PETROLEUMSTILSYNET

Investigation report

Report	
Report title Hydrocarbon leak in the process plant at Hammerfest LNG	Activity number 001901027

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

Summary

Involved	
Main group T-L	Approved by/date Kjell Arild Anfinsen
Members of the investigation team Per Endresen, Espen Landro, Bryn Aril Kalberg	Investigation leader Arne J Thorsen

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(må lages på nytt)

1 Summary

A hydrocarbon (HC) leak occurred during normal operation in the process plant at Melkøya on 5 January 2014. The PSA resolved on 7 January 2014 to conduct its own investigation of the incident.

Gas was detected by a gas detector at 21.10 on Sunday 5 January, and the gas alarm sounded. A large part of the sealing liquid, n-pentane, for pump 25-PA-102B escaped to the atmosphere while the liquid pressure fell rapidly by about 15 bar. The stuffing box between pump and shaft was then unable to prevent a leak of process medium, which now had a passage to the air.

The plant was shut down at 21.32, and flaring began at 21.45.

Two operators were out in the plant immediately before the incident. They were evacuated.

The leak site was determined to be through the stuffing box for pump 25-PA-102B. Wear was observed on one of the gaskets in the box. The underlying causes of this wear have not been clarified.

Calculating the leak rate and quantity is difficult. Simulations have been carried out in an attempt to match leak rates with detector readings. These indicate a leak rate of 0.1-0.3 kg/s and a leak quantity of 250-750 kg.

Actual consequences:
No personal injuries or material damage were suffered. Production was halted for three days.

We assume that the HC leak has not harmed the environment.

Potential consequences:
Had the gas ignited, an explosion would have resulted which could have caused two fatalities. One person was in the immediate vicinity and another out in the plant could have been affected. An explosion would also have caused damage to equipment and structures, which would have shut down the plant.

We assume that this would not have harmed the environment.

One nonconformity has been identified:

- time elapsed between the alarm sounding and the start of pressure blowdown

and three improvement points:

- location of the emergency response team – establishment of coordination point (CP)
- understanding of risk when gas is detected
- use of trend data and maintenance history in continuous monitoring and operation of the plant.

2 Introduction

An HC leak occurred during normal operation in the process plant at Melkøya on 5 January 2014. The PSA resolved on 7 January 2014 to conduct its own investigation of the incident.

Composition of the investigation team:
Arne J Thorsen, investigation leader
Espen Landro
Bryn Aril Kalberg
Per Endresen

Procedure:
The investigation team travelled to Hammerfest on Sunday 12 January 2014.

The police reported on 11 January 2014 that they were considering requesting help with this case. On arrival in Hammerfest, the need for such support was discussed in a meeting with the police.

A brief review of the incident was presented by Statoil the next day, followed by a tour of the site. The police decided to investigate the leak. A plan for providing support was drawn up.

Over the following days, a number of police interviews were conducted with the PSA present. The PSA team conducted some additional interviews and reviewed documents.

The investigation team went back to Stavanger on 16 January 2014.

The team returned to Hammerfest on 17 February 2014 to conduct supplementary interviews, and went home on 19 February 2014 after a brief review meeting with the police.

Mandate:
1. Clarify the scope and course of the incident
    a. map and assess safety and emergency response aspects
    b. map and assess the work done and assessments made ahead of the start-up after the first and second incidents.
2. Describe and assess the actual and potential consequences
    a. harm caused to people, material assets and the environment
    b. the incident’s potential to harm people, material assets and the environment.
3. Identify and describe possible uncertainties/unclear aspects
    a. observed nonconformities from requirements, approaches and procedures
    b. improvement points.
4. Discuss and describe possible uncertainties/unclear aspects.
5. Identify possible regulatory breaches, recommend further follow-up and propose measures to be taken.
6. Prepare a report and covering letter in accordance with established templates.

Time frame
The time frame for completing the assignment will be agreed after initial investigations have been completed.

3 Course of events

Position before the gas leak
This was basically a calm evening at Melkøya, with stable production and no vessels berthed. No meteorological measurements are made in this part of the facility, but the average of the

four metering points around the plant showed a wind strength of 2.0-2.7 m/s with gusts of 3.1-3.7 m/s from a south-easterly direction (128° and 141°) when the leak occurred around 21.20.

No work was under way out in the plant. Two active work permits (WPs) were in place
- vessel on the field (Snøhvit)
- excavation permission, parking heavy vehicle off -road.

Neither of these were relevant for the incident.

Personnel on duty this evening/night:
- 14 technicians, regarded as sufficient by the shift supervisor
- four apprentices
- one insulator (not out in the plant this evening)
- catering staff
- guards and security.

Two operators were out in the plant immediately before the leak.

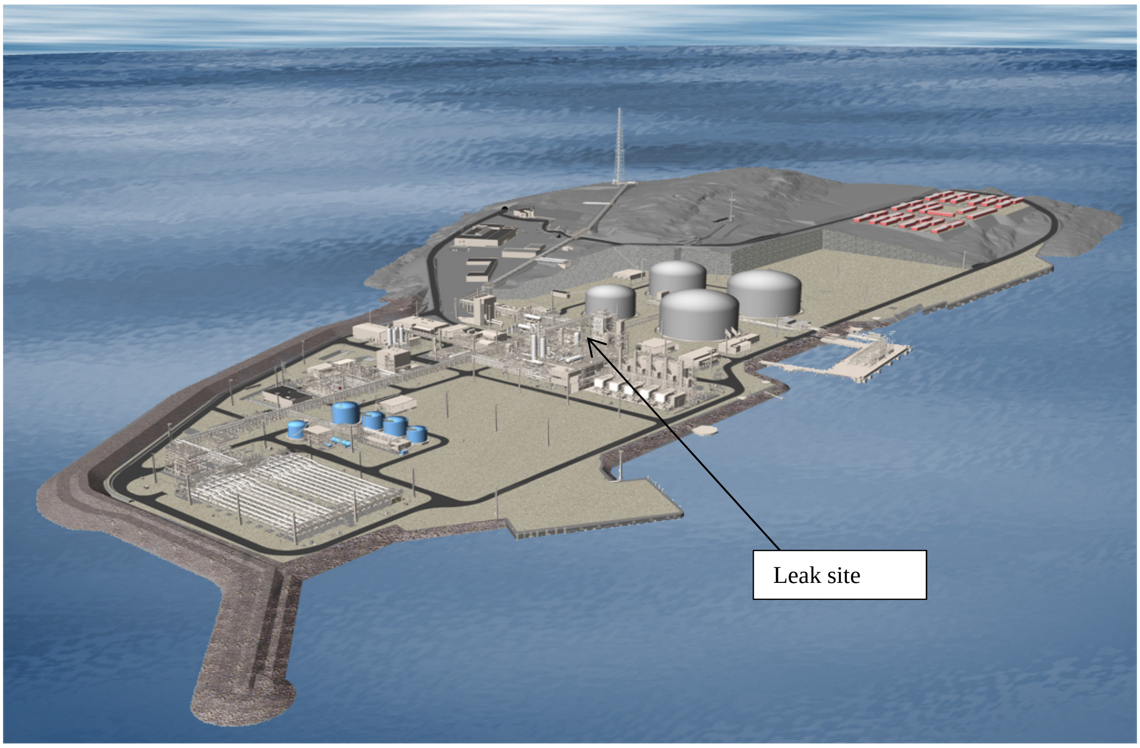


Illustration 1. Schematic diagram of Melkøya.

Incident

Gas was detected by a gas detector at 21.20 on Sunday 5 January and the gas alarm sounded. A large part of the sealing liquid, n-pentane, for pump 25-PA-102B escaped to the atmosphere while the liquid pressure fell rapidly by about 15 bar. The stuffing box between pump and shaft was then unable to prevent a leak of process medium, which now had a passage to the air. The gas alarm closest to the pump sounded four seconds later, followed by the next alarm after another four seconds. Four minutes after the leak began, at 21.24, 11 detectors were at high-high (HH), or 10 per cent of the lower explosion limit (LEL). The number of detectors at HH simultaneously varied up to 12 on two occasions – first at 21.29 and again at 21.30. Nineteen different detectors in areas G and F on the barge were at HH between 21.20 and

22.13. The area was then declared gas-free. Two detectors at the highest level in area F, level 4, detected gas, with one of them entering HH at 21.26.

The plant was shut down at 21.32, and flaring began at 21.45.

Sunday 5 January 2014

21.20	first detection of gas
21.24	11 gas detectors at HH – in other words, 10 per cent LEL
21.26	gas detector reached HH on level 4 in neighbouring area F
21.29	12 detectors simultaneously read HH
21.30	12 detectors simultaneously read HH
21.32	valve 25-ESV-1695 closed and the plant shut down
21.45	flare valve 25-HV-1816 opened to the flare
21.52	blowdown valve 25-BDV-1765 opened to the flare
21.57	blowdown valve 25-BDV-1756 opened to the flare
22.13	area declared gas-free
22.14	fire damper to the sub-station closed
22.55	emergency response terminated
02.10	fire alarm caused by transmitter fault
02.19	external operator reports observed leak in a heat exchanger. The latter is isolated with manually operated valves.

Response to the incident

Detection of the gas at 21.20 unleashed a gas alarm and all ignition sources were automatically disconnected. The external operator reported observation of the leak to the control room by radio. The control room ordered the operator to leave the area.

The operator was working at level 2 in area F, and both heard and saw the leak. Instead of taking the safer and quicker emergency exit between areas G and F, he went through area G and around the back of the leak. He had visual contact with the leak on several occasions while evacuating. He had emergency response functions and mustered at the garage.

The shift supervisor called the operations manager on duty to ask how to “block in” the leak site. The duty manager could not answer directly, and had to contact several technical specialists. The duty manager called the shift supervisor back soon afterwards without specific advice. In consultation with the duty manager, the shift supervisor decided to “stop the plant” by closing the “1695” valve. This 25-ESV-1695 valve shuts off feedstock to the plant.

The external incident manager was in the administration building when the alarm sounded. He drove down into the plant via the “south gate” together with a member of the action and reaction team (ART) and a smoke diver. They established a coordination post (CP) by the jetty, behind the building east of the process barge. The incident manager created the CP after an overall assessment of such factors as wind direction, fire hydrants, potential and so forth. He eventually brought together seven people there, and they laid out hoses.

No evacuation alarm was given, on the grounds that full control of all personnel had been established. An evacuation alarm would also automatically open all gates. The incident manager had closed the “north gate” and did not want it reopened to prevent anyone from entering that way. This would have been unfortunate because of the gas and wind direction.

He attempted to observe the leak site from the CP, and saw a few puffs of gas above the explosion panels.

Around 22.13, after five minutes without detection of gas in the area, the control room ordered the incident manager to send in personnel to:

- isolate the pump
- blow down entrapped volumes
- shut off and blow down sealing liquid.

However, nine per cent LEL was detected by one detector, and the control room ordered personnel to be withdrawn.

The control room waited a further five minutes without gas detection before emergency response personnel were again permitted to enter. They carried out the assignment.

The incident manager inspected the area around the pump and noted ice build-up fanning out from the stuffing box. See his sketch on illustration 2. The ice build-up could not be seen on the other side of the pump. Noted that the plastic flask and not-return valve were ice-covered.

Illustration 2. Sketch of the location of the observed ice build-up.

The emergency response team then withdrew to the administration building and prepared all the equipment for a possible new intervention.

The incident manager returned to the area between 01.30 and 02.00 to take photographs. These are the ones we have received copies of.

Later that night, at 02.10, the fire alarm/flame detector sounded. On investigation, this proved to be caused by a fault with the transmitter.

During the night, after 02.00, the incident manager (but now as an operator) was down on the barge with three other operators and an apprentice to move an N_2 heater to the area near the pump which had leaked in order to prepare for purging the pump. While they were working on the heater, he noticed a strange HC smell. On close inspection, he found a leak in a heat exchanger which carried a label reading “minor HC leak”. The control room ran down the heat exchanger and the area operator took over externally. At 02.19, the external operator reported an observed leak in the heat exchanger. The latter was isolated with manually operated valves. It was repaired during Monday by replacing its internal components.

After the emergency response was over, at 22.55, an assessment was made of how the plant should continue to be operated. The shift supervisor, the production engineer, the production engineering head and the asset integrity function were among the participants in this assessment. The production engineering head resolved that production should not be resumed, but that the systems should be stabilised, the first compressor started up and so forth.

Eight additional people were called in during the course of the incident.

Production resumed on Wednesday 8 January 2014.

The leak in heat exchanger 26-HB-101 has not been included in this investigation.

Illustration 3. The leak site.

Illustration 4. Close-up of the leak site.

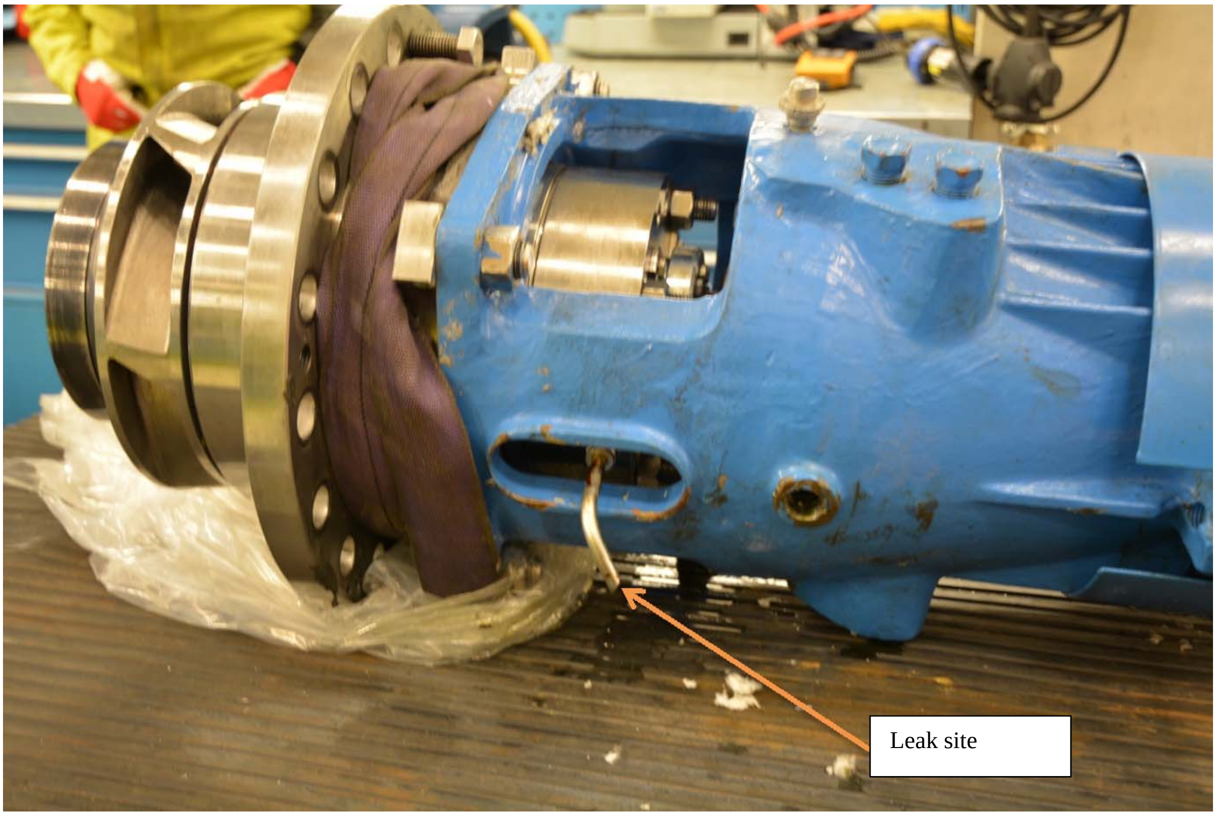


Illustration 5. Close-up of the stuffing box before disassembly.

The stuffing box

Pump 25-PA-102B was disassembled and taken to the workshop on Tuesday 14 January, where the stuffing box was removed from the shaft and broken open to look for damage. Deposits were found in the box which should not be there, along with some small visible damage to wear rings and gaskets. Statoil resolved to send the stuffing box to the manufacturer for closer examination. This work began on 29 January 2014 at EagleBurgman in Wolfratshausen. This investigation showed 0.8 mm of wear on the gasket at position 6. See the cross-section in illustration 7. That means an opening will occur in the stuffing box there. The n-pentane sealing liquid has leaked out via this route. The liquid has a normal operating pressure of 73 bar, while the process medium pressure is 60 bar. That provides an overpressure of 13 bar in relation to the medium. When the sealing liquid disappeared, pressure fell to around 15 bar. The stuffing box depends on overpressure from the sealing liquid to maintain its sealant function against the process. With an overpressure of 45 bar, the process medium has several opportunities for leaking into an area where sealing liquid is normally present. Some of these opportunities are at positions 1, 2 and 12 on the cross-section in illustration 6. The process medium leaks out via the same route as the sealing liquid.

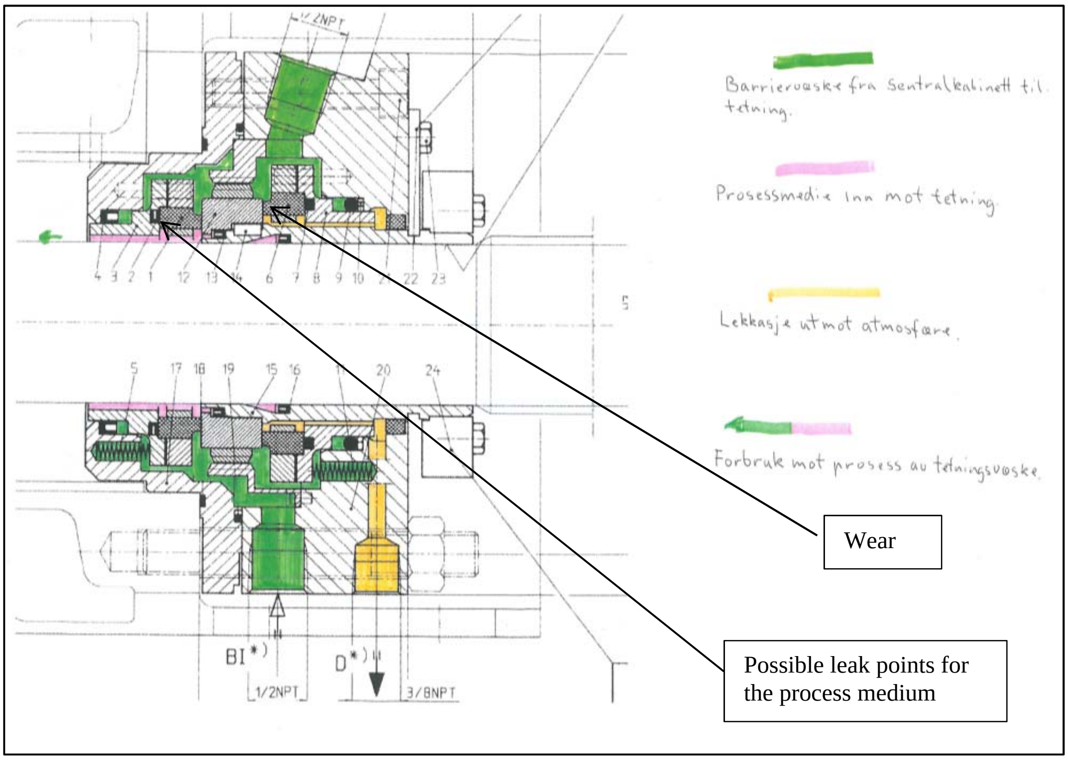


Illustration 6. Cross-section of the stuffing box.

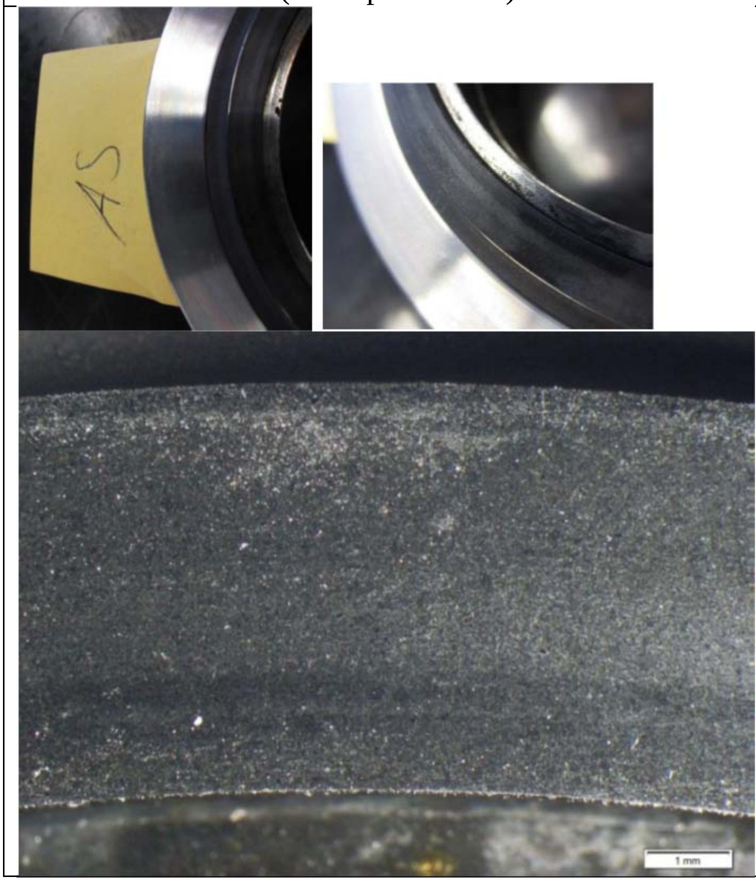
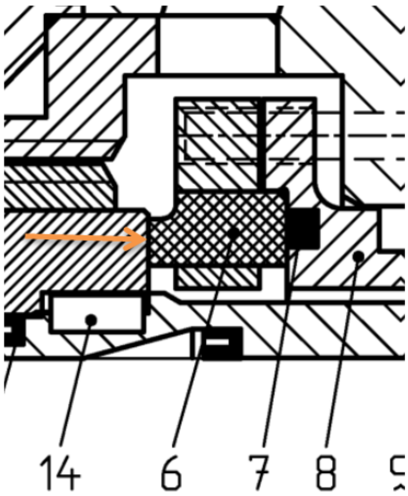
<table>
<tr><td>Position 6 seal face (atmospheric side)</td><td>Abrasive wear (-0.8mm)</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Illustration 7. From the Inspection Report Mechanical Seal from EagleBurgman, page 6.

Power consumption for pumps 25-PA-102A and 25-PA-102B ahead of the incident
Like much of the other equipment at Melkøya, pumps 25-PA-102A and 25-PA-102B are monitored. That includes recording and retaining trends in power consumption by the electric motors which drive the pumps.

The trend for pump 25-PA-102B showed a clear increase in fluctuations in energy consumption over the five days before the incident. See illustration 8.

This type of information on trends is not assessed continuously by Statoil. The trends are extracted and used in connection with maintenance planning, analyses of various types of incidents and so forth.

The energy consumption trend for the pumps is not shown on any display in the control room.

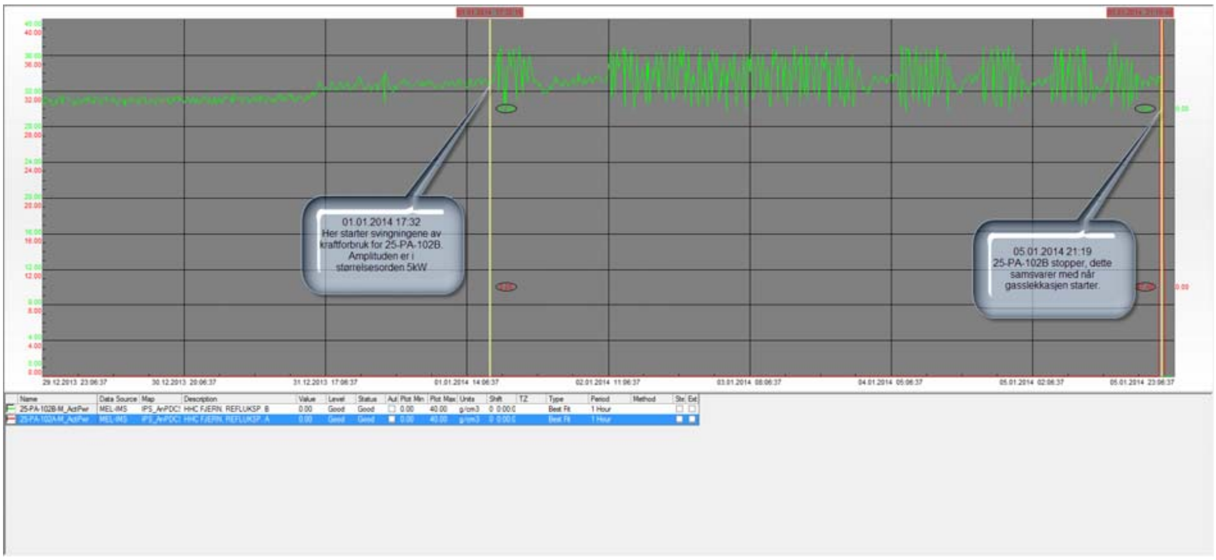


Illustration 8. Trend for energy consumption.

4 Potential of the incident

Actual consequences:
No personal injuries or material damage were suffered. Production was halted for three days.

We assume that the HC leak has not harmed the environment.

Potential consequences:
Had the gas ignited, an explosion would have resulted which could have caused two fatalities. One person was in the immediate vicinity and another out in the plant could have been affected. An explosion would also have caused damage to equipment and structures, which would have shut down the plant.

We assume that this would not have harmed the environment.

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: where conformity with the regulations has been identified.

5.1 Nonconformity

5.1.1 Time elapsed between the alarm sounding and the start of pressure blowdown

Description
It took too long after the gas alarm sounded to start pressure blowdown by opening the flow of gas to the flare.

Grounds
The shift supervisor decided to undertake a manual running down of the plant and manual pressure blowdown in that part of the facility where the leak occurred

The gas alarm was sounded at 21.20. After assessing the position and conferring with the operations manager on duty, the shift supervisor decided at 21.32 to shut down the plant by closing valve 25-ESV-1695.

The control room continued to work to identify which valves should be closed to isolate the leak site with the minimum volume of entrapped gas. Valve 25-HV-1816, the first leading to the flare, was opened at 21.45.

Requirements
Section 50 of the technical and operational regulations on competence
Section 52 of the technical and operational regulations on practice and exercises
Section 35 of the technical and operational regulations on depressurisation and flare system

5.2 Improvement points

5.2.1 Location of emergency response team – establishment of coordination point (CP)

Description
The CP was established close to the incident/leak point. This did not reflect the jobs to be done by the emergency response team.

Grounds
The external incident manager established the CP by the jetty, behind the building east of the barge. The CP was established after an overall assessment of such factors as wind direction, fire hydrants, potential and so forth. A total of eight people were eventually brought together. They deployed fire hoses for use in a potential response.

This was done when nobody was missing or injured. The only people in the plant were the eight members of the emergency response team.

Requirements
Section 50 of the technical and operational regulations on competence
Section 52 of the technical and operational regulations on practice and exercises

5.2.2 Understanding risk in the event of gas detection

Description
People working out in the plant had an inadequate understanding of risk in the event of gas detection and of the importance of following orders from the control room.

Grounds
Immediately after the gas alarm sounded at 21.20, the external operator reported observation of the leak to the control room by radio. The control room ordered the operator to leave the area.

The operator nevertheless chose to make a round of the barge in areas surrounding the leak site before leaving the area and going up to the administration building. He was thereby exposed to a possible explosion and/or fire for an unnecessarily long time.

Requirements
Section 7 of the framework regulations on responsibilities pursuant to these regulations (see also the guideline on employees)
Section 2-3 of the Working Environment Act on employees' duty to cooperate (especially sub-section 2 a)
Section 25 of the Fire and Explosion Prevention Act on employees' duty to promote safety
Section 52 of the technical and operational regulations on practice and exercises

5.2.3 Use of trend data and maintenance history in continuous monitoring and operation of the plant

Description
Trend data is not used actively in combination with maintenance history. In the continuous monitoring and operation of the facility, data for essential equipment are not extracted regularly or subject to qualified technical analysis and assessment.

Grounds
The power consumption trend for the electric motor driving pump 25-PA-102B shows a clear increase in power consumption fluctuations over the five days between the incident.

Eighty to 90 per cent of the work performed over the past six years on the relatively similar 25-PA-102 A/B and 25-PA-103 A/B pumps has been done on the 25-PA-102B unit.

Requirements
Section 23 of the management regulations on continuous improvement
Section 57 of the technical and operational regulations on monitoring and control
Section 58 of the technical and operational regulations on maintenance

5.3 Barriers which have functioned

Emergency response in connection with the incident involved local personnel at the plant. Information received during the investigation indicates that the response was implemented in overall accordance with established plans.

Defined ignition sources were disconnected when gas was detected.

Plant shutdown was activated at 21.32 with the use of valve 1695, and pressure blowdown was activated at 21.45. Both systems functioned as intended when activated.

6 Other comments

Gas quantity and leak rate
It is not possible to calculate either the quantity or the rate of the leak using traditional methods based on pressure, temperature and hole size, as is usual with such leaks. No measurement points for relevant data are available near the pump, and the geometry and leak mechanics at the leak point make it very difficult to calculate a sensible hole size. Statoil has commissioned a computational fluid dynamics (CFD) study of the HC leak from Lloyd's Register Consulting. The picture of the gas cloud provided by the detectors as they registered gas makes it possible to calculate back to an assumed leak rate and size.

A number of assumptions and simplifications are made in the study in order to use computerised models of reality. The influence of the composition of the gas on the detectors and wind, turbulence and equipment density are examples of such assumptions and simplifications. The study tests out various leak quantities area by area. The result of the simulation is then compared with the actual readings from the detectors during the leak. Uncertainty prevails about the results of this simulation.

The study concludes that the leak lay between 0.1 and 0.3 kg/s, most probably 0.2 kg/s. Table 4.1 in the study (see illustration 9) shows that correct readings are obtained for level 2 of area G right up to 0.6 kg/s, while 0.2 kg/s is too small and 0.3 kg/s gives the correct leak quantity at level 4 in area G. In area F, on the other hand, the study shows that 0.2 kg/s is too much at level 4 and that 0.2 kg/s is correct at level 3. It is important to note that this is in the area with few detectors. The simulation fails to provide any sensible result at all for level 2 of area F. From 0.2 kg/s to 0.6 kg/s has given unclear readings in the simulation, with some of the detectors giving excessive readings while other are too low with the same leak quantity. At 0.6 kg/s, the simulation shows that the ignitable gas cloud is 400 m^3, not 100 m^3 as the study concludes at a leak rate of 0.2 kg/s.

According to the study, the leak quantity was 250-750 kg, with a probable quantity of 500 kg given a constant leak rate over 40 minutes. The study is also based on point detectors, and uses the line detectors to delineate gas-free areas.

Tabell 4.1 – Oversikt over sammenligning mellom simuleringer med forskjellige lekkasjerater og faktiske utslag på gassdetektorer. L betyr at lekkasjeraten regnes som for liten i forhold til observarsjoner på område og nivå. Tilsvarende er OK kompatibelt med raten, S for stor rate, og ? betyr at raten er for høy for noen detektorer og for lav for andre.

Område	Nivå	0,2 kg/s	0,3 kg/s	0,4 kg/s	0,6 kg/s	0,8 kg/s	1,0 kg/s	1,3 kg/s
CAG1	1	OK	OK	S	S	S	S	S
CAG1	2	OK	OK	OK	OK	S	S	S
CAG1	4	L	OK	S	S	S	S	S
CAF1	1	OK	OK	S	S	S	S	S
CAF1	2	?	?	?	?	S	S	S
CAF1	3	OK	S	S	S	S	S	S
CAF1	4	S	S	S	S	S	S	S

Illustration 9. Table 4.1 from the CFD study.

Stress in piping

Stresses have been recorded in the pipes leading into and out of pump 25-PA102B . This has been corrected. What effect this might have had on the pump and its positioning has not been investigated in more detail.

Leak in stuffing box for pump 25-PA-102B
The underlying cause of the leak has not been clarified. A number of pumps with similar stuffing boxes are installed at Melkøya, and no investigation has been made of whether similar faults could have arisen on other stuffing boxes.

7 Appendices

A: The following documents have been used in the investigation

- P&IDs of 21 and 25 systems
- Cause and effects from SAS database 25-FFIC-1003
- Plot planer
- Event logger
- Action card DFU 1
- Notification M1 41417350 25-PA-102B
- Print-outs from PCDA
- Cross-sectional diagram of stuffing box

B: Overview of personnel interviewed