# Investigation report

| **Report** | |
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| Report title<br>Investigation report on a steam leak at Mongstad on 8 November 2012 | Activity number<br>001902023 |

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

**Summary**

A powerful steam leak occurred at the Mongstad refinery during normal operation on 8 November 2012. Nobody was seriously injured in the incident, and material damage was limited. However, it had a major damage potential with the threat of several fatalities. A two-inch steam pipe ruptured completely, allowing large volumes of superheated steam and water to flow out rapidly at an estimated rate of 16.9 kilograms per second. Had the leak occurred a few hours later, as many as four people could have suffered life-threatening injuries or been killed. The big escape of steam was accompanied by an extremely loud noise, which was experienced as extremely painful by people close to the incident.

The leak was caused by extensive corrosion beneath the pipe insulation. Only about 0.5mm of an original material thickness of 3.9mm remained in parts of the fracture zone. The main reason for this external corrosion is assumed to be wetting of the insulation over a long period as a result of corrosion in and damage to its mantling, while periodic blowoffs in the steam pipe provided optimum temperatures for corrosion. The leak may also have occurred from a steam tracing pipe.

| **Involved** | |
|---|---|
| Main group<br>T-L | Approved by/date<br>Kjell Arild Anfinsen/8 March 2013 |
| Members of the investigation team<br>Bryn Aril Kalberg, Odd Hagerup and Einar Ravnås | Investigation leader<br>Einar Ravnås |

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**Contents**

(må lages på nytt)

## 1 Summary

A powerful steam leak occurred at the Mongstad refinery during normal operation on 8 November 2012. Nobody was seriously injured in the incident, and material damage was limited. However, it had a major damage potential with the threat of several fatalities. The Petroleum Safety Authority Norway (PSA) resolved on 15 November 2012 to conduct its own investigation of the incident.

Two days earlier – on 6 November 2012 – a small leak was found, water was dripping out of the insulation around a two-inch blowoff pipe running from the bottom of the steam separator in the cracker system. This pipe is used three-four times a week to remove sediment from the separator. It is insulated and heated by a small bore steam tracing pipe, which was assumed to be the source of the leak. Repairing such leaks is routine work, and preparations began by starting to erect scaffolding beneath the leak location. This had almost been completed at the end of the working day on 7 November 2012. Three people worked to erect the scaffolding – two usually at a height and one at ground level. The heads of the two working above ground would have been close to its site if the leak had occurred during this job. Had the leak occurred later, while the repair was being made, up to four people could have suffered life-threatening injuries or been killed.

The actual leak occurred abruptly at 05.45 on 8 November 2012. The steam line ruptured completely and large volumes of steam, estimated at 16.9 kilograms per second, flowed out at great speed to form a large steam cloud in the direction of the wind, which was blowing strongly from the north-west. The big escape of steam was accompanied by an extremely loud noise, which was experienced as extremely painful by those in the vicinity. Communication between people in the area and between the plant operator and the control room was virtually impossible because of the noise level. After 12 minutes, the leak site was isolated by closing the valve immediately beneath the steam separator. Preparations to shut down the plant had already been initiated at that time.

Extensive corrosion under the insulation was the cause of the leak. The external mantling (metal sheath) was substantially corroded over large areas and small holes were clearly visible. Only about 0.5 mm of an original material thickness of 3.9 mm remained in parts of the fracture zone on the steam pipe. Internal corrosion in the latter appeared to be limited. Insulation was wet around the whole pipe. The main reasons for the extensive external pipe corrosion are assumed to be long-standing moistness in the insulation as a result of the corroded and damaged mantling, and the fact that periodic blowoffs in the steam pipe have provided optimum temperatures for corrosion to develop. The leak may also have occurred from the steam tracing pipe.

The damaged piping has been investigated by Statoil's materials laboratory at Rotvoll to determine whether fatigue caused the fracture as a result of corrosion and reduced wall thickness. Results show that the pipe failure was a straightforward load fracture owing to the reduced wall thickness.

## 2 Introduction

A powerful steam leak occurred at the Mongstad refinery during normal operation on 8 November 2012. Nobody was seriously injured in the incident, and material damage was limited. However, it had a major damage potential with the threat of several fatalities.

The Petroleum Safety Authority Norway (PSA) decided on 15 November 2012 to conduct its own investigation of the incident.

Participants in the investigation team:

Odd Hagerup, principal engineer, structural safety
Bryn A Kalberg, special adviser, emergency response
Einar Ravnås, principal engineer, process integrity (investigation leader)

The investigation team has based its assessments and analyses on:

- conversations and interviews with personnel involved at Mongstad from 19-20 November 2012
- verification at the leak site on 19 November 2012
- review of documents
- Statoil memo, *General considerations concerning injuries from steam*, 14 December 2012
- Statoil report: *Failure analysis of fractured pipe from D-1535 Mongstad* (MAT-2013001)
- Statement from the chief company medical officer at Mongstad of 12 February 2013 in relation to the incident of 8 November involving extraordinary noise from pipe rupture

Investigation team's mandate:

1. Clarify the incident's scope and the course of events
    a. clarify and assess conditions related to safety and emergency response
2. Describe the actual and potential consequences
    a. injuries to people and damage to material assets and the environment
    b. assess the potential for injuries to people and damage to material assets and the environment
3. Identify and describe observations of direct and underlying causes
    a. observed nonconformities from requirements, methods and procedures
    b. improvement points
4. Discuss and describe possible uncertainties/ambiguities
5. Identify possible regulatory breaches, recommend further follow-up and propose responses
6. Prepare a report and accompanying letter in accordance with templates
7. Set a timetable for implementing the work

It was decided that the PSA's investigation would not involve an in-depth description of underlying causes and the preparation of a human/technology/organisation (HTO) diagram. We refer in this context to Statoil's internal investigation of the incident.

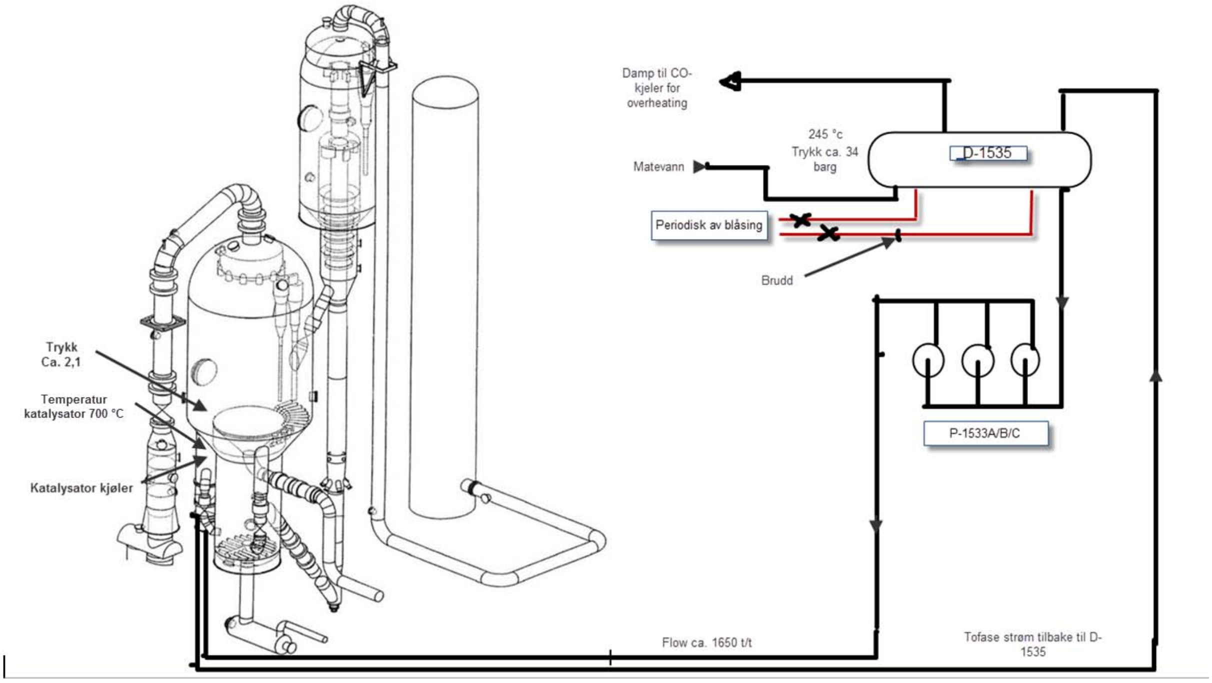
# 3 Course of events

## 3.1 Background

### 3.1.1 The cracker and steam separator


*Aerial view of the Mongstad refinery. The leak occurred in the cracker (red arrow). Key: Cracker; Process plant B.*

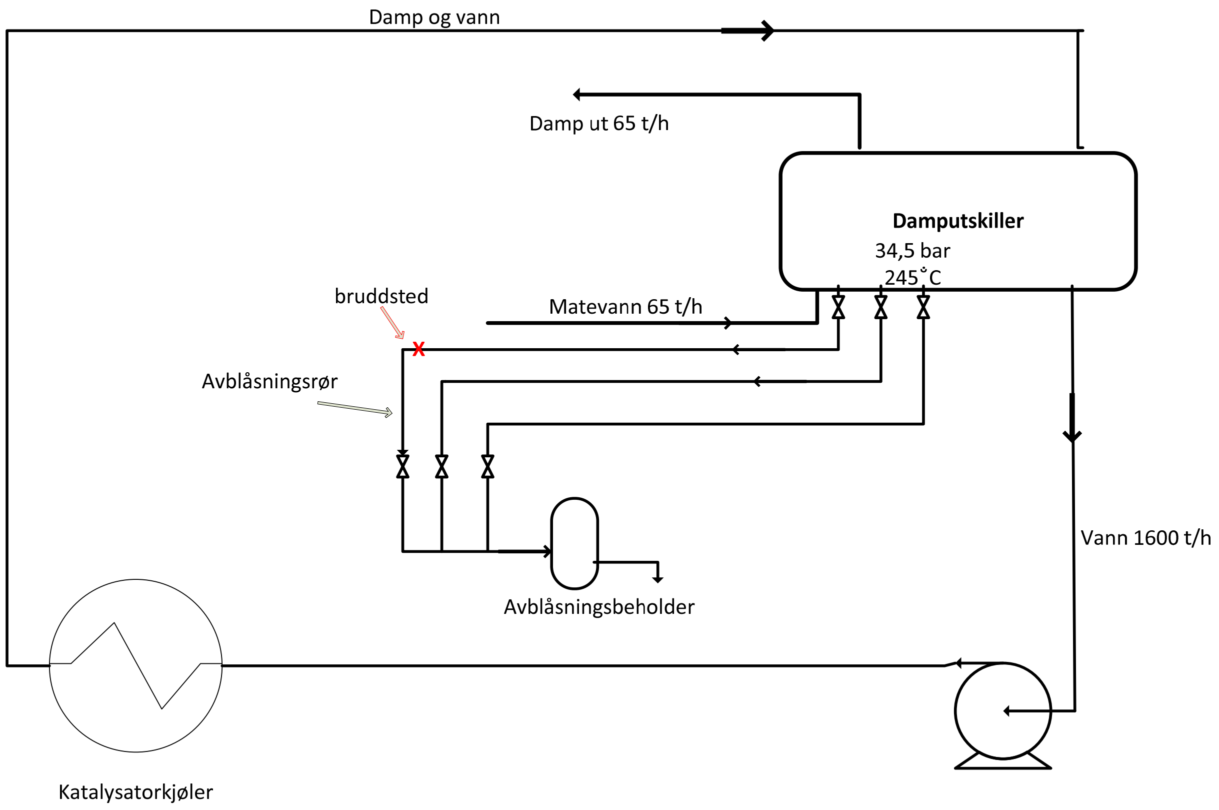
The first stage of the Mongstad refinery was constructed in 1974, and this facility was expanded and upgraded in 1989 – including the installation of a cracker. Conducted at a pressure of 2.1 bar and a temperature of about 510°C, the cracking process incorporates a catalyst to split heavy hydrocarbons into lighter components. Petroleum coke forms in this catalyst, and must be burnt off in a separate regenerator at a temperature of about 735°C.




*The cracker and the regenerator where coke is burnt off and steam produced are shown on the left, with the steam separation process illustrated to the right. Key: Pressure abt 2.1; Temperature catalyst 700°C; Catalyst cooler; Flow abt 1 650 t/h; Steam to CO cooler for overheating; Feedwater; Pressure abt 34 barg; Periodic blowoff; Fracture; Two-phase steam back to D-1535.*

Surplus heat is produced during the combustion process. The catalyst is cooled down by water under high pressure and temperature. This heat transfer is so substantial that the water boils vigorously. The part of the regenerator where this occurs is called the catalyst cooler in this report. A two-phase blend of water and steam is led to a steam separator, where the steam is separated from the water before being led into the refinery's steam system. The water is pumped back to the catalyst cooler. Keeping the water as clean as possible is important, so a little of it is blown off both from the water surface and from the bottom of the steam separator to remove sediments and unwanted particles. While automatic blowoff from the water surface is continuous, the bottom is blown off manually three-four times a week to a blowoff vessel at ground level. Each blowoff lasts about four seconds.

Two valves are installed on this pipe, one beneath the steam separator and the other at ground level. The steam separator is located about eight metres above ground. The upper valve is normally open, so that pressure in the pipe is constant, while the lower valve is the one used for periodic blowoff. With a diameter of two inches, the pipe runs back and forth under the separator and is about 30 metres long.  The leak occurred in this blowdown pipe.

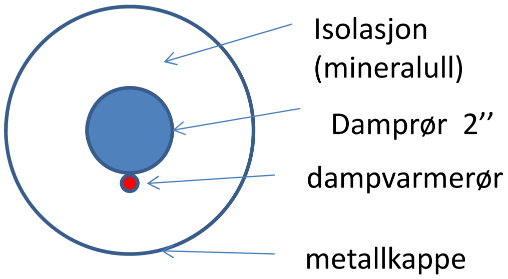



*Key: Steam and water; Steam out 65 t/h; Steam separator; Feedwater; Fracture site; Blowoff pipe; Blowoff vessel; Water 1 600 t/h; Catalyst cooler.*

### 3.1.2 Steam tracing pipe

To prevent liquid in the water and steam pipes from freezing at low winter temperatures, a small bore (about 20mm) pipe running alongside keeps them heated while not in use. The steam in this pipe has a pressure of about 3.5 bar and a temperature of around 175 °C. The pipes are insulated by about 5cm of mineral wool and protected by an external metal mantling intended to prevent moisture intrusion. The pipes are insulated to safeguard people, limit heat loss and enhance the steam tracing pipe's efficiency.

A lot of steam tracing pipes are used at Mongstad. This system has suffered frequent leaks, which create big challenges in the form of wet insulation and corrosion under insulation (CUI). Normal leak points are at flanges or from local corrosion. The leaks are often small, in the form of drops or thin jets, so that it can take time before they are discovered. Since




*Cross section of the blowoff pipe. Key: Insulation (mineral wool); Steam pipe two-inch; Steam tracing pipe; Mantling* moisture and temperature create good conditions for external piping corrosion, leaks should be dealt with quickly. Three people are permanently employed on this work to keep on top of it. Leak sites are often difficult to access. Scaffolding must be erected in many cases. Such jobs are so frequent that they have become routine. A work process of this kind had been initiated when the incident occurred, since the leak was assumed to be in a steam tracing pipe rather than the actual steam pipe. Such tasks require an approved work permit (WP), but no safe job analysis (SJA) has been conducted before the work was started.

### 3.1.3 Surface programme – corrosion monitoring and repair

Surface corrosion under insulation on process equipment and piping is a major challenge for the industry. Preventing and repairing rust damage take place continuously or periodically at Mongstad. Water intrusion through weakened mantling creates favourable conditions for invisible corrosion. Damage repair is based on inspection findings and risk analyses (risk-based inspection programme for stationary equipment – RBI), and on pipeline inspection in Statoil (RIS). Priority is given to the systems at highest risk. So process equipment and hydrocarbon systems have higher priority than steam, water and other utility systems. Area-based repairs are also conducted to enhance efficiency.

The area where the incident occurred was included in the plans for surface maintenance, with repairs due in 2013. (Three packages remain in the pipe track with completion before the 2014 turnaround.) Work has been done by a contractor who has now relinquished the contract, and Statoil is seeking a replacement. Area repairs have been delayed in relation to earlier plans. In addition, equipment is regularly monitored and checked at planned intervals to keep track of internal and external corrosion as well as wall thickness in order to ensure that the equipment operates within the limits set by regulations, standards and internal requirements.

Checks of the upper end of the pipe where the steam leak occurred were conducted in 2009 by X-raying the pipe connector from the vessel and by spot checks of the pipe (without erecting scaffolding). The results lay within acceptable limits. Moreover, the lower section at the outlet was replaced downstream from the blowoff valve.

### 3.1.4 The inspection programme

A RIS inspection programme for piping has been developed based on criticality, risk and consequences. This will now be transferred to a new programme based on Shell’s RIS programme.

The inspection programme is based on analyses of corrosion conditions, criticality and risk assessments. Basic analyses and assessments are conducted by Mongstad with support from other company units. The contractor’s inspection programme is drawn up on the basis of these assessments with support from Statoil. Detailed programmes and sample selection, scope and notation on drawings/P&IDs are carried out by the contractor doing the inspection.

Priorities are determined by criticality and the probability of corrosion. Hydrocarbon systems have top priority. Design data provide the basic input for analyses. Experience and operating information are included when updating analyses and inspection programmes.

Collaboration between inspection, process and operational functions to provide quality assurance of the data used is necessary for ensuring the best possible analysis.

Analyses of the steam system utilised design values which specified a constant high temperature and thereby no danger of corrosion because water would evaporate, the pipe wall would be dry and the threat of corrosion small. The pipe was accordingly neglected. Following the incident, it transpired that those responsible for monitoring corrosion development had inaccurate operational data for this pipe. As a result, it was assumed to be far less exposed to corrosion than was actually the case. (A temperature of 250°C was assumed while it was actually 20-60°C – ideal for corrosion.)

In light of the incident and new information, future risk assessments for all steam/water systems will now be based on operating parameters as well as on design data, experience and updating of inspection programmes.

Better collaboration/communication between operational and technical personnel is required to achieve an integrated understanding by those who draw up plans for risk-based inspection, including RIS. The material used in the steam tracing pipe does not appear to have been assessed with regard to corrosion. This is AISI 316 steel exposed to chloride stress corrosion cracking at temperatures above about 60°C when moisture is present along with chlorides.

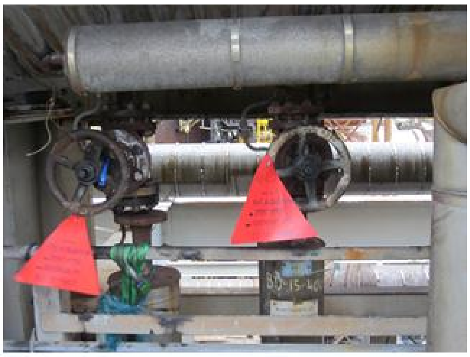
#### 3.1.5 Design base for steam separator and blowoff pipe

The steam separator and cracker cooler are defined as part of the cracker system and therefore designed to process standards. Their main purpose is to exploit surplus heat to generate steam, and they have the same function and role as a steam boiler. Dedicated boiler standards are used when designing normal units of this kind. These would require a greater material thickness (6.2 mm) for the blowoff pipe where the leak occurred than process standards (3.9 mm). The difference in thickness could have been sufficient to postpone the fracture point until repairs had been carried out in this area via the surface programme (corrosion under insulation).

### 3.2 Incident of 8 November 2012

A small leak was discovered on 6 November 2012 from the insulation around the blowoff pipe running from the base of the steam separator. This is used three-four times a week to remove sediment from the separator. It is fitted with a steam tracing pipe and insulated, and warm water was dripping from a point on the mantling which encased the pipe. The leakage was assumed to come from the steam tracing pipe. Because of the insulation, the actual leak point was not visible. Such leaks are common and repairing them is a routine job. Work was initiated by starting to erect scaffolding under the leak in order to access and repair it. The scaffolding job was almost finished at the end of the working day on the afternoon of 7 November 2012. At that point, the framework of the scaffolding had been erected and the topmost platform was to be put in place and secured the following day. Three people worked to erect the scaffolding – two usually at a height and one at ground level. The heads of the two working above ground would have been close to the leak site had occurred it during this job.


*Fracture site* *Top platform on scaffolding*



*Ventilen til venstre ble stengt og lekkasjen stanset*

*The valve on the left was shut and the leak ceased.*

The actual leak occurred abruptly at 05.45 on 8 November 2012. The steam line ruptured completely and large volumes of steam, estimated to be 16.9 kilograms per second, flowed out at great speed to form a large steam cloud downstream in the direction of the wind, which was blowing strongly from the north-west. The big escape of steam was accompanied by an extremely loud noise, which was experienced as extremely painful by those in the vicinity. Communication between people in the area and between the plant operator and the control room was virtually impossible. After 12 minutes, the leak was isolated by closing the valve under the steam separator. The outflow then stopped immediately and the intolerable noise ceased.

## 3.3 Response to the incident by operational personnel

### 3.3.1 The leak location

One of the plant operators was in the area when the leak occurred. The noise was so high that he felt he was knocked to the ground and that it was painful to remain there. The leak started without warning. Since no gas detection was activated, he quickly concluded that a steam leak had occurred and began work to identify its source and opportunities to halt it.

The assistant operations supervisor went out into the plant immediately when notified of the incident. He worked with the plant operator to find the location and stop the leak. The actual leak area was quickly located, and the supervisor tried to follow the pipe upstream to see where it came from. Despite the noise, he managed to hear some reports from the control room (panel) operator and thereby learnt that the level of liquid in the steam separator was starting to fall. He was twice on a level with the separator, and began on the second occasion to shut and open the blowoff valves beneath the separator to see if this affected the noise level. When he came to the final valve, the noise quickly fell and the leak ceased.

A plant operator from the B-2 area also arrived. He quickly realised the difficult communication position, particularly between control room operators and operations personnel on the scene. He accordingly used his bicycle to get 50 metres from the noise zone and inform the panel operator of the position in the leak area. At the same time, he received details about important alarms and general conditions in the plant. This included information that the water level was falling in the steam separator and that preparations were being made to shut down the plant. The operator sought to convey this to the other operator and the assistant operations supervisor by cycling to and fro several times.

The response personnel, under the leadership of the assistant operations supervisor, had themselves to assess their personal safety and the action to be taken. Conditions assessed were the probability of new fractures, the wind direction and possible escape routes. Nevertheless, the high noise level represented a potential risk in that staying calm and thinking clearly in such circumstances was challenging.

With steam spreading over a wide area, uncertainty prevailed about where and at what distance from the leak site it was safe to move in the area. This was not a big problem during the incident because the operations personnel stayed upwind of the leak site. Calculations of steam dispersion have been carried out by Statoil after the incident. See appendix 1.

### 3.3.2 The control room

The control room operators quickly became aware that this was an incident with a high level of noise. They were unable to hear anything reported by the operations personnel in the leak area, and received no feedback that the latter had heard what was being said from the control room. The cycling plant operator helped to clarify the position a little.

A number of alarms eventually sounded, and the control room operators quickly realised that the water level in the steam separator was falling even though new feedwater was flowing in. They modified the operating conditions somewhat to reduce cooling demand on the cracker cooler, but it was impossible to maintain the level in the separator. Signals from the low-level switches were overridden to postpone automatic shutdown and gain a little more time. The water level was very low and was carefully monitored, and the operators began to prepare for a shutdown. Before this was initiated, the outside operations personnel managed to stop the leak and the control room stabilised operations. Closing the blowoff pipe immediately under the steam separator had no short-term consequences for continued stable operation.

## 3.4 Notification of the authorities

The incident occurred at 05.45 on Thursday 8 November 2012. Statoil sent a written notification to the PSA at 12.06 on 12 November 2012. Since serious incidents are to be notified by phone, the PSA has not established a system for continuous monitoring of written notifications it receives. As a result, the notification from Statoil Mongstad was first picked up by the PSA's duty officer on Tuesday 13 November 2012.

During our conversations at Mongstad, we formed the clear impression that the Statoil management had already understood the seriousness of the incident during Friday 9 November 2012.

## 3.5 Investigations after the incident

### 3.5.1 Site inspection

An inspection of the site showed that the blowoff pipe had been completely ruptured. Immediately past the (downstream) fracture site, the pipe had been bent by 90 degrees at two points about a metre apart (see the photographs). The big outflow created reaction forces

*Røret oppstrøms bruddstedet har svingt til venstre og vridd seg kraftig*

*The pipe upstream of the fracture site has swung to the left and twisted sharply.*

*Damprøret nedstrøms bruddstedet viser kraftig korrosjon*

*The steam pipe downstream from the fracture site shows heavy corrosion.*

which meant the pipe swung sharply back on itself and became twisted. It had clearly struck sharply against two large steam pipes, but further twisting was prevented by a strong beam. The latter probably prevented new fractures occurring upstream from the fracture site.

Insulation and mantling were flung across the area. Heavy corrosion was generally present around the whole pipe diameter over a large area. Local corrosion normally takes the form of pitting with subsequent penetration which produces a leak in the form of a jet.

Only about 0.1mm of an original material thickness of 3.9 mm remained in parts of the fracture zone. Internal corrosion in the line appeared to be limited. The steam tracing pipe had little corrosion and suffered limited damage from the incident.

The mantling was heavily corroded over large areas of the pipe, and had clear holes. Insulation was wet around the whole pipe. The main reasons for the extensive external pipe corrosion in the facture zone are assumed to be long-standing moisture intrusion from the outside in the insulation as a result of the corroded and damaged mantling, and the fact that periodic blowoffs in the steam pipe provided optimum temperatures for corrosion.

The water leak which had been attributed to the steam tracing pipe could also have come from the actual steam pipe. Small holes in the latter were visible close to the fracture zone. It is nevertheless impossible to be certain about that. The holes in the steam pipe could have arisen during the incident. This type of fracture in steam pipes as a result of corrosion is infrequent. Corrosion normally weakens the material and small holes occur which gradually get bigger. Leaks are therefore usually discovered before they get large. In this case, heavy corrosion must have been concentrated in a small area around the whole diameter of the pipe. All the same, the leak has probably started in a small area and spread immediately because of reduced material thickness, and the final section has ruptured because of a big outflow and powerful movements.

Denne fliken av røret ble revet av
og viser kraftig korrosjon

*This bit of pipe was ripped off and shows heavy corrosion.*

Rester av metallkappen ble kastet
av røret

*Remains of the mantling were thrown off the pipe.*

### 3.5.2 Investigation of pipe and fracture

The damaged pipe was sent to Statoil’s material laboratory at Rotvoll to determine whether fatigue had caused the fracture as a result of reduced wall thickness or corrosion. Parts of the steam pipe were also sent for investigation. The results show that the pipe suffered a straightforward load fracture as a result of reduced wall thickness. See appendix 2.

The steam tracing pipes are manufactured in AISI 316 stainless steel, where chloride stress corrosion cracking has been found. This material is exposed to stress corrosion cracking at temperatures above about 60$^{o}$C in environments which contain chloride.

Many small leaks and constant repairs to steam tracing pipes show that water intrusion into insulation must be a general problem. Saline water intrudes to create chloride stress corrosion cracking with leaks from steam tracing pipes and general corrosion of carbon steel pipes.

# 4 Potential of the incident

## 4.1 Actual consequences

The plant operator was in the area when the fracture occurred. The assistant operations supervisor and the operator from B-2 came to the site. Six operators in all were identified for possible exposure to high noise. The strength of the noise exposure is not known. These six operators were reported to the Mongstad company medical service (BHT). Audiometry shows that two of the six had changes since the latest measurements by the BHT. The four others had no identified threshold changes. See appendix 3.

Material damage from the incident is insignificant and limited to pipe damage. The control room prepared to shut down the whole plant, but the leak was stopped before this was initiated. Production was not halted, and no output was lost. The natural environment was unharmed.

## 4.2 Potential consequences

Had the leak occurred two hours later, work on erecting the scaffolding would have continued. The pipe could also have ruptured the day before while the scaffolders were erecting the scaffolding framework. In both cases, two scaffolders would have been above ground and could have been directly exposed to the incident. A scaffolder would also have been on the ground – in other words, at a slightly greater distance from the leak site.

The pipe could have ruptured after the scaffolding was ready. A critical point would then have been preparations/approval for starting to remove insulation. Assuming that the insulation would be removed while the pipe was pressurised, up to four people could in the worst case have been exposed to the incident (two insulators, one coordinator and one operator).

The main consequences for people who might have been directly exposed are:

- burns from superheated steam and water
- the pressure energy in the expanding steam could have caused direct injury and possible secondary injuries if people were thrown from the scaffolding
- hit by loose pipe fragments
- hearing damage.

A maximum of four people could have suffered life-threatening injuries or been killed.

The potential for material loss was limited to lost production related to a possible shutdown of the plant as well as the material damage caused by the incident.

The potential for damage to the natural environment was negligible.

# 5 Observations

The PSA’s observations fall generally into three categories:

- nonconformities: observations where the PSA believes that regulations have been breached
- improvement points: observations where deficiencies are found, but insufficient information is available to establish a breach of the regulations
- conformities/barriers which have functioned: used where conformity with the regulations has been established.

## 5.1 Nonconformities

### 5.1.1 Corrosion under insulation

**Nonconformity**
The system for checking corrosion under insulation has not been implemented in an adequate manner.

**Grounds**
Despite the great attention paid to corrosion under insulation, the system has been inadequate. It emerged during the interviews that this reflects the use of inaccurate data (temperature) and erroneous assessments when conducting analyses for the inspection programme.

Inspections have been carried out through spot checks of the relevant system on the connection under the vessel and at the outlet pipe (replaced) from the condenser vessel at ground level. This does not constitute an adequate check of the pipe.

The system for inspection follow-up does not detect when analyses need to be reassessed and the inspection programme updated. Because it was classified as low risk, the water system has been given insufficient priority. The original analyses were based on design data for a pressure of 36 bar and a temperature of 250 °C. The probability of corrosion under the insulation on insulated piping with a high continuous temperature has been considered low because intruding water would quickly evaporate and the pipe surface would remain dry. Operating data show that the pipe has been operated periodically and has had a temperature in the 20-60 °C range. This information has not been used in corrosion assessments.

Preparation and execution of the spot-check programme are left to contractors without adequate follow-up by Statoil personnel.

The mantling around the insulation on the steam pipes is in very poor condition. Combined with earlier experience, this has had no clear effect on the scope of corrosion checks. The many leaks in steam tracing pipes show that intrusion of saline water into the insulation is a general problem, which has given rise to frequent incidents of chloride stress corrosion cracking in AISI 304/316 stainless steel.

***Requirements***
*Section 50 of the technical and operational regulations on competence.*
*Section 57 of the technical and operational regulations on monitoring and control.*
*Section 21 of the management regulations on follow-up.*

### 5.1.2 Piping and systems used or operated periodically

**Nonconformity**
The corrosion monitoring programme for piping and systems used periodically and therefore subject to fluctuating temperatures is not good enough.

**Grounds**
Those responsible for corrosion monitoring had a general understanding that piping connected to a pressure vessel operated at the same pressure and temperature it was designed for.

Piping operated below its design temperature could be exposed for much heavier corrosion.

A number of pipes were operated in a corresponding or similar way to the one where the leak occurred.

Immediately after the incident, a small leak occurred in a hydrocarbon pipe which was also operated periodically and at a lower temperature.

The technical and operational system managers had no obvious common approach for identifying faults of this type.

***Requirements***
*Section 50 of the technical and operational regulations on competence.*
*Section 57 of the technical and operational regulations on monitoring and control.*

### 5.1.3 Notifying the supervisory authorities

**Nonconformity**
The PSA was not notified early enough about the relevant incident.

**Grounds**
As specified in section 29, paragraph 1 of the management regulations, hazards and accidents must be notified to the PSA immediately by phone.

The incident occurred at 05.45 on Thursday 8 November 2012. Statoil sent a written notification to the PSA at 12.06 on Monday 12 November 2012. We acquired the clear impression during our conversations at Mongstad that Statoil's management had already understood the seriousness of the incident during Friday 9 November 2012.

***Requirement***
*Section 29 of the management regulations on notification and reporting of hazard and accident situations to the supervisory authorities.*

## 5.2 Improvement points

### 5.2.1 Risk assessment

**Improvement point**
Risk assessment when repairing steam leaks is inadequate.

**Grounds**
It emerged from the interviews that repairing leaks in heat tracing pipes was so common that this represented routine work. A dedicated group was established to work permanently on it. Such work requires an approved work permit (WP), but no safe job analysis (SJA) was conducted before this specific assignment.

The outflow of hot water during the repair work was unpleasant for the scaffolders, who had to protect themselves with rainclothes. This water flow could have been reduced or possibly halted by closing some valves for the heat tracing system.

A risk assessment ahead of the work could in this case have identified the leak point, and closing some valves could have reduced/eliminated the potential of the incident.

***Requirements:***
*Section 58 of the technical and operational regulations on maintenance.*
*Section 17 of the management regulations on risk analyses and emergency preparedness assessments.*

### 5.2.2 Surface maintenance programme

**Improvement point**
Progress in the surface maintenance programme has been low.

**Grounds**
The condition of a number of pipes is unknown. This applies to steam/water piping and liquid-bearing hydrocarbon pipes with steam tracing. Because it was assumed that the pipes

were operating at a temperature which differed from the actual operating condition, inspection was reduced to spot checks.

The condition of the mantling and the leaks which have occurred show that improvements are required quickly. The surface maintenance programme has extended over a number of years, and the latest updated plans call for the final module to completed in the summer of 2014. This programme is delayed for several reasons, including a recent change of contractor.

***Requirement***
*Section 58 of the technical and operational regulations on maintenance.*

### 5.2.3 Pipe class and design requirements

**Improvement point**
The pipe class and original design requirements differ between the steam separator and steam boilers, and can create uncertainty.

**Grounds**
It emerged from the conversations that different pipe classes have been utilised in the steam systems, depending on the design code applied. Pipe class 600 in accordance with the earlier boiler regulations has been used when designing the steam system. New regulations on inflammable or pressurised substances came into force on 1 March 2004. These required a significantly greater wall thickness than for corresponding piping in the process plant which accorded with the process code and had pressure class 300. Differing pressure classes are unfortunate in a system operating with the same type of medium. Identification of piping designed in accordance with two codes seems unclear and is not incorporated in inspection assessments.

***Requirement***
*Section 7 of the technical and operational regulations on installations, systems and equipment.*
*Section 8 of the technical and operational regulations on materials.*
*Section 57 of the technical and operational regulations on monitoring and control.*
*Section 58 of the technical and operational regulations on maintenance.*

### 5.2.4 Tagging of valves and piping

**Improvement point**
Tagging of piping and valves is deficient.

**Grounds**
During our inspection of the plant, we observed that valves and piping were poorly tagged.

***Requirements***
*Section 7 of the technical and operational regulations on installations, systems and equipment.*

### 5.2.5 Communication with incident personnel under very high noise levels

**Improvement point**
Lack of communication between plant operators and the control room when noise levels are very high.

**Grounds**
Personnel in the area close to the leak were exposed to very loud noise. This meant in part that communication between the plant operators and the control room failed to function satisfactorily. The plant operator only heard part of what the control room said, while the latter failed to hear anything the plant operator reported. As a result, the control room also failed to receive any feedback on whether the plant operator had received its information.

The operators emphasised that communication problems between plant personnel and the control room would have been a further challenge if it had become necessary to run down the facility while the plant operators were exposed to the noise.

***Requirement***
*Section 22 of the technical and operational regulations on communication systems and equipment.*

### 5.2.6 Routines for and understanding of overriding safety functions

**Improvement point**
Routines for and understanding of overriding safety functions could be improved.

**Grounds**
Safety systems are designed to maintain important safety functions when equipment and components are subject to abnormal loads or are operated outside their design value and normal operating area.

***Requirement***
*Section 10 of the technical and operational regulations on safety functions.*

## 5.3 Barriers which have functioned

Despite the nonconformities and improvement points presented above, we note that the position was normalised without further escalation. This must mean that a large number of barriers have functioned. We have not identified and analysed all of these in detail. We confine ourselves to mentioning a couple which functioned:

- operations personnel came across as competent and experienced, and responded to the circumstances in a purposeful manner
- systems for technical monitoring of the process provided control room personnel with information which was important for understanding the position.

# 6 Discussion of uncertainties

Given all the leaks from steam tracing pipes and the continuous repairs to these, the pipe in this case also appeared to be leaking and in need of repair. But it was also conceivable that the volume of hot water emerging from the insulated pipe came from a leak in the main pipe before the fracture, or from both pipes. Analyses show a number of small cracks were present in the steam tracing pipe as a result of chloride stress corrosion. Saline water had penetrated the insulation because the mantling was damaged and corroded. The cracks do not appear to be large enough to have occasioned the water flow observed on the day before the fracture.

Signs of small holes could be seen on the steam pipe, but this was so damaged that it is difficult to say whether there were one or more larger holes before the fracture. Both pipes have probably leaked water/steam.

Assessing the potential consequences of the incident is beset with uncertainties. We have assumed that a maximum of four people could have been directly exposed by the incident. In this context, we have made an estimated assessment based to a large extent on information we received at Mongstad.

Great uncertainty relates to the extent of possible injuries to personnel who might have been directly exposed to the incident. This assessment has been based on Statoil's memo entitled *General considerations concerning injuries from steam* of 14 December 2012. This explains the uncertainty related both to the theoretical calculation model and to the assessment of consequences. Our assessment of the scope of damage builds to a great extent on estimated assessments.

## 7 Appendices

B: The investigation has drawn on the following documents:

1. Statoil memo: *General considerations concerning injuries from steam*, 14 December 2012.
2. Statoil report: *Failure analysis of fractured pipe from D-1535 Mongstad* (MAT-013001).
3. Statement from the chief company medical officer at Mongstad of 12 February 2013 in relation to the incident of 8 November involving extraordinary noise from a pipe rupture.

C: Overview of personnel interviewed

4. List of personnel interviewed