See chapter 7 for a more detailed description of these conditions.

2 Background information

In connection with production flaring, a gas leak occurred on 8 April 2019 on the Aasta Hansteen facility operated by Equinor.

2.1 Description of the facility and the organisation

Aasta Hansteen lies in the northern Norwegian Sea, 120 kilometres north-west of Norne. The water depth in the area is 1 270 metres. Aasta Hansteen was proven in 1997, and the plan for development and operation (PDO) was approved in 2013. The field has been developed with a floating Spar platform featuring a vertical cylindrical hull moored to the seabed. In addition come two four-slot subsea templates and two satellite templates with one slot each. These structures are tied back to the platform by flowlines and rigid steel risers. The Aasta Hansteen Spar was towed to the field in early 2018. All production wells were predrilled in 2018 and the field came on stream that December.

Gas from Aasta Hansteen is transported in the Polarled pipeline to the Nyhamna terminal in Møre og Romsdal county. Associated light oil is loaded into tankers for shipment to market.

Licensees in production licence 218 are:

- Equinor Energy AS	51%
- Wintershall Norge AS	24%
- OMV (Norge) AS	15%
- ConocoPhillips Scandinavia AS	10%

Equinor is operator for the field.

2.2 Position before the incident

Aasta Hansteen was in normal operation before the incident on 8 April. A wind speed of 14 knots with a direction of 324 degrees north-west was recorded.

Recurring problems with a recompressor meant parts of the production on Aasta Hansteen had been flared for periods. When the recompressor was out of service, the flare valve (43ESV1036) had to be in the open position. The recompressor had not been operational for a time ahead of the incident but, when the latter occurred, it had just restarted and the flare valve was closed.

2.3 Description of the flare system and equipment relevant to the incident

The flare system is designed to prevent escalation of hazards and accidents through a rapid reduction of pressure in the plant. Aasta Hansteen's high-pressure flare is a closed system, which means that possible leaks into it are recycled to the process plant. In an event which leads to depressurisation, pressure in the high-pressure flare knockout drum (43VD001) will rise above its operational level and the quick-opening flare valve (43ESV1036) will open. A rupture disc (43PSE1041) installed in parallel with the flare valve will burst if the valve fails or does not open fast enough. The rupture disc is a safety device and bursting should not in itself increase risk. In the Aasta Hansteen incident, however, the rupture disc burst in such a way that the flanged connections failed to keep it in place in its holder, and a hydrocarbon leak occurred.

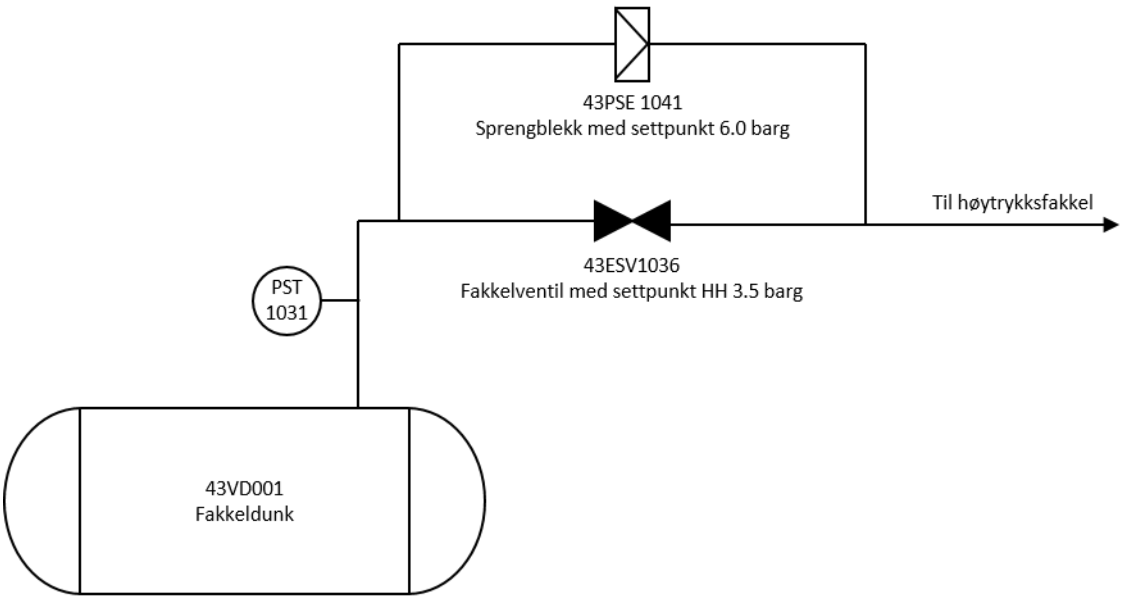
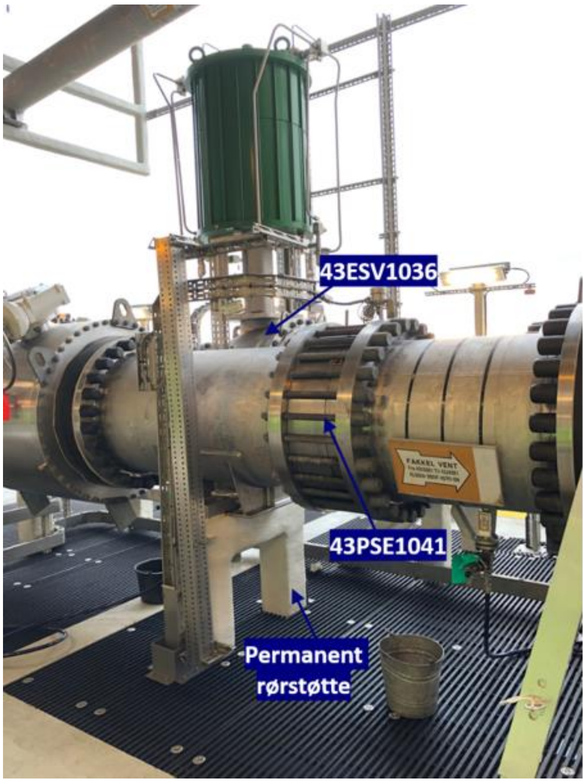


Figure 1 Simplified diagram of the high-pressure flare knockout drum and flare valve configuration.



Photos 1 and 2: Taken at the incident site while disassembling the rupture disc on 11 April 2019 (PSA).

2.4 Abbreviations

ESV – Emergency shutdown valve
PSE – Pressure safety element (rupture disc)
PST – Pressure safety transmitter

3 PSA investigation

3.1 About the investigation

Notification of the gas leak was given to the PSA’s duty officer by phone at 14.04 on Monday 8 April 2019. The notification form was formally submitted later the same day. A video meeting was held with Equinor at 10.00 on 9 April 2019, when the company provided information on the incident. This was updated in a new video meeting at 14.00. Following that meeting, the PSA decided to investigate.

The PSA’s investigation team arrived on Aasta Hansteen on 10 April 2019. Interviews with personnel directly and indirectly involved in the incident and an inspection of the incident site were conducted on 10-12 April 2019. Personnel in the Aasta Hansteen land organisation at Equinor in Harstad were interviewed on 2-3 May 2019. On 6 November 2019, the team had a meeting at Skui with Haakon Ellingsen AS, which represents BS&B (manufacturer of the rupture disc concerned) in Norway. Documentation has been obtained from both Equinor and Haakon Ellingsen.

This report has been prepared by the team on the basis of meetings, presentations, interviews, inspections and reviewing the documents received. The team has not carried out its own technical investigations, but has based its assessments on the analyses commissioned by Equinor.

3.2 Investigation team mandate

The investigation team was given the following mandate for its work.

a. Clarify the incident's scope and course of events (with the aid of a systematic review which typically describes the timeline and incidents).
b. Assess the actual and potential consequences
    1. Harm caused to people, material assets and the environment.
    2. The incident's potential to harm people, material assets and the environment.
c. Assess direct and underlying causes.
d. Identify nonconformities and improvement points related to the regulations (and internal company requirements).
e. Discuss and describe possible uncertainties/unclear aspects.
f. Discuss barriers which have functioned (in other words, those which have helped to prevent a hazard from developing into an accident, or which have reduced the consequences of an accident).
g. Assess the player's own investigation report.
h. Prepare a report and a covering letter (possibly with proposals for the use of reactions) in accordance with the template.
i. Recommend – and normally contribute to – further follow-up.

The purpose of the PSA's investigation work is to help prevent similar incidents by identifying improvement points at players involved, and through experience transfer to other players in the industry.

3.3 Composition of the investigation team

The PSA's investigation team has comprised:

Bente Hallan	–	process integrity
Kristi Wiger	–	process integrity
Eivind Sande	–	process integrity, investigation leader

4 Course of events

During leak testing of parts of the Aasta Hansteen flare system, a leak at the rupture disc installed in parallel with the flare valve for the high-pressure flare was registered on 25 March 2017. The test was conducted at the construction yard in South Korea. As a result, flanges related to the rupture disc were re-machined.

When the rupture disc was reassembled and reinstalled, clarification was obtained from BS&B on the torque for tightening bolts in the rupture disc holder. The manufacturer specified a torque of 426 Nm for this 30-inch disc. A new leak test was thereafter conducted on 19 April 2017, which also failed. Technical and commercial discussions were subsequently held over this and several other rupture disc on Aasta Hansteen, and were still ongoing when the platform left the yard on 28 September 2017.

A new leak test related to the rupture disc took place on 18 February 2018 while Aasta Hansteen lay in the Digernes Sound off Stord. In all, leaks were recorded in 13 of 16 rupture disc holders. These included the relevant rupture disc (43PSE1041) installed in parallel with the flare valve on the high-pressure flare.

Representatives from the manufacturer were present when the rupture disc was removed from the flare system at Stord, and a report from this inspection was issued on 23 February 2018. The rupture disc holder was then sent for re-machining at BS&B. After re-machining and reassembly, the disc was confirmed to be leak-free by a new test on 2 April 2018.

Because of the challenges experienced, rupture disc holders of another type were ordered in November 2018. Plans called for them to be installed during the autumn turnaround in 2019.

Aasta Hansteen left Stord on 12 April 2018 and began production on 16 December 2018.

On 25 July 2018, the alarm from the sensor monitoring whether the rupture disc had burst was blocked because a fault caused the alarm to sound continuously despite the disc being intact.

Flaring from full production took place on 19 February 2019 after an export compressor tripped. This proceeded normally, with no leaks occurring.

Actions related to signals from the rupture disc sensor were changed on 4 April 2019.

A diffuse leak from the 10-inch rupture disc for the wet gas cooler was registered on 6 April 2019. A notification was written for this discovery.

Day of the incident, 8 April 2019

At 13.12 on 8 April 2019, the flare valve on the high-pressure flare was closed. Prior to this, the platform had produced with the flare open because of problems with a recompressor.

At 13.28.38, a signal from a pressure transmitter on the gas export compressor caused the latter to trip. That led in turn to the gas being routed to the high-pressure flare knockout drum, where the pressure rose and its pressure transmitter gave a high-high (HH) alarm of 3.5 barg at 13.28.52.6. At the same time, a signal was sent to the flare valve (43ESV1036) to open. Pressure in the drum continued to rise, and the rupture disc intended to protect the drum against overpressure burst at 13.28.54.4. The measured pressure in the drum at that point was about 4.3 barg.

When the disc burst, parts of its edge were drawn into the flare line. This meant that a gas leak simultaneously occurred from the disc holder. The signal from the end limit switch on the flare valve was received at 13.28.55.3.

Five people in all visually observed the gas leak – three working close to the flare valve and two working down on the Spar deck. One of the trio working nearby was about 10 metres from the leak site. He heard something happen in the system, sounds from valves moving and being activated, and then a relatively quiet spell before the knockout drum could be heard filling. That was followed by a big bang before a leak was seen from the point where the rupture disc is installed in the flare line. The visual observation was that the whole flange was leaking, but that the jet was strongest towards the process plant. He signalled to the two others working nearby to get away, and they ran to the living quarters. Both smelt gas and observed the leak visually. On reaching the quarters, they heard that a general alarm had been activated. The leak was very noisy and was described by eyewitnesses as large. The day before, the person who had been closest to the leak was working much closer – only about four metres from the leak site.

The two eyewitnesses working on the Spar deck heard abnormal flows in pipes, and therefore looked down to the sea where they observed a play of colours on the surface. Looking up to the leak site, they saw a gas cloud extending beyond the platform edge. Both immediately began running towards the quarters. They did not have time to secure their workplace, where they had been using an air drill, since their assessment was that they had to get away from the area as quickly as possible. A general alarm was activated immediately after they began running. They heard an announcement over the PA system as they ran across the Spar deck.

The first gas detector (70GPP200A-186) gave an HH alarm at 13.29.26.9. That caused group 1N ignition source disconnection at 13.29.31.2.

The second gas detector to activate (70GPP200A-083) gave a high alarm at 13.29.35.0. That meant a confirmed gas alarm in module P200, and deluge was automatically activated at 13.29.38.2 on mezzanine deck north. It was activated on the lower and cellar decks north and south at 13.29.39.1.

Depressurisation and group 2A ignition source disconnection were automatically activated at 13.29.39.3. The general alarm was activated at the same time.

The second gas detector to activate (70GPP200A-083) gave an HH alarm at 13.29.45.8. A third detector (70GPP200A-193) gave a high alarm at the same time.

All the people on board had been counted by 13.40. There were 80 of them. The plant was declared to be depressurised at 13.55. Deluge ceased at 14.15, when no detectors recorded the presence of gas.

Demobilisation and normalisation began at 14.50.

Time	Event
13.12.00.086	Closure command given to 43ESV1036 flare valve
13.12.15.386	43ESV1036 flare valve left open position
13.12.44.186	43ESV1036 flare valve closed
13.28.38.685	27PDT1179 pressure transmitter on turbine to export compressor warned of pressure build-up for seal gas of <=0.15 bar
13.28.52.588	43PST1031 pressure transmitter for flare knockout drum received HH alarm (PSD) >=3.5 bar
13.28.52.588	43ESV1036 flare valve received open command – production flaring
13.28.54	43PSE1041 rupture disc burst, external leak occurred
13.28.54.388	43ESV1036 flare valve left closed position
13.28.55.287	43ESV1036 flare valve open
13.29.26.901	70GPP200A-186 gas detector HH-alarm >=30% LEL (single gas alarm)
13.29.31.196	Ignition source disconnection group 1N
13.29.32.292	ESD 2.11
13.29.35.000	70GPP200A-083 gas detector H alarm >=20% LEL (confirmed gas alarm)
13.29.38.163	Deluge on mezzanine north activated
13.29.39.063	Deluge on north and cellar decks north and south activated
13.29.39.295	Ignition source disconnection group 2A
13.29.39.295	Depressurisation starts from B&G node
13.29.39.295	43ESY1036 abnormal condition (ESD)
13.29.39.487	ESD 2.1 general alarm
13.29.39.487	ESD 2.4 depressurisation
13.29.45.799	70GPP200A-083 gas detector HH alarm >=30% LEL
13.29.45.799	70GPP200A-197 gas detector H alarm >=20% LEL
13.40	Confirmed POB
13.55	Depressurised plant
14.15	Deluge stopped. No detectors showing gas.
14.50	Demobilisation and normalisation

5 Potential of the incident

5.1 Actual consequences

Gas leak with a combined rate of > 0.1kg/s from two leak points in the flare line downstream from the high-pressure flare knockout drum.

Production from Aasta Hansteen was shut down for 10.5 days as a result of the incident.

5.2 Potential consequences

Equinor's calculations show that the leak rate would have been up to 3.6kg/s if the whole rupture disc had entered the flare line and the leak had only been limited by the gap between the flanges previously holding in the disc.

If all or part of the rupture disc had followed the gas flow into the line, it could have caused damage to or – in the worst case – a hole in the flare line downstream from the disc.

6 Causes and discussions

6.1 Direct cause

The direct cause of the gas leak was that the rupture disc burst in such a way that its edge was drawn into the flare line in two places. That led in turn to the loss of the seal at these points, permitting a gas leak.

6.2 Underlying causes

The team has determined that a combination of the following conditions could be underlying causes of the incident:

- misaligned installation could have caused variations in the clamping force around the disc's circumference
- a pre-assembled rupture disc was chosen, although the manufacturer recommended a pre-torqued version
- the rupture disc holder is installed in a horizontal pipe, although vertical installation is recommended for large dimensions with this type of disc
- the big dimensions made it very demanding to install the disc and its holder in the line
- the project organisation failed to pay sufficient attention to the challenges of getting the disc leak-free.

6.3 Issues relevant for this type of rupture disc

According to the rupture-disc supplier and its representatives in Norway, the type involved here – with large dimensions and stringent requirements for reliability – are demanding with respect to installation in piping and to bolt tightening. According to the documentation received, the total weight of holder and disc on Aasta Hansteen is 338 kilograms.

The rupture disc was delivered with a pre-assembled holder, where the bolts must be tightened after installation. Such a solution is very sensitive to movements and distortions by the piping it will be installed in. On Aasta Hansteen, the disc is installed in a horizontal pipe. Installing the disc vertically reduces the installation challenges. The supplier recommends a pre-torqued solution for this type of application and the dimensions involved. Since the disc is then pre-installed and tightened in the holder, it can be installed in the piping without the actual disc being affected. The assembly can also be removed for inspection without having to replace the disc. This must be done for each removal of a pre-assembled holder like the one used on Aasta Hansteen.

The rupture disc which broke was a non-fragmenting type, which means it should burst at the relevant pressure without disintegrating into fragments. The disc is meant to remain whole even after bursting.

6.4 Leak rate

According to Equinor's gas spreading analysis, the actual consequence was a gas leak with a leak rate of 0.08kg/s, giving a gas cloud of roughly 60m^3. The calculation is based on a leak point with a hole size of 110 square millimetres. This leak was reportedly directed towards the platform's west side – in other words, directly into the process area. The analysis also notes a secondary and smaller leak point on the other side of the disc, directed out over the platform edge, but this point is not included in the analysis since it was not considered likely to affect the main conclusions.

The team's conclusion from its investigation is that both leaks were significant for the build-up of the gas cloud. This rests on the observation made during the pressure test before disassembly that leaks occurred at two points. The main leak was located at three o'clock (directly towards the process plant) and a secondary leak was located at six o'clock (directly downwards). That deviates from the description in Equinor's gas spreading analysis, where the second point is said to be located on the opposite side of the rupture disc from the main leak.

Witness observations during the incident back the team's conclusions, while Equinor's analysis contains an inconsistency between the calculated gas cloud and the gas detector responses in the area. Furthermore, descriptions of the damage to the disc in Equinor's material technology investigation support the team's observation. These describe plastic deformations compatible with the disc being drawn into the line at two points, one at three o'clock and the other at six o'clock.

Based on Equinor's calculations of the leak rate from the largest point, the team's assessment is that the combined rate from both points exceeded 0.1kg/s.

7 Observations

The PSA's observations fall generally into two categories.

- Nonconformities: this category embraces observations which the PSA believes to be a breach 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 Deficiencies in the requirements for the flare valve

Nonconformity
Requirements for the flare valve in various documents and systems were inconsistent.

Grounds
The process safety report specifies that flare valve 43ESV1036 requires a total opening time of < two seconds, and must open quickly to avoid pressure build-up in the high-pressure flare system.

According to the document on safety requirement specification global functions (ESD/F&G), valve opening time for 43ESV1036 is required to be < two seconds. It is not clear here whether the response time in SAS forms part of the time requirement or is merely the operating time for the valve.

The safety requirement specification local functions (PSD) document specifies < three seconds for opening the 43ESV1036 flare valve with an HH alarm from pressure transmitter 43PST1031. This safety function is specified here to include pressure transmitter, signal processing in PSD node and valves with their solenoids and actuators.

Flare valve 43ESV1036 has been tested with three seconds as the requirement for total opening time. That does not meet the specification in the process safety report.

The maximum opening time for flare valve 43ESV1036 is set to four seconds in SAS. That does not correspond with the requirements in the other documents.

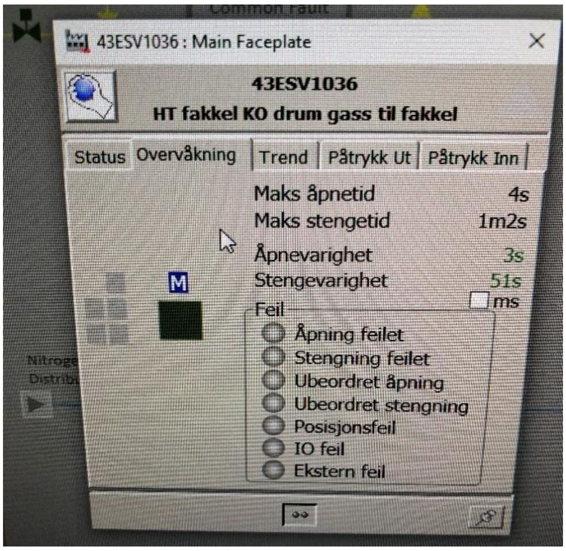


Photo 3: Screen capture from the central control room, 12 April 2019 (PSA).

Requirement
Section 5, paragraph 4 of the management regulations on barriers.

7.2 Deficiencies in the installation of the rupture disc with holder

Nonconformity
The rupture disc, the rupture disc holder, pipe supports and the associated piping system were not configured in a robust manner.

Grounds

a) Insufficient checking was done to ensure that the chosen type of rupture disc and holder was suitable for large-diameter horizontal installation.

b) The installation manual for rupture disc holder S90-7R specifies that these must be installed using nuts and bolts with “lightly oiled” threads. The Norwegian version translates this as “lightly lubricated” and refers to a table with tightening torques. This table specifies that the torque values are based on the threads being lightly oiled, clean and turning evenly with a friction coefficient of $\mu = 0.16 \sim 0.20$.

   Furthermore, the table indicates that the presence of rust, use of certain thread compounds or dry installation could alter the effective clamping force, and that this can in turn have a strong impact on the rupture disc’s function.

   In a comment on the value given for the 30-inch dimension, the table indicates that this applies to MSS SP-44 class 150 flanges. The torque value was therefore specified as 426 Nm through a separate engineering instruction.

   When installing the rupture disc and holder 43PSE1041, bolts and nuts were lubricated with Molycote G-Rapid Plus. This thread compound has a low friction coefficient of $\mu = 0.10$.

   Using the wrong compound on the bolts when installing disc and holder in the line has meant that the clamping force on the disc was higher than if the bolts had been treated as specified.

c) During assembly/disassembly, the downstream line had to be jacked up so that the flanges which the disc and holder were to be installed between were in line and the bolts could be inserted through the holes in the pipe flanges.

Requirement
Section 10, paragraph 1 of the facilities regulations on installations, systems and equipment

8 Barriers which have functioned

Gas detection functioned and deluge was activated automatically on confirmed gas detection.

All sectioning valves closed and all depressurisation valves opened. All shutdown functions worked as intended.

Depressurisation was implemented automatically on confirmed gas detection. This did not form part of the original design, but was introduced as a compensatory measure related to the long deluge activation time.

Assessing the emergency response was not part of the mandate for the PSA investigation, but the team's view is that the response to the incident functioned as planned.

9 Discussion of uncertainties

Uncertainty has prevailed over whether the clamping force on the rupture disc was correct and equal around the whole disc circumference. The tightening torque was measured during disassembly after the incident. In the team's view, this measurement was insufficient for concluding that the clamping force on the disc was correct over its whole circumference. Part of the bolting force, for example, could have gone to pulling together the two pipe flanges which the holder is mounted between. Another factor is that the two flanges were not exactly in line after the rupture disc had been disassembled. The downstream side had to be jacked up in order to remove the bolts.

If the two flanges were not exactly parallel, this could have meant the clamping force on the disc was not completely equal around the whole circumference, although the same tightening torque had been applied to all the bolts.

The team considers it to be very unlikely that the rupture disc could have come completely free from the holder and been blown further along the flare line. This is based on the fact that only a small part of the circumference was drawn into the line.

Some uncertainty prevails about the amount of pressure build-up behind the disc before it burst. This is because the pressure transmitter which signals the flare valve to open has a sampling frequency of one Hertz. That gives a one-second interval between each pressure measurement.

After the incident, Equinor has introduced measures which include changing to a pre-torque rupture disc holder. However, a similar incident was experienced on 18 January 2020 at the same point with the new disc on Aasta Hansteen. A rapid pressure rise arose in the flare system after a gas compressor tripped. It was subsequently verified that a small external gas leak also occurred on this occasion. Small registrations by the gas detectors could again be seen after the incident. On disassembly, the disc was found to have been drawn into the line circumference in roughly the same way as on 8 April 2019. Equinor has appointed a work group to take a new look at the causal picture. Uncertainty accordingly prevails over which factors were the most important in causing the first incident to occur.

10 Assessment of the player's investigation report

Equinor decided to investigate the incident on the same day it occurred. The investigation team was established the following day. Its leader came from Equinor's corporate investigation unit. They flew out to Aasta Hansteen on 10 April 2019 together with the PSA's team. Equinor's investigation report was received by the PSA on 6 August 2019.

Three analyses were conducted as part of the investigation work:

1. material technology investigation of the rupture disc from Aasta Hansteen, dated 22 May 2019
2. gas spreading and fire analysis, dated 11 June 2019
3. finite element analysis, dated 10 June 2019.

The description of the course of events coincides with the PSA team's observations and assessments.

The investigation report concludes that uncertainty prevails about the direct causes.

A detailed investigation of how the challenges with the rupture disc were handled in the project is included in the report.

Insufficient bolt torque is not considered as part of the causal analysis, based on the measured torque when post-tightening the bolts after the incident. The PSA team does not consider this sufficient to dismiss inadequate torque as a possible cause of the incident.

Equinor has conducted a finite element analysis of the rupture disc and holder based on bolting forces and the effect of friction. The result shows that the pressure at which the disc bursts increases with rising bolting force. The leak which occurs when the disc is pulled in reflects low friction between disc and holder. These two components are analysed here as a separate system independent of the pipe system it is installed in. In the PSA team's view, it would also be relevant to take account of the effect of external loads. It would have been appropriate to conduct an analysis which took account of loads from specific gravity and possibly from fastening and support of the pipe system around the rupture disc. The PSA team considers that these forces could have affected the clamping force on the actual disc.

When assessing the leak rate, account has only been take of the leak at the three o'clock position (viewed in the direction of flow) under actual consequences. The PSA team considers that there was also a leak at six o'clock, and has therefore assessed the leak rate as somewhat higher than the figure of 0.08kg/s presented in the Equinor report. The team backs this conclusion with witness descriptions and results from the gas dispersion analysis compared with actual registration by the gas detectors.

No assessments are described of the possible consequences if all or parts of the rupture disc had come loose and been drawn into the flare lie.

11 Document list

The following documents have been utilised in the investigation

1. Varsel om uønsket hendelse utslipp HC lekkasje Aasta Hansteen 8 April 2019
2. Aasta Hansteen Synergi 1576211 related to the incident
3. Utility P&ID HP Flare Drum and Metering, C134-FS-P-XB-4302-01, Rev 13, dated 8 April 2019
4. Trender 2019 Gassdetektorer rundt 43PSE1041 på P280
5. Beredskap Gasslekkasje 8.4.2019 AHA_ Første møte
6. Beredskap Gasslekkasje 8.4.2019 AHA_Fokustavle og aksjoner
7. Beredskap Gasslekkasje 8.4.2019 AHA_Ressurser og Situasjonsplott
8. C134-FS-J-XX-0006-01 ESD shutdown hierarchy, APS, ESD1 AND ESD2
9. C134-FS-J-XX-0006-02 ESD shutdown hierarchy, ESD2
10. EventLogExport Thursday 11 April 2019
11. Punch list items search - system 43
12. Trend 8.4.2019 43PST1031 HP Flr KO drum scrub gas outlet
13. Notifikasjoner tilhørende 43-systemet
14. FV og KV utført på 43 systemet 2019
15. TR3001 process safety v4.01
16. TR3002 flare, vent and drain v4.02
17. TR3003 emergency depressurisation v3.0
18. C134-FS-P-RA-0006 04 2 flare system report - Aasta Hansteen
19. AT 43 system 120419
20. Notifikasjoner 120419
21. Utført arbeid fakkelsystem 120419
22. Disp 161706 Responstid Delugesystem topside
23. Functional schematic diagrams
24. E-mail 12042019 - SWCR 6455 - SCD – Logger
25. Query search system 43
26. Trend tripp 0804 trykk HP fakkelutløp
27. Trend tripp 1902 trykk HP fakkelutløp
28. Aasta Hansteen - SOW for material analysen
29. SOW for gasspredningsanalysene Aasta Hansteen ifm uønsket hendelse utslipp gasslekkasje 08042019
30. Servicerapport fra Ellingsen Instruments, dated 23 February 2018, ATS-COM-245
31. BSB_Torque-30in_EI_HM_5000 REV_A
32. Process safety report, C134-FS-P-RA-0007, Rev. 06
33. Safety requirement specification global functions (ESD/F&G), C134-FS-S-RA-0159, Rev. 11
34. Safety requirement specification local functions (PSD), C134-FS-S-RA-0035, Rev. 13
35. Installation, operating and maintenance manual (IOMM) (BSB), C134-FS-253101-MA-0002, Rev. 02
36. BS&B engineering instruction EI-HM-5000, Rev A. *Special Torque Values For 30", S90-7R ASME CL.150 safety head with ABAS+ sensor*
37. Page from brochure: Disk Holder SRB-7RS-TR
38. Incident log for 43ESV1036 from 3 November 2018 til 3 May 2019
39. Page from brochure: S90-7R pre-assembled insert safety head
40. Integritetsvurdering sprengblekk – barrierefunksjon
41. Complete incident log from 8 April 2019, 09.00-18.00
42. OQ-TOP-AHA-J-060 Automatic operation of 43ESV1061 based on 43ESV1036 status
43. SWCR 06455 Flare system - SCD updated as per OQ-TOP-AHA-J-060
44. SYS 43 Complete SIF
45. 5 Nov18 barg måling 43PST1031
46. 8 April 19 Volum i fakkelsystem
47. 19 February19 Faklingsevent

48. C134-FS-J-SP-0015 10 23 May 2018 OF-P functional specification ESD
49. AD20-VF-430004-6 Rev0 - spool data
50. AD20-VF-430004-6 Rev4 - spool data
51. FW FW A H Topsides - QE536A2P08 rupture sensor installation - tightening torque
52. E-mail: FW Survey of Rupture Discs installations
53. E-mail: RE Survey of Rupture Discs installations
54. Installed clamp type bracing
55. E-mail: RE AH Topside rupture disc vibration punches
56. Letter from Ellingsen to Statoil 09032018 - 133860 - Tilbud - Remaskinering BSB Holdere Premium
57. Final test Stord - IKM testing - N_2He re-test of burst disc Aasta Hansteen - test no WP-001A, Re-test #1, 2 April 2018, no leakages.
58. 1 test Stord - IKM testing - N_2He Re-test of burst disc Aasta Hansteen - test no WP-001A, initial test, 18 February 2018
59. Flare test Korea - IKM testing - N_2He leak test of HP flare Aasta Hansteen, initial test, 25 March 2017
60. Granskingsrapport COA ACC Intern ulykkesgransking Equinor: *Gasslekkasje i sprengblekkholder Aasta Hansteen 8. april 2019* A DPN L2 2019-11
61. Materialteknisk undersøkelse av sprengblekk fra Aasta Hansteen, dated 22 May 2019. Materialavdelingen, Trondheim (FT MMT MI) (Vedlegg til Equinors granskingsrapport)
62. Gasspredning- og brann-analyse, dated 11 June 2019 (Vedlegg til Equinors granskingsrapport)
63. FE analyse, dated 10 June 2019 (Vedlegg til Equinors granskingsrapport)
64. E-mail fra Haakon Ellingsen AS “Oppfølging av møte 06112019 - Dokumentasjon vedr Aasta Hansteen”
65. Aasta Hansteen - IOM - monterings instruks for moment relatert til pre-assembled S90-7R holder 30"
66. Installation operating and maintenance manual Aasta Hansteen - BS B IOMM
67. Special torque values for 30” S90-7R ASME CL.150 safety head with ABAS+ sensor - BS B torque-30in EI-HM-5000 REV-A

12 Appendix

A: Overview of participants in interviews and meetings (separate document)