

Investigation report

Report	
Report title Mongstad refinery - Naphtha leak in cracker, 24 October 2017	Activity number 001902045

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Summary
<p>A naphtha leak occurred at Mongstad on 24 October 2017. It was discovered by an operator who was investigating the area following a verbal report of an unusual smell. The leak arose because of internal corrosion in a minimum flow line for pump protection (pump protection line) in the cracker. Statoil has subsequently estimated the leak rate at 0.01 kilograms per second (kg/s). The process section containing the leak was isolated, the emergency response organisation mobilised, and personnel evacuated the plant on activation of the factory alarm.</p> <p>The investigation has identified four nonconformities. Of these, the most important for the incident was inadequate assessment of changes to operating conditions. The other three concern deficiencies in maintenance and inspection, inadequate compliance with routines and information transfer for safe operation of the plant, and inadequate understanding of risk and identification of risk conditions when clearing up naphtha-polluted materials.</p> <p>An improvement point concerning the evacuation alarm was also identified.</p>

Involved	
Main group T-L	Approved by/date Kjell Arild Anfinssen/19 February 2018
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1 Summary

A naphtha leak occurred at Mongstad on 24 October 2017. It was discovered by an operator who was investigating the area following a verbal report of an unusual smell. The leak arose because of internal corrosion in a minimum flow line for pump protection (pump protection line) in the cracker. Statoil has subsequently estimated the leak rate at 0.01 kilograms per second (kg/s). The process section containing the leak was isolated, the emergency response organisation mobilised, and personnel evacuated the plant on activation of the factory alarm.

The investigation has identified four nonconformities. Of these, the most important for the incident was inadequate assessment of changes to operating conditions. The other three concern deficiencies in maintenance and inspection, inadequate compliance with routines and information transfer for safe operation of the plant, and inadequate understanding of risk and identification of risk conditions when clearing up naphtha-polluted materials.

An improvement point concerning the evacuation alarm was also identified.

2 Introduction

The leak at Statoil Mongstad occurred and was identified during regular operation, and comprised cracker naphtha. The PSA decided to investigate the incident on 26 October.

Composition of the investigation team

Vivian Sagvaag	- occupational health
Ove Hundseid	- process integrity
Bryn Aril Kalberg	- logistics and emergency preparedness
Morten Andre Langøy	- structural safety, investigation leader

The investigation took the form of interviews, inspection of the plant, a document review and appraisals, as well as information from analyses conducted for Statoil by external consultants and its own materials laboratory.

Mandate for the investigation

1. Clarify the incident's scope and course of events.
 - a. Clarify and assess safety and emergency response aspects.
 - b. Clarify assessments made ahead of the incident.
2. Describe actual and potential consequences.
3. Assess direct and underlying causes, with an emphasis on human, technological, operational and organisational conditions.
 - a. Observed nonconformities from requirements, approaches and procedures.
 - b. Improvement points.
4. Discuss and describe possible uncertainties/unclear aspects.
5. Assess the incident in relation to earlier investigations and possible relevant supervisory activities at Mongstad.
6. Identify possible regulatory breaches, recommend further follow-up and propose use of instruments.
7. Assess the operator's own investigation of the incident.
8. Prepare a report in accordance with the template.

3 Abbreviations and explanations

CUI	Corrosion under insulation
DAL	Dimensioning accidental load
ISO drawing	Isometric drawing
ISS	Insulation, scaffolding and surface treatment trades
LEL	Lower explosion limit
LPG	Liquefied petroleum gases
ppm	Part per million
PS	Performance standard
PS1	Performance standard 1– containment
PSA	Petroleum Safety Authority Norway
RBI	Risk-based inspection
RS	Turnaround
Timp	Technical integrity management programme
TLV _{8h}	Maximum threshold limit value for average concentration over eight hours
TR	Technical requirement – internal Statoil standard
TTS	Technical condition safety
SAP	Computer system for enterprise management
Synergi	System for registering, analysing, processing and following up accidents, near-misses and undesirable incidents
WP	Work permit

4 Background

4.1 Brief description of the cracker

The first stage of the Mongstad refinery was built in 1974. It was expanded and upgraded in 1989, when the cracker was built. This facility is a catalytic cracker where residue molecules are cracked to smaller molecules with the aid of catalysts and high temperatures. Product from this process is sent on to fractionation column T-1509, where the lighter fractions are separated into cracker naphtha, light cycle oil and decant oil. The figure below presents a simplified diagram of the column with associated processes. Shown by an arrow in Figure 1, the leak occurred in a minimum flow line for pump protection (pump protection line). Operational conditions in the line were eight barg and about 150°C. The leak medium was cracker naphtha.

The naphtha is sent on to naphtha stripper T-1511, where lighter products are stripped out. The leak occurred in the piping system between the fractionation column and the naphtha stripper. An overview of Statoil Mongstad with the location of the cracker is provided in figure 2 (source: Statoil).

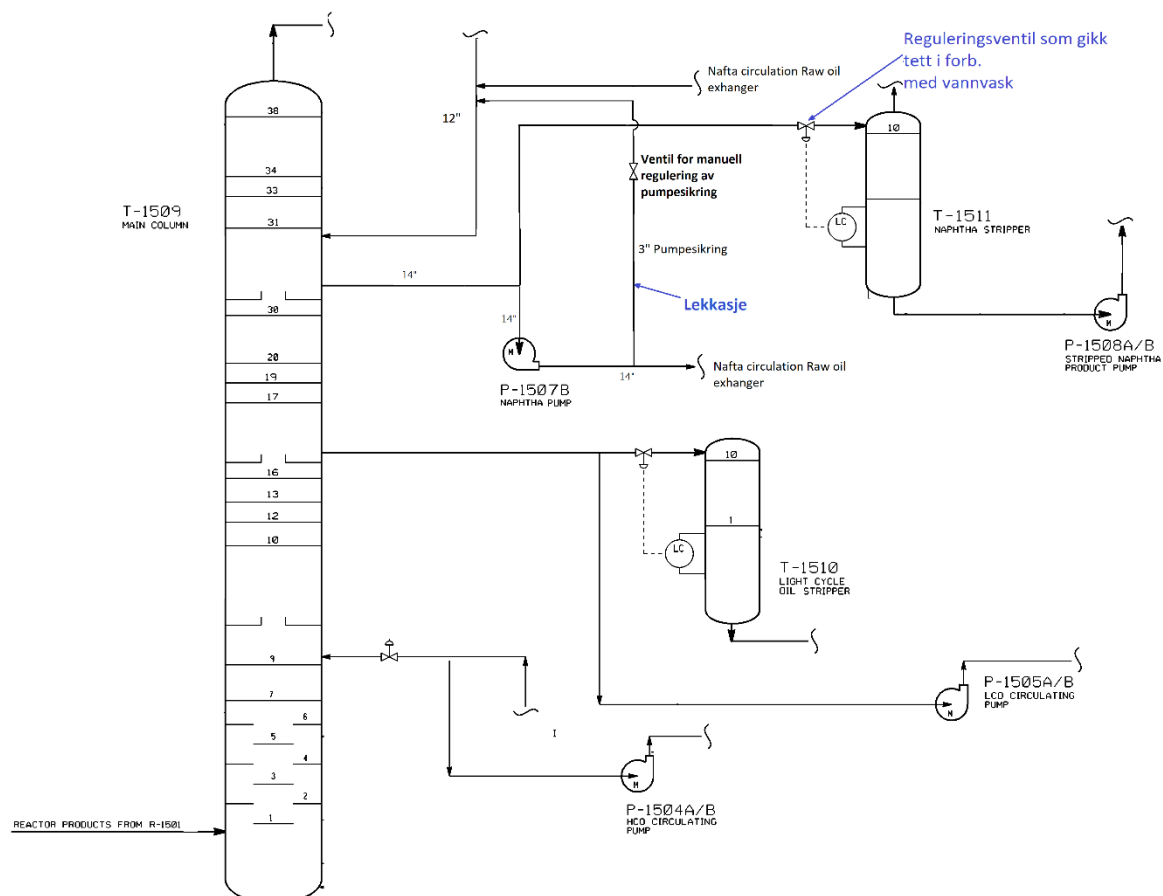


Figure 1: Flow diagram for the fractionation column and naphtha offtake. The arrows show the leak point (*Lekkasje*) and the valve choked as a result of water washing.



Figure 2: Overview of Statoil Mongstad. The red arrow shows the cracker.

The three-inch pipe where the leak occurred is a protection line installed to ensure that pump P1507B is not run against a closed outlet. The leak point is shown, after removal of insulation, by a red arrow in Figure 3.



Figure 3: The leak point marked by a red arrow. Pipe insulation was removed after the incident. Source: Statoil.



Figure 4: Transition between the 14-inch main pipe and the three-inch pump protection line. The pipe insulation was removed after the incident. Source: Statoil.

The pump protection line was defined as one of several corrosion loops¹ at Mongstad. The line with the leak ran between two pipes of 12 and 14 inches respectively, as shown in Figure 4. The three-inch pipe has a bright surface because it was painted externally in connection with a surface treatment project in 2014 to avoid corrosion under insulation (CUI). No check for internal corrosion was made at the same time.

4.2 Corrosion

Piping and equipment in a refinery are exposed to both internal and external corrosion. CUI is often the most serious external problem because it can be difficult to spot before a leak occurs. The PSA has previously investigated piping leaks associated with CUI at Mongstad. It investigated serious incidents in 2012 (PSA, 2013) and 2016 (PSA, 2017) involving escapes of steam and hydrogen respectively, and both caused by CUI.

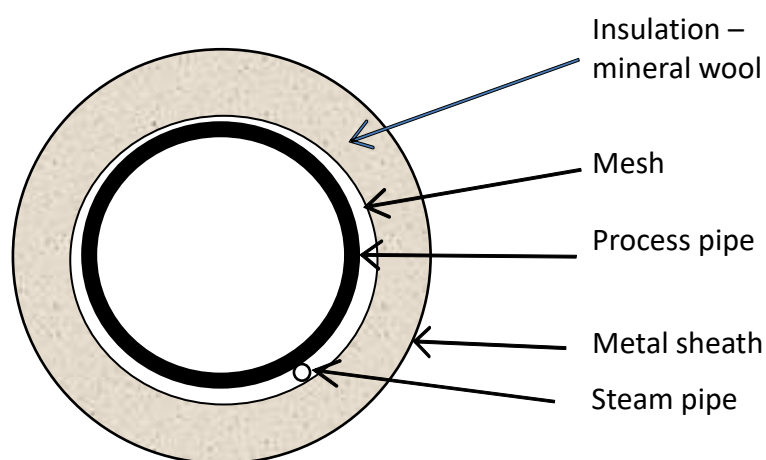


Figure 5: Illustrative cross-section of insulated three-inch pipe with a nominal wall thickness of 5.5 mm and a 1.5 mm corrosion allowance in the pump protection line.

The leak on 24 October 2017 also occurred in an insulated pipe, as illustrated in Figure 5, but the corrosion was internal rather than external as in the case of CUI. This pipe was inspected externally in 2014, when surfaces with corrosion were subject to surface treatment, but had not been checked for internal corrosion since 2013 (Statoil, 2017C).

4.2.1 Internal corrosion

A number of corrosion mechanisms can occur in a refinery. The American Petroleum Institute (API 571) identifies more than 30 of them. Where the leaking pump protection line is concerned, Statoil has identified mechanisms caused by ammonia chloride and ammonia hydrosulphide (Statoil, 2017B). These cause wall thinning. That must be managed and is described in the next section. Stress corrosion caused by hydrogen sulphide has also been identified as a damage mechanism.

¹ The corrosion loop concept is explained in section 4.2.2.

4.2.2 Risk-based inspection (RBI)

Piping and equipment exposed to internal corrosion are inspected at regular intervals for monitoring and repair. These intervals are based on the risk of leaks, and the methodology used is known as risk-based inspection (RBI). Risk is calculated as the product of the probability and consequences of a leak. An important prerequisite for RBI is the provision of accurate information to determine probability and consequences for all equipment and piping. This is done by dividing the facility into corrosion loops, where possible corrosion and damage mechanisms are identified. The pipe with the leak forms part of corrosion loop 15-CL-08A *Heavy naphtha circulation to/from T-1509 (above tray 30) and to T-1511*. Possible changes in operating conditions for this loop must be documented.

Two basic requirements for RBI are that changes to operating conditions are assessed in relation to their impact on corrosion rates and thereby on inspection planning, and that inspection results are assessed against the expected corrosion rates. The inspection interval for the relevant piping loop was originally calculated to be five years.

4.2.3 Incidents and leaks caused by internal corrosion

An LPG leak occurred in the reformer (A-1400) in the summer of 2017 owing to internal corrosion in a pipe in a blind gate where chlorine and water had accumulated. The reformer converts naphtha to petrol. This incident was investigated by Statoil's corporate investigation unit (Statoil, 2017), and its cause identified as changes to operating conditions. These altered corrosion conditions, and led to higher corrosion rates. According to the RBI method, changes in operating conditions and inspection findings should lead to closer monitoring.

4.3 Condition and operation of the plant

4.3.1 General

A technical integrity management programme (Timp) both identifies nonconformities with today's standards and weakening of the plant's physical condition. Condition assessments are made both for the individual barrier performance standard (PS) and for each plant section. Results for the individual PSs form the basis for specifying plant condition. In addition to the Timp assessments, independent technical condition safety (TTS) reviews, inspections and notifications are included in the condition assessment.

The refinery is exposed to corrosion, both external and internal. This is reflected in the Timp assessment of PS1 containment as level E. Figure 6 presents the Timp for the whole of Mongstad – but representative for the cracker – in May-June 2017. Statoil concludes in the Timp assessment that area B1 has:

- areas where surface condition remains unclarified, many finds in the surface project
- high internal corrosion in the naphtha circulation
- many unregistered leaks in 2016
- a substantial number of inspection order notifications with a high level of risk.

On the basis of findings, particularly in heat exchangers during the 2014 turnaround (RS), Statoil has concluded that the corrosion rate had risen from RS08 to RS14. That applied particularly to the naphtha flow in A-15/1600 and downstream from the plant (A-47/5000/5200). It has recommended an assessment of whether the process must be modified

somewhat to reduce the future corrosion rate. Measures identified by Statoil include changed use of anti-salt chemicals in T-1509 and the naphtha circulation. This change is intended to prevent corrosion in plants downstream from the cracker. A new chemical has also been tested in the facility.



Figure 6: Timp for Mongstad, May-June 2017.

Figure 7 present the development of leaks at Mongstad in terms of number and leak rates. Determining a specific trend is difficult, and the degree of seriousness is affected by a number of factors. These include the medium, the amount leaked and the leak point. A number of serious leaks in recent years have been caused by corrosion.

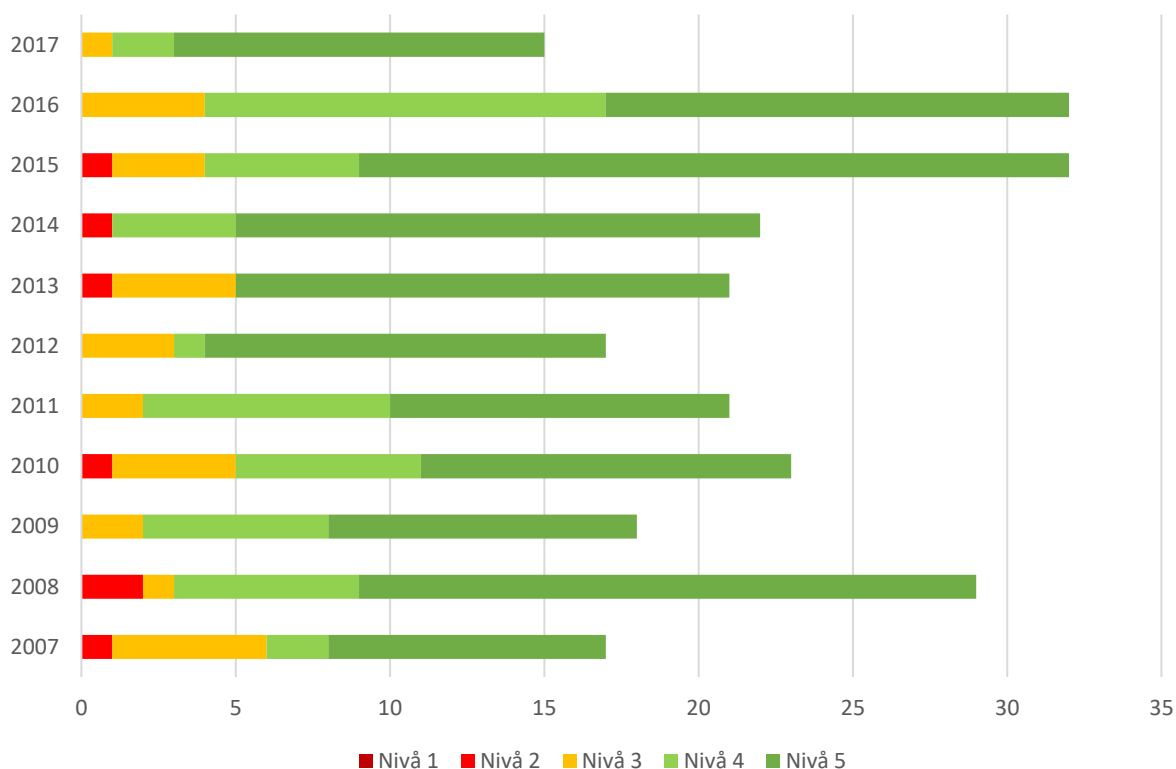


Figure 7: Overview of oil and gas leaks per annum at Mongstad categorised by leak rate. Level (nivå) 1 comprises leaks of > 10 kg/s, level 2 is 1-10 kg/s, level 3 is 0.1-1 kg/s, level 4 < 0.1 kg/s, and level 5 << 0.1 kg/s.

4.3.2 Operation of fractionation column T-1509

Problems with salt precipitation and corrosion in the naphtha loop for T-1509 have been known about for several years. Crude oil received by Mongstad contains salt which follows the feed stream through the plant. Catalysts can also contribute to salt formation. Conditions in the naphtha section of the fractionation column allow salt to precipitate. During operation, such precipitation restricts fluid flow and a higher differential pressure therefore builds up ahead of the naphtha section. Chemicals are injected (shock dosing) about once a week to dissolve the salt. This removes some but not all of it, and the quantity accordingly accumulates over time. The operators can see this because the pressure ahead of the naphtha section increases. This build-up is used to determine the timing of water washing.

Such washing is carried out by injecting steam while reducing the temperature in the naphtha section as much as possible. That causes water to condense there and wash out salt deposits. After the wash, flow in the naphtha loop is increased to flush out water and salt. During the process, problems sometimes arise because salt has blocked control valve 15-FIC-017.

The need for water washing has increased in line with a higher production volume, and possibly because the salt content of the feedstock has risen. Washing currently takes place about once a month. Minimising this process is advantageous for operation. The plant must be run differently during washing, which is not a simple procedure. Attention is therefore focused on measures to reduce salt precipitation. Optimal operation of the desalination facility is important for reducing the quantity of salt in the plant. Chemicals are also added to reduce the need for water washing. In addition, the temperature in the naphtha section has been raised as much as possible to reduce the amount of precipitated salt.

4.3.3 Pump protection line

The leak occurred in the protection line for pump P-1507B, which has been installed to safeguard the pumps if they are run against a closed valve. In such cases, the protection line ensures a minimum flow through the pump to prevent it being damaged.

Flow in the loop is regulated by a manual valve adjusted by the plant operators. This valve needs adjusting to ensure that some fluid circulates through the protection line if the main line is closed. Since the quantity of fluid flowing through the loop is not measured, the amount passing through the valve cannot be verified. The operators report that they get an indication of the flow by feeling whether the valve is warm (from the fluid flowing through). A log system has been established where various points must be checked and signed off at specified intervals (Statoil, 2017D). This includes opening the valve to flush the protection line. This procedure and its execution differed from person to person.

When the pipe was cut out, the section upstream from the valve was found to be full of corrosion residues/salt, see Figure 8. This means there cannot have been much flow through the pipe and, without the opportunity to measure flow, it has not been discovered. Without flow, the result will be a blind gate. According to the RBI programme, these are particularly vulnerable to corrosion. The temperature here will fall because there is little or no flow, and water can condense out and result in corrosion.



Figure 8: Vertical section of the pipe filled with porous/uncompacted deposits. No sign of significant wall thinning could be seen in this part of the pipe. (Statoil, 2018)

4.3.4 Inspection of the naphtha loop

A risk-based inspection of the relevant naphtha loop was conducted in 2012. The result was entered as M2 notifications (corrective maintenance) for inspection in SAP. Inspection of the relevant pipe with the leak was conducted in 2013, when wall thickness was measured at vulnerable points, typically bends and before choke valves. Corrosion was found, but not at a level considered critical.

Findings were made in 2012-15 during inspection of the main pipe upstream and downstream from pump P-1507B (which the protection line where the leak occurred belonged to). In 2015, 3.5 mm of internal thinning was discovered upstream from the pump. Strength calculations of the pipe concluded that it could remain in the preventive maintenance programme up to 2019.

Inspection of the downstream pump in 2015 discovered three mm of pitting corrosion. Leaving this uncorrected was also considered to be acceptable.

Before restarting after the naphtha leak, a number of pipes were inspected to ensure that the plant had sufficient integrity to start up again. A further pump protection line with substantial corrosion was then discovered, and removed before start-up. It emerged from interviews that the pumps are started against closed valves so that the protection line has no mission. Statoil is now assessing whether these protection lines are needed.

In connection with the 2014 turnaround, corrosion was found in the T-1509 column and T-1511 naphtha stripper. This was restricted to the trays in the column rather than the actual pressure containment (walls). Signs of corrosion were also found in the 2008 turnaround.

4.4 Assessment of plant integrity

Corrosion is an important element in the activities concerned with maintaining control of the plant's technical condition. These include process monitoring, maintenance including inspection, assessment and possible changes to operational routines and operating conditions, and assessment of changes and findings. An overall assessment of these activities could lead, for example, to altered inspection intervals for internal corrosion. They are pursued by several technical disciplines with different reporting lines. No overall assessment of all relevant disciplines has been made to evaluate whether this could affect plant integrity and whether the inspection programmes must be amended as a result of changed operating conditions.

4.5 Health effects of naphtha exposure

Cracker naphtha is classified as carcinogenic and a reproductive toxicant, primarily because of its benzene content (0.7-1.2 per cent). In addition to its toxic properties, benzene has a low threshold limit value for the permitted level of pollution in the working atmosphere (TLV_{8h} one ppm). Inhalation can cause drowsiness and dizziness at low concentrations, while high concentrations can have narcotic effects. It can also be absorbed through contact with the skin and damage health.

5 Naphtha leak 24 October 2017

5.1 Timeline

- 06.30 Night shift report verbally that they have detected more smell than normal in the A-1500 area
- 06.45 Operator starts a round
- 07.00 Operator detects a "smell" by the pump/piping in the cracker. Reports by walkie-talkie to control room
- 07.02 Operator discovers leak from pump/piping in the cracker. Reports by walkie-talkie to control room
- 07.05 20% LEL alarm from detector 30-AA-261A at leak point
- 07.07 On-scene commander requests evacuation alarm
Several failed attempts made to activate evacuation alarm. Evacuation order given by walkie-talkie
- 07.11 Evacuation alarm sounded. Alarm functioned after a reset
- 07.15 Feed bypassed
- 07.19 Triple alert
- 07.19 30% LEL alarm from detector 30-AA-261B at the leak point
- 07.21 Emergency response at incident site. Fire appliances 1, 2 and 4 mobilised. Appliance 4 lays foam. Starts fire water pump 3001
- 07.22 Shut down of plant B1 activated. Confirmation of no ignition sources at leak site
20% LEL alarm from detector 30-AA-261A at leak site
30% LEL alarm from detector 30-AA-261B at leak site
- 07.25 Area foam-covered
- 07.28 Smoke divers enter area to measure gas

- 07.29 Flow rate halved in heat exchanger downstream from P-1507
- 07.32 Bypass initiated. External fire appliance and ambulance arrive
- 07.33 No gas meters in area activated
- 07.34 Flow rate in heat exchanger downstream from P-1507 equal to zero
- 07.42 Observation – leak reduced to drips
- 07.46 A-1500 – cracker – run down and in bypass. Line pressure reduced to three bar
- 07.58 Response team member enters and closes valve to pump protection line
- 08.06 Pump protection line closed
- 08.43 Area B1 cordoned off
- 08.52 Continued dripping observed from leak – two-three drops per second
- 08.54 Leak site isolated from rest of plant
- 08.55 “Danger over” signal sounded

Source: Statoil.

5.2 Factory alarm – evacuation

Immediately after the control room received the warning from the plant operator of a leak in the cracker, the decision was taken to activate the factory (evacuation) alarm. This failed to function at the first attempt, and had to be reset before working after one minute and 55 seconds. In the meantime, evacuation had been initiated via walkie-talkies.

The incident occurred in the morning before all the day personnel had entered the plant. This was accordingly a favourable time for evacuation. A total of 108 people were evacuated.

5.3 Notification of the authorities

Statoil notified the emergency services – police, fire and ambulance (triple alarm).

The PSA’s log shows that it was notified by phone at 07.55, 40 minutes after the incident occurred.

5.4 Emergency response to the incident

Emergency response personnel were mobilised, and handled the incident in accordance with plans.

Communication with the emergency services – police, fire and ambulance – via the public safety radio network functioned well.

5.5 Working environment when stripping insulation after the incident

After the incident had been normalised, the leaking pipe was cut out and replaced. To do that, the insulation had to be stripped from the pipe. This job was planned by Statoil Mongstad and coordinated with the ISS company responsible for the job. Section 1 of the relevant work permit (WP) failed to identify risks in the activities to be pursued. Section 2B of the WP identified the need for cut-resistant gloves and for cordoning off the work site because of the danger of dropped objects. However, the threat of exposure when removing naphtha-polluted

insulation was not identified. No safe job analysis (SJA) was conducted for the work. Nor was the need for an SJA assessed by the specialists involved in the planning or approval phases of the relevant WP, and not by the operators involved nor those doing the work either.

6 Investigations after the incident

6.1 Inspection, interviews, and document and system reviews

A total of 29 people were interviewed by the PSA team during its investigation. The interviews were conducted in Statoil's operations office at Mongstad on 26-27 October and 15-16 November. Statoil had an observer present who also organised the interviews in accordance with the specified timetable.

Material technology investigations were performed by Statoil's materials department in Trondheim. In that connection, a meeting took place with the PSA team on 18 December 2017.

6.2 Investigations of the leak pipe and deposits in it

The material technology investigations confirm that the leak was caused by internal corrosion. Efforts have been made to clarify the type of corrosion and its possible underlying causes. All photographs in this section are taken from the report of Statoil's material technology investigations (Statoil, 2018).

A close-up of the leak site on the underside of the horizontal section (which proved on close inspection of the incident site to have a slight upward inclination) is shown in Figure 9. In practice, the area where the leak occurred was corroded right through, as seen in Figure 10. The investigations showed that "the centre of the pipe is filled with uncompacted but nevertheless fairly tight-packed deposits in the centre and towards the top of the pipe, and in addition by hard and layered coating/scale against the pipe wall between about 1 and 11 o'clock. Substantial wall thinning coincides with the hard coating, most prominently at 6 o'clock. An intermediate 'mixed' zone also shows signs of layering, but is not as compacted and falls out when removing the uncompacted deposits in the centre." (Statoil, 2018). Figure 11 shows a cross-section of the pipe with the coating, which resembles tree rings. The report also states "The hard coating found in the pipe where the leak has occurred comprises in the order of 35-40 'strata', which corresponds with the number of water washes carried out since 2014, and which could therefore indicate a relationship between coating formation and the water wash procedure."



Figure 9: Close-up of the leak site from the outside of the pipe. Little sign of external corrosion, but discolouration and rust run-off can be seen in the area around the leak. Scale in millimetres.

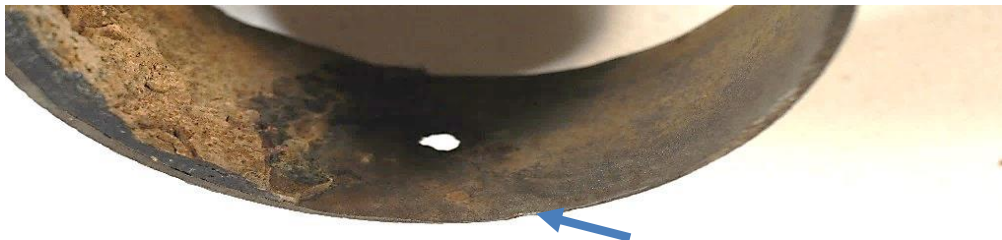


Figure 10: The arrow indicates that, in practice, the pipe wall has been corroded all through in the area near the leak point (light circle in the centre). Distance between leak point and arrow is about 20 mm.



Figure 11: Cross-section of the horizontal section of the pipe loop. Twelve o'clock is at the top and 6 o'clock at the bottom.

However, the actual mechanism behind the coating formation has not been clarified. This is because the analysis methods used have not been able to verify the composition of the coating and because the actual process conditions in the protection line are not known.

The conclusion is that the leak in the pump protection line has probably occurred because a lack of chloride control and consequent ammonia chloride corrosion. It could also be related to water wash/chemical treatment (Statoil, 2018). This is likely because ammonia chloride corrosion is one of the possible corrosion forms identified in the RBI analysis. A low flow rate owing to inadequate control of regulation for the protection line has contributed to the deposition. The consequence has been an even lower flow rate, reduced temperatures and thereby condensation of water.

6.3 Assessment of Statoil's investigation of the incident

The team has reviewed the report (Statoil, 2018B) and concluded that Statoil's description of the incident and its course accords with its own findings. The Statoil investigators classify the incident as Green 4, as the highest actual level of seriousness for costs/loss, and a potential Yellow 3 for leakage of oil/gas/flammable fluid and fire/explosion.

7 Potential of the incident

Statoil's notification gave a preliminary estimate of 0.3 kg/s for the leak rate, later calculated as 0.013 kg/s. However, it is difficult to specify the actual leak rate with certainty because the pipe interior was filled with corrosion residues. How much this helped to reduce the leak is uncertain. An analysis of the pipe where the hole occurred shows that the latter was restricted by the coating. This is illustrated in Figure 12.

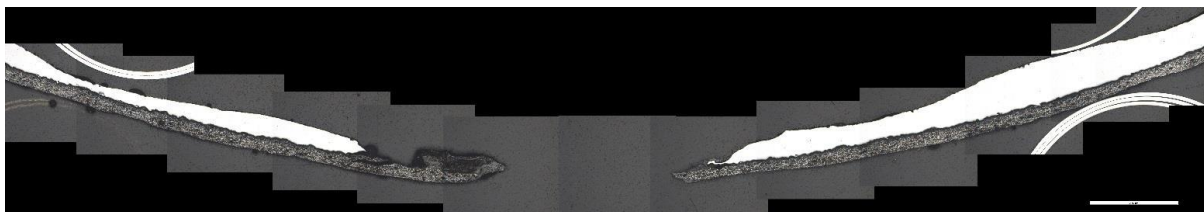


Figure 12: Cross-section of the pipe wall over the hole. The metal coating (grey) covers some of the opening in the pipe wall (white), so that it is in reality larger (about six mm) than was observed when measuring on the external surface.

If the leak had lasted longer, the coating might have broken off and the hole would have become considerably larger, with an associated increase in leak size. The leak route was also hampered by corrosion products as shown in Figure 13.

The leak did not ignite during this incident. Escaping fluid was led to the plant's drain system. Insufficient information is available to make a detailed assessment of the incident's potential had it ignited. However, the leak was sufficiently large that it could have resulted in a substantial fire had ignition occurred. Factors which would have been significant for the size of such a blaze include:

- the actual leak rate
- gas dispersal in the plant as a result of vaporisation
- the extent of naphtha in the plant before ignition
- duration of the leak before and after ignition
- spread to other process segments
- fire-fighting.

Statoil's investigation report calculates the potential leak at 0.61 kg/s, and classifies it as "possible level of seriousness 3" – in other words, 0.1-1 kg/s. The probability of ignition for the potential leak is regarded as low.

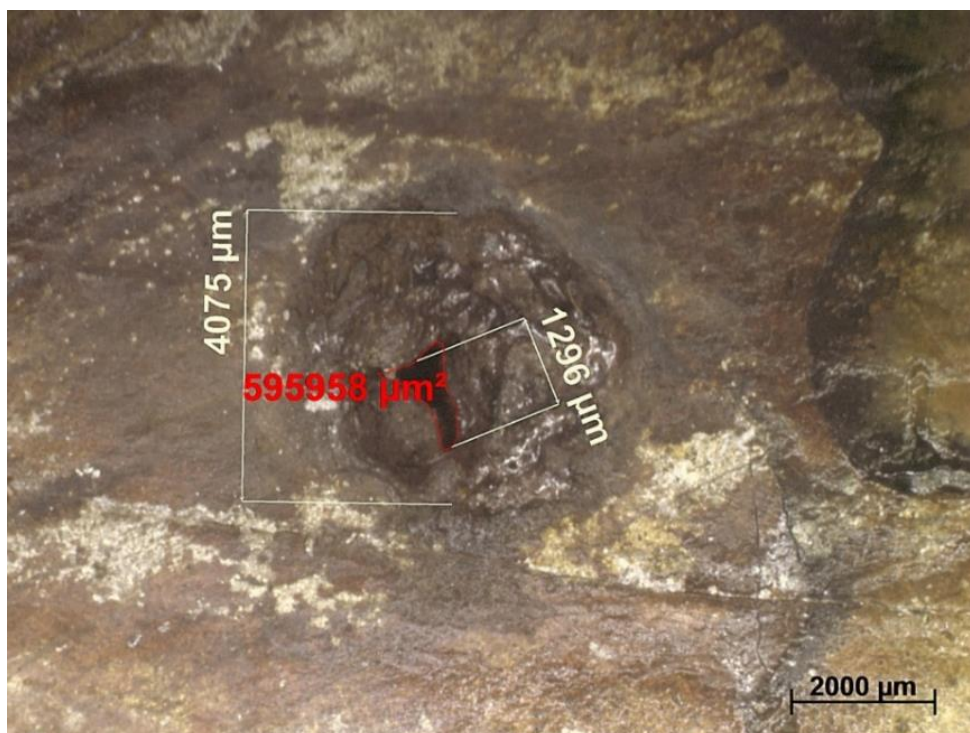


Figure 13: Measurement of the leak route with the aid of stereomicroscopy. Since compact (internal) corrosion products largely cover the hole in the pipe, the leak route (area) is probably somewhat smaller than an “open” hole would suggest. Stereomicroscopic measurements suggest in the order of 0.6 mm².

7.1 Assessment of actual and potential exposure for personnel involved

The plant operator who discovered the leak was about two metres from the leak point and did not come into direct contact with naphtha. When the control room confirmed that this was a naphtha leak, the operator withdrew further from the site. The personal gas meter this person carried gave no alarm for high LEL levels. Ventilation is good in the area where the leak occurred. The concentration of vaporised naphtha components in the plant operator’s breathing air is considered to have been low. The operator states that no discomfort or symptoms were experienced which could be related to acute toxic exposure.

Emergency response personnel were equipped with fire-fighting garments and compressed-air respirators. They reportedly did not come into direct contact with naphtha.

After the incident had been normalised, the pipe with the leak was stripped of its insulation and removed. The WP for the job failed to identify the risks of the work, specify gas metering to identify the fire, explosion or exposure potential, or require equipment to protect against chemicals other than cut-resistant gloves. However, the personnel doing the work reported that they were aware that the insulation could be naphtha-polluted. They accordingly used nitrile gloves with a long cuff to protect their skin against exposure during the work. The personnel had not worn a chemical-resistant suit, but reported that they no naphtha had got on their clothes or unprotected skin. Based on information from interviews, the scale of skin exposure appears to have been insignificant since the correct skin protection was used and other areas of skin were not exposed. Respirators were not worn since gas measurements (LEL, CO₂, O₂ and H₂S) before and during the job had given no readings. However, benzene

in the work area was not measured to determine the exposure threat during the work. Measuring the LEL is not considered sufficient for assessing the exposure threat. Given the good ventilation in the incident area and the fact that the leak had stopped before insulation removal, the concentration of volatile components in the work atmosphere is regarded as low. The probability of exposure to hazardous levels of naphtha is considered to have been low. Under slightly different circumstances, such as a larger leak volume or doing the job with inexperienced personnel who confined themselves to the content of the WP, the exposure level could have been significantly higher.

8 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.

8.1 Nonconformities

8.1.1 Inadequate assessments of changes to operating conditions

Nonconformity

Changes to operating conditions have not been adequately assessed in terms of how these could affect the integrity of the plant.

Grounds

Operating conditions in the plant have changed over time. Feedback from interviews indicates that the amount of salt in the plant has increased because of its higher content in the feedstock received by Mongstad. Operation of the plant has been adjusted to deal with this. Various chemicals and water washing have been used to remove the salt. No overall review has been conducted with all technical disciplines to assess whether this might have affected the integrity of the plant and whether inspection programmes must be amended as a result of the changed operating conditions.

The investigation team has been told by Statoil that this is something the company itself has become aware of, and that it is in the process of making alterations to ensure that changes to operating conditions are adequately taken into account by relevant technical disciplines.

Requirement

Section 11, paragraph 3 of the management regulations on the basis for making decisions and decision criteria: "Necessary coordination of decisions at various levels and in different areas shall be ensured so that no unintended effects arise."

8.1.2 Deficiencies in maintenance and inspection

Nonconformity

No changes have been made to maintenance routines in the RBI programme after the discovery of corrosion in the naphtha loop.

Grounds

Inspections have revealed corrosion rates in the naphtha loop which are higher than those assumed in the RBI programme. Examples include:

- 3.5 mm of internal thinning were found in the upstream pump in 2015
- inspection in 2015 found three mm of pitting corrosion in the downstream pump.

If inspections of the plant reveal corrosion rates higher than those assumed, amendments to inspection intervals and the number of inspection points must be assessed for the RBI programme. Statoil had not done this for the naphtha loop.

Requirement

Section 58 of the technical and operational regulations on maintenance: “The responsible party shall ensure that land facilities and parts thereof are maintained, so that the required functions are safeguarded in all phases of the lifetime.”

8.1.3 Inadequate compliance with routines and information transfer for safe operation of the plant

Nonconformity

Compliance with routines for information transfer were inadequate.

Grounds

It emerged from interviews that night shift personnel had noticed an unusual level of smell in the cracker before the leak was discovered. This observation was communicated to the day shift verbally but not in writing. The investigation team believes it was a matter of chance that the day shift had picked up the night shift’s smell observation.

Personnel did not follow their own routines in day-to-day operation. A log system had been established, for example, where various points in the cracker were to be checked and signed off at specified intervals. Interviews revealed that the procedure for conducting the check rounds varied from person to person, and that all check points were not always included. The log for the previous week showed that not all the points in the log were signed off.

Requirements

Section 45, paragraph 2 of the technical and operational regulations on procedures: “It shall be ensured that procedures are established and used in such a way as to fulfil their intended functions.”

Section 54 of the technical and operational regulations on transfer of information at shift and crew changes: “In connection with shift and crew changes, the responsible party shall ensure necessary transfer of information on the status of safety systems and ongoing work, as well as other information of significance to health, safety and the environment during work activities, cf. section 15 of the management regulations.”

8.1.4 Inadequate understanding of risk and identification of risk conditions when clearing up naphtha-polluted materials

Nonconformity

A lack of risk understanding and inadequate identification of risk conditions were shown in connection with preparing and checking the WP for removing insulation containing naphtha-polluted materials.

Grounds

Several findings indicate an inadequate understanding of risk at all levels when planning and executing the work to be done.

- The WP was approved without identifying risks with the job. Nor were requirements specified for gas metering of the fire, explosion or exposure potential, and no requirements were set for chemical-resistant protective equipment other than cut-resistant gloves. Nevertheless, personnel doing the work could be expected to come into contact with naphtha, both by inhalation and by skin contact.
- Inadequate identification of risks in the WP indicates insufficient involvement of health, safety and environmental expertise in the planning phase. It emerged from interviews that no systematic procedures existed about when HSE specialists such as occupational hygienists should be involved in the planning phase for jobs.
- The needs for an SJA was not assessed in the planning phase for the work.
- The investigation team was informed that gas measurements (LEL, CO₂, O₂ and H₂S) had been conducted before and during the execution of the work, even though this was not identified in the WP. Such measurements are suitable for assessing the fire and explosion potential, but are not regarded as adequate for evaluating the exposure potential for and level of hazardous components in the working atmosphere.

Requirements

Section 12, paragraph 1 of the management regulations on planning: “The responsible party shall plan the enterprise's activities in accordance with the stipulated objectives, strategies and requirements so that the plans give due consideration to health, safety and the environment.”

Section 53, paragraph 1 of the technical and operational regulations on risk information during work operations: “It shall be ensured that the employees are provided with information on health risk and the risk of accidents during the work to be performed.”

8.2 Improvement point

8.2.1 Evacuation alarm

Improvement point

The evacuation alarm failed to work.

Grounds

When the decision was taken to activate the evacuation (factory) alarm, it failed to function and had to be reset. It first worked after one minute and 55 seconds.

Requirements

Section 22, paragraph 3 of the technical and operational regulations on communication systems and equipment: "The onshore facilities shall be outfitted with alarm systems that can notify the personnel at all times of hazard and accident situations."

Section 67, litera d of the technical and operational regulations on handling hazard and accident situations: "The responsible party shall ensure that necessary measures are taken as soon as possible in the event of hazard and accident situations so that the onshore facility's personnel can be evacuated quickly and efficiently at all times."

9 Other comments

Work permits

The paper version of WPs are thrown away after a week. Possible handwritten comments, measurement results, changes or final signatures can thereby be lost. WPs for work carried out in connection with the clear-up had been thrown away when the PSA requested them.

10 Discussion of uncertainties

Descriptions provided during interviews conducted by the team concerning the incident and events immediately before and after agreed with each other. Statoil has provided the information requested, and the team has not found any contradictory information during the investigation.

Details of changes to routines for water washing (timing and quantity of water) have not been unambiguously established by the team's inquiries. The team has decided that this is not significant for its conclusions.

11 References

- PSA (2013). *Investigation report on a steam leak at Mongstad on 8 November 2012.*
- PSA (2017). *Investigation report following gas leak at Statoil Mongstad on 25 October 2016.*
- Statoil (2017). *Gransking av : LPG lekkasje i A-1400 på Mongstad 30.07.2017.*
- Statoil (2017A). *Granskningsrapport Lekkasje av H₂ rikt prosessmedium i område A-1200 på Mongstad. COA INV Intern ulykkesgranskning.*
- Statoil (2017B). *Corrosion loop: 15-CL-08A.*
- Statoil (2017C). *Svar til Ptil - Ifbm lekkasje på naftarør 24.10.2017.*
- Statoil (2017D). *Signert rutineliste i anlegget .*
- Statoil (2018). *Materialteknisk undersøkelse av rørsloop med lekkasje - Mongstad naftalekkasje MAT-2017185. 2018-01-02.*
- Statoil (2018B). *Granskingsrapport COA INV Intern ulykkesgranskning: Naftalekkasje i A-1500 anlegget på Mongstad 24.10.2017.*

12 Documents reviewed

- NDT Radiographic report - Naftalekkasje A-1500*
- Presentasjon: Svar til Ptil ifbm lekkasje på naftarør 24 October 2017*
- OM205.01 Arbeidstillatelse AT*
- OM205.03 Gjennomføre sikker-jobb-analyse SJA*
- ISO tegninger av rør med lekkasje*
- Presentasjon: Minimums opplæring for adgang til landanlegg i PM WR2602*
- Rapporteringsmatrise hendelser*
- Shift log 241017*
- Timp korrosjonsvurderinger November 2017*
- Timp PS1 PS8 PS12 område B1*
- Timp PS1 vurdering av område B1*
- Røntgen bilde av røret*
- RS14 T-1511 DeTec Inspection Report*
- RS14 T-1511 Bilderapport*
- RS14 T-1509 Utvendig bilderapport*
- RS14 T-1509 PT av braketter*
- RS14 T-1509 NDT rapport sveis (JD)*
- RS14 T-1509 NDT rapport sveis (IF og Z2)*
- RS14 T-1509 DeTec Inspection Report*
- Oppsummering historikk 15-CL-08 A, B og C loop*
- Inspeksjonsrapporter T-1509, T-1511 og 15-CL-08A*
- Organisasjonskart Statoil Mongstad - 2017*
- Mandat gransking av naftalekkasje, RUH1521795 - MON*
- Bilder: Gransking naftalekkasje - Bilder*
- B1 Vask av T-1509*
- Innsatsplan Brannområde 250*
- Presentasjon: Innsatsplan-brannområde 250*
- OP-00-36 Runde B-området Statoil Mongstad - 1027659*
- Timp_System15_Aug2017*
- Varsel om uønsket hendelse - Naftalekkasje i krakkeranlegg – 24102017*
- Sikkerhetsdatablad Krakker nafta*
- WP: 24233940 dismantling insulation on 1310-PL-15-0917*

Stillingsbeskrivelser A.1 Prosessanlegg (PA), A.1.1.1 Leder PA, A.1.2.1 Driftsleder A og Driftsleder B

Arbeidsprosesskrav, WR2506: Styring av helse- og arbeidsmiljørisiko

R-110046 – Arkivere avsluttet arbeidstillatelse (AT) – Mid & downstream

HMS system Verneutstyr: Anlegg: 1500 Utstyr: P-1507A-B

P&ID E004 A-1500-P-008-01 Rev X

P&ID E001 A-1500-P-009-01 Rev 0

Flow diagram E004-A-1500-P-F-012 Sheet 01 Rev B

13 Appendix

Overview of personnel interviewed.