PETROLEUMSTILSYNET

Investigation report

Report	
Report title Hammerfest LNG Melkøya – LNG leak from road tanker, 17 June 2018	Activity number 001901036

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

Involved	
Team T-L	Approved by/date Kjell Arild Anfinsen/13 December 2018
Members of the investigation team Jorun Bjørvik, Bente Hallan, Anthoni Larsen, Bryn Aril Kalberg	Investigation leader Bente Hallan

Contents

1 Summary

An LNG leak occurred while loading a road tanker on 17 June 2018 at Equinor's Hammerfest LNG plant on Melkøya. The PSA decided on 18 June 2018 to investigate the incident.

The leak occurred as a direct consequence of leaving a valve to the cold vent line on the road tanker from Barents Naturgass (BNG) in the open position when the operation in the truck filling station at the plant had been completed.

In its investigation, the PSA team has concentrated on Equinor's handling of the incident.

The actual consequence of the incident was an LNG escape to the environment. Equinor has estimated the leak at about 996kg, with an initial rate of 0.06kg/s, and has judged the escape to have had small environmental consequences. The incident caused no material damage or production shutdown.

With regard to the potential consequences, the PSA would refer to Equinor's gas dispersion and fire analysis, which shows that the leak from the tanker could, under marginally different circumstances, have been ignited. The analysis furthermore concludes that the driver could have suffered third-degree burns in the space of two-three seconds in the event of possible ignition.

The PSA investigation has identified two nonconformities:

- deficient knowledge about and updating of operating documentation
- design weaknesses in the system for overloading prevention and deficiencies in ignition source control.

Three improvement points have furthermore been identified:

- lack of follow-up of BNG
- lack of clarity over who should evacuate in the event of a factory alarm
- the clock in the emergency response centre showed the wrong time.

2 Abbreviations

ADR	European Agreement Concerning the International Carriage of Dangerous Goods by Road
BNG	Barents Naturgass
CAP	Critical action panel
CCR	Central control room
CCTV	Closed circuit television
ESD	Emergency shutdown
Flir	Forward looking infrared
Hazop	Hazardous operations
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
P&ID	Piping and instrument diagram
PSA	Petroleum Safety Authority Norway
SAS	Safety and automation systems

3 Introduction

3.1 The investigation

An LNG leak occurred in connection with loading a road tanker just before 13.40 on 17 June 2018 at Equinor's Hammerfest LNG plant on Melkøya. The PSA was notified of the incident at about 14.45 on 17 June 2018. A video meeting was held with Equinor on Monday 18 June 2018 where personnel from Hammerfest LNG provided information about the incident. The PSA decided on the same day to investigate the incident.

Interviews were conducted by the investigation team with personnel directly and indirectly involved in the incident at Hammerfest LNG on 20-22 June 2018. Video meetings were also held on 14 September and 3 October 2018 to discuss conditions related to the ESD level and event log. Observers from Equinor were present during the interviews and participated in the video meeting. A conversation was also held with the main safety delegate during the stay at Melkøya. The tanker driver was not interviewed, since the direct cause of the incident was identified at an early stage and the PSA's investigation concentrated on Equinor's handling of the incident.

The investigation team's report has been drawn up on the basis of presentations, interviews of Equinor and Barents Naturgass (BNG) personnel, and documents received. This report covers direct and underlying causes which are both technical and operational in character.

3.2 The investigation team's mandate

1. Clarify the incident's scope and course of events
    a. identify and assess safety and emergency response aspects
    b. identify assessments made ahead of the incident
2. Describe the actual and potential consequences
3. Assess direct and underlying causes, with the emphasis on human, technical, operational and organisational conditions
    a. observed nonconformities from requirements, methods and procedures
    b. improvement points
4. Discuss and describe possible uncertainties/unclear aspects
5. Identify regulatory breaches, recommend further follow-up and propose use of enforcement powers
6. Assess the player's own post-incident investigation (possibly after a report has been published)
7. Prepare a report and accompanying letter in accordance with the template

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After the report has been completed and published:

assess and summarise internal lessons learnt from the investigation, including possible learning points related to the regulations and recognised norms.

The composition of the PSA's investigation was as follows:

Bente Hallan, process integrity (investigation leader)
Jorun Bjørvik, process integrity
Bryn Aril Kalberg, logistics and emergency preparedness
Anthoni Larsen, logistics and emergency preparedness

4 Background information

4.1 Hammerfest LNG

Hammerfest LNG is a plant for receiving and processing natural gas from the Snøhvit field in the Barents Sea. It stands on Melkøya outside Hammerfest, and an undersea road tunnel gives access to the island. The reception/gatehouse with access control for people and vehicles is at Meland at the landward end of the tunnel.

Snøhvit production is piped for 160km from the subsea installations to Melkøya, where facilities are provided for wellstream processing, storage and loading. End products are liquefied natural gas (LNG), liquefied petroleum gas (LPG) and condensate. The facility came on stream in 2007. It was developed by Equinor (then Statoil), which now operates it.

Liquefaction involves separating out the heaviest components and cooling the gas to -163°C. This process passes through several stages. LNG is stored in tanks for transport by ship or road tanker.

The plant was originally built for loading to ships. An LNG filling station for road tankers was also established later. This handles an estimated 1 000 loadings per annum with vehicles from two companies (BNG and GasNOR).

4.2 Area where the incident occurred

The incident occurred at the LNG filling station for road tankers. This is positioned within the fence by the south gate to the plant, close to the LNG tank farm.

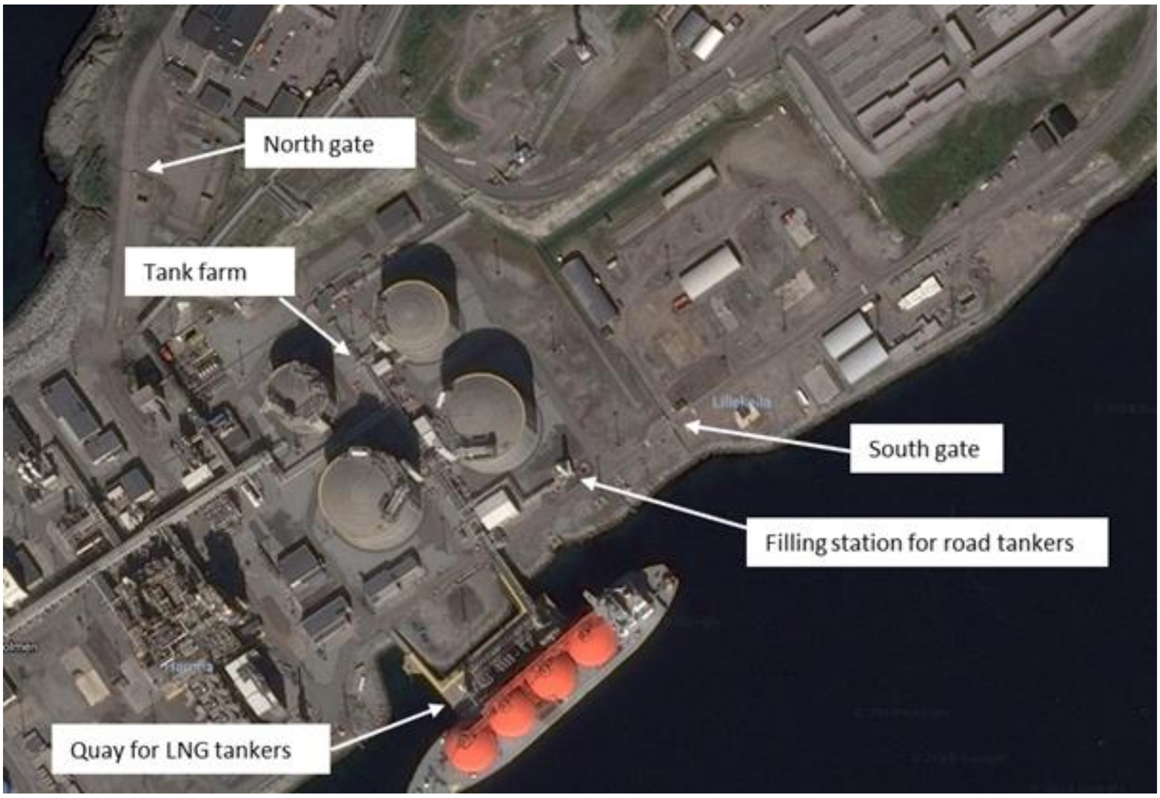

Figure 1 Overview of the area where the incident occurred. Source, background image: Google Maps.

4.3 LNG

Liquefied natural gas (LNG)

LNG is a cryogenic liquid – in other words, a gas liquefied by cooling. A gas is technically defined as cryogenic in Equinor’s operating procedures when it has been cooled below 160°C at normal atmospheric pressure. Liquefied gas used in LNG filling stations for road tankers is natural gas – primarily composed of methane – and nitrogen (used for precooling and testing equipment at low temperatures before this is utilised for LNG).

Odourless and colourless, natural gas is extremely flammable and explosive. Its explosion limit is five to 15 volume per cent in air at 20°C.

Trapped liquid

If liquefied cold gas is entrapped in a pipeline between two valves or in a tank with no outlet, a temperature rise would increase the pressure in pipeline or tank. This trapped liquid could have serious consequences, such a pipeline/tank rupture.

4.4 Equipment and system involved in the incident

The station for loading road tankers with LNG comprises an LNG supply vessel – known as the “thermos” – as well as pumps for transferring LNG to road tankers, connecting hoses and a local control panel used for the actual loading. See figure 2. The filling station is partly enclosed with walls which are open at top and bottom.

Connection points are provided on the road tanker for the loading hose and gas return, along with safety valves which protect the vehicle’s piping and loading/return hoses against overpressure. The outlet for these valves is a vent line at the rear of the tanker. In addition to overpressure protection, a manual system ensures that the level in the tanker does not exceed the permitted maximum for road transport. This system is referred to as “absolute overloading protection”.

The LNG supply vessel is loaded from the storage tanks. When loading a road tanker, the valve between the storage tank and the supply vessel is closed. This means that the level in the supply vessel must be at least sufficient for one consignment before a loading sequence starts.

A simplified diagram showing the main components utilised in loading LNG into a road tanker is presented in the figure below.

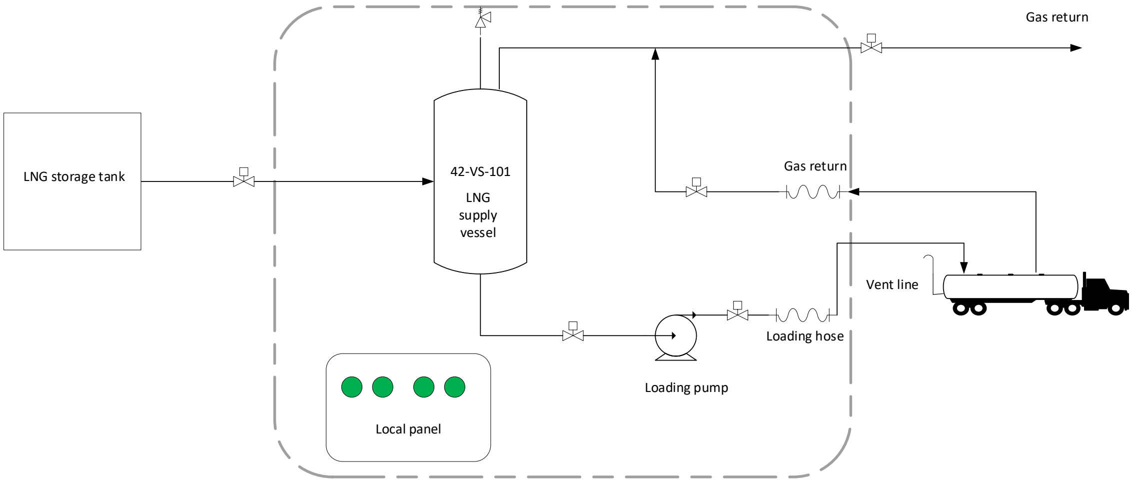

Figure 2 Main components used for road-tanker loading,

4.4.1 Loading a road tanker

The road tanker arrives at the Meland main gate and reports to the gatekeeper. A defined procedure governs permission to enter the plant for loading. The central control room (CCR) is notified that a tanker is on its way.

This vehicle enters the actual plant through the south gate. Each driver is issued by the Meland gatekeeper with an entry card and equipment as prescribed by the procedure, and opens the gate themselves to drive in. On arrival at the filling station, the driver calls the CCR for permission to begin loading the vehicle.

Before loading a road tanker can begin, the level in the LNG supply vessel must be sufficient to fill at least one vehicle.

LNG is normally pumped into the tanker, but loading can also be conducted without a pump based on the static pressure of the liquid column in the LNG supply vessel.

Loading of the vehicle takes place from the LNG supply vessel, which is connected to it by hoses – one for LNG supply and another for gas return. The LNG supply vessel is sealed from the LNG storage tank while tanker loading is ongoing.

The local panel in the filling station is the driver's main interface for controlling the loading. It comprises lights and switches/push buttons. A defined sequence of activities must be implemented before LNG can start being loaded in the tanker ("green line"). Once the process has begun, the loading button must be pressed every four minutes. When the level approaches maximum, the manual method is used to prevent overloading (absolute overloading protection). This is described in more detail in the next chapter on level measurement. Should the maximum level be exceeded, defined procedures exist for returning LNG from the tanker to the LNG supply vessel. The CCR is contacted when loading has been completed.

A stoppage during the loading process can occur because an incident requires shutdown of the plant, because the emergency stop is activated, or because the driver fails to press the loading button by the deadline (four minutes, plus five minutes to restart loading).

When the loading sequence stops, defined valves will close in the filling station and between the LNG storage tank and supply vessel. Which valves close depends on what has halted the process. An emergency stop will initiate ESD 11i. See the description in section 4.5.

4.4.2 Level measurement and absolute overloading protection

Requirements are set for maximum loading of road tankers, based on the type of tank and the product being transported. If the tanker has been overloaded, LNG must be returned to the LNG supply vessel.

The driver can use three different level measurements during a loading operation:

- measuring the level in the road tanker (pressure measurement)
- measuring the level in the LNG supply vessel (change in level)
- calculated quantity loaded, readable from the local panel in the filling station.

A manual system called absolute overloading protection is used to ensure that the tanker does not become overloaded. The driver monitors the level measurements during the loading operation, and utilises the manual system when the level in the tanker approaches the defined limit. The manual system comprises two pipes inside the tank on the vehicle with try-cock valves (V21 and V26). See figure 3. Piping at the valve outlets (V21 and V26) is connected to a small scrubber tank, and the top-mounted outlet from this is connected with the outlet piping from the safety valves to the open air via a vent line at the rear of the vehicle. The level measurement piping stand with their openings down inside the tank at the level to be measured. In the relevant tank, these levels are 84.6 and 90 per cent respectively. When using the manual system, the first step is to open V21 cautiously and, based on the sound, identify whether the phase at the measuring point is liquid or gaseous. The valve is closed again, and may have to bereopened to confirm the liquid phase. This process is repeated with V26 when liquid is confirmed at V21. When liquid is identified through V26, the desired level in the tanker has been achieved. V26 is then closed and the loading process halted. During this manual level check, small quantities of LNG will be released through the vent line at the rear of the vehicle.

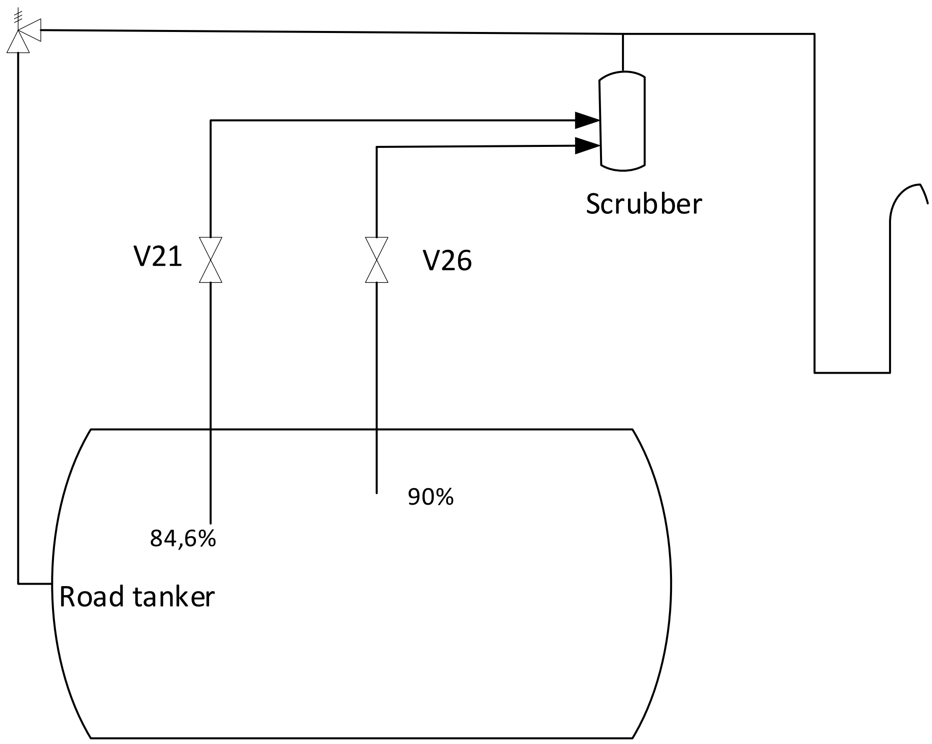

Figure 3 Outline of overloading protection on the road tanker.

Fiscal metering to calculate the exact volume in the tanker is based on weighing at Meland.

4.5 Shutdown and isolation of the LNG filling station

The shutdown level at the filling station is ESD 11i, which is initiated automatically by the following actions [ref 2]:

- confirmed fire alarm at the filling station
- confirmed gas alarm at the filling station
- other ESD levels.

In addition, the following manual actions can initiate ESD 11i:

- two emergency stop switches in the field adjacent to the filling station
- one emergency stop switch for the filling station in the CCR
- from a switch on the critical action panel (CAP) in the CCR.

ESD 11i trips the LNG loading pump as well as isolating the LNG storage tank from the LNG supply vessel and the LNG supply vessel from the road tanker.

A confirmed gas alarm is given if two of 12 detectors in the filling station measure a minimum of 20 per cent of the lower explosive limit (LEL).

4.6 Requirements for personnel and follow-up of BNG

BNG has a contract with Equinor to fetch LNG from Hammerfest LNG. This company owns the tank trailer, while Hoyer Group Norge AS (Hoyer) is contracted to supply the tractor unit and driver. Hoyer is responsible for training, following up and certifying the driver, while BNG contributes specialist LNG expertise and emergency preparedness.

Generally speaking, the drivers must have a valid driving licence for the relevant vehicle as well as proof of ADR competence in transporting dangerous goods. New drivers receive training in tank loading through an internal mentoring scheme, and must have the approval of their mentor before carrying out a loading operation on their own.

In addition, the driver must have taken Equinor's HSE24 and access course in order to work and drive inside the plant.

These conditions are regulated by the service agreement for use of the Hammerfest LNG truck filling station entered into by Equinor on behalf of the Snøhvit group and BNG (2 May 2018). Appendices and a procedure for loading of LNG road tanker, E066-AN-P-KF-0001, are attached to this service agreement.

The service agreement gives Equinor the opportunity to check that BNG is meeting both the technical requirements for equipment and the qualifications required by the driver.

However, it emerged from the interviews that Equinor has not conducted any follow-up beyond ensuring that the drivers have valid HSE24 and access courses, even though they operate part of the process equipment related to the LNG plant when loading LNG into the road tankers.

It was explained that BNG is an Equinor customer, and that Equinor does not have the same routines for following up customers as it does with suppliers doing work at the plant.

5 Course of events 17 June 2018

5.1 Position before the incident

The plant was in normal operation with stable production.

Weather conditions: north-westerly wind, 1.5m/s at the start of the incident, rising to 4.5m/s during its course. The wind blew from the incident area towards the quays and the sea. Because four large storage tanks are located west/north-west of the filling station, however, some uncertainty prevailed about possible turbulence around the station.

The *Arctic Aurora* LNG carrier was berthed due south of the filling station.

5.2 Timeline

The description of the course of events is based on interviews with personnel at Hammerfest LNG as well as a review of documents made available in connection with the investigation work.

This timeline shows which information was available to Equinor at the respective times.

Efforts have been made to adjust the time to take account of the fact that the clock in the emergency response centre was running about 10 minutes fast.

12.05	Entry of the BNG road tanker to the plant registered at Meland
12.05-	Readying, start-up and loading of road tanker

13.39	
From 13.39	CCR received alarms from gas detectors in the filling station for road tankers. Muster alarm initiated after about 30 seconds
13.39.44	First H alarm from gas detector 74-AB-L175-01-0101
13.40.04	First H alarm from gas detector 74-AB-L175-01-0100
13.40.30	First H alarm from gas detector 74-AB-L175-01-0106
13.40.51	First H alarm from gas detector 74-AB-L175-01-0101
13.49	"People on board" (POB) overview established
13.50	Evacuation completed. One person missing. This was the loading master on the berthed LNG carrier. He remained on board the vessel.
13.50	Triple alert and second-line mobilisation
14.00	Public emergency services arrived at Melkøya: - Hammerfest fire brigade (two vehicles) - police (two officers) - ambulance (two people)
14.06.02	First HH alarm from gas detector 74-AB-L175-01-0100
14.21.30	First simultaneous HH alarm from two detectors – confirmed gas alarm
14.21.31	ESD 11i activated by confirmed gas
14.29.36	ESD 11i activated manually from the CCR
14.35	Clearance by shift supervisor introduced for all traffic out to the island
16.00	Smoke divers were dispatched to the ring road to observe the leak with binoculars and Flir camera. Based on their observations, the downward trend of the gas detectors and identification of ventilation gaps in the filling station, the decision was taken that no manual intervention would be made at the present time to stop the leak
16.00-20.18	The leak was monitored
20.18	Smoke divers began preparing for a secure intervention after the detectors in filling station no longer detected gas
20.43	Smoke divers received approval to intervene in the filling station. They identified that valve V21 on the road tanker was open
21.01	Valve V21 on the road tanker was closed by the smoke divers and the leak ceased
Abt 22.00	The police demobilised

5.3 Description of Equinor's handling of the incident

At about 13.40 on Sunday 17 June 2018, the CCR received alarms from gas detectors in building L-175 (the filling station for road tankers). The detectors activated at 11-14 per cent LEL, and the trend was rising. CCTV in the CCR showed that LNG was escaping from the vent line at the rear of a BNG road tanker in the filling station.

It was observed via CCTV in the CCR that LNG in liquid phase was emerging sporadically from the vent line and evaporating on the ground.

After about 30 seconds, the evacuation alarm was activated as a result of the gas detection. Evacuation took place through the north gate. Uncertainty arose about whether people in the guardhouse at the south gate should evacuate when the muster alarm sounded. They were told to evacuate by the shift supervisor. One person was found to be missing when evacuated

personnel were counted. This turned out to be loading master on the *Arctic Aurora* LNG carrier, which was berthed at the quay. He remained on board.
The first-line emergency response organisation mustered in the emergency response centre and the emergency response team established a command centre in the fire engine garage. The second-line emergency response organisation mustered at 14.00. In addition, extra personnel who were not on duty turned out to support the emergency response organisation. Personnel from BNG also turned out at the plant to assist.

It was decided that allowing the plant to continue running stably would be the best approach, not least because previous experience had shown that an ESD could lead to incidents elsewhere. Continuous consideration was given to a possible production shutdown during the incident.

The *Arctic Aurora* gas carrier, which was berthed outside the filling station, was contacted with a recommendation to consider leaving the quay. Its master decided to remain in place since the vessel was designed for a hydrocarbon leak on board and was not therefore considered to represent a risk as an ignition source.

ESD 11i was automatically activated as a result of simultaneous HH alarms from two of 12 gas detectors in the filling station at 14.21.31. The LNG supply vessel had already been isolated from the LNG storage tank when the loading sequence began. ESD 11i was manually activated from the CCR at 14.29.36.

The wind strength in the area increased during the course of the incident, and CCTV showed that the leak from the road tanker was declining. The gas detectors also confirmed a declining trend for the leak. On the strength of these observations, two smoke divers were dispatched to the ring road which runs above the leak site. At that point, no gas could be seen emerging any longer from the vent line at the rear of the road tanker. Using binoculars and a Flir camera, the smoke divers observed that no cloud of hydrocarbons was forming outside the filling station. They also saw that the station was designed with ventilation openings at ground level and beneath the roof of the building.

Based on these observations and on the fact that trapped volumes were under control as a result of the isolation, the decision was taken to allow the leak to bleed out by itself. When gas could no longer be detected inside the filling station, the emergency response team was sent in. It quickly identified that one of the try-cock valves (V21) on the vehicle was in the fully open position. This was closed, and the little remaining leak ceased immediately.

6 Causes and discussions

6.1 Direct cause

The direct cause of the leak was that valve V21 had not been closed during verification of the liquid level in the road tanker.

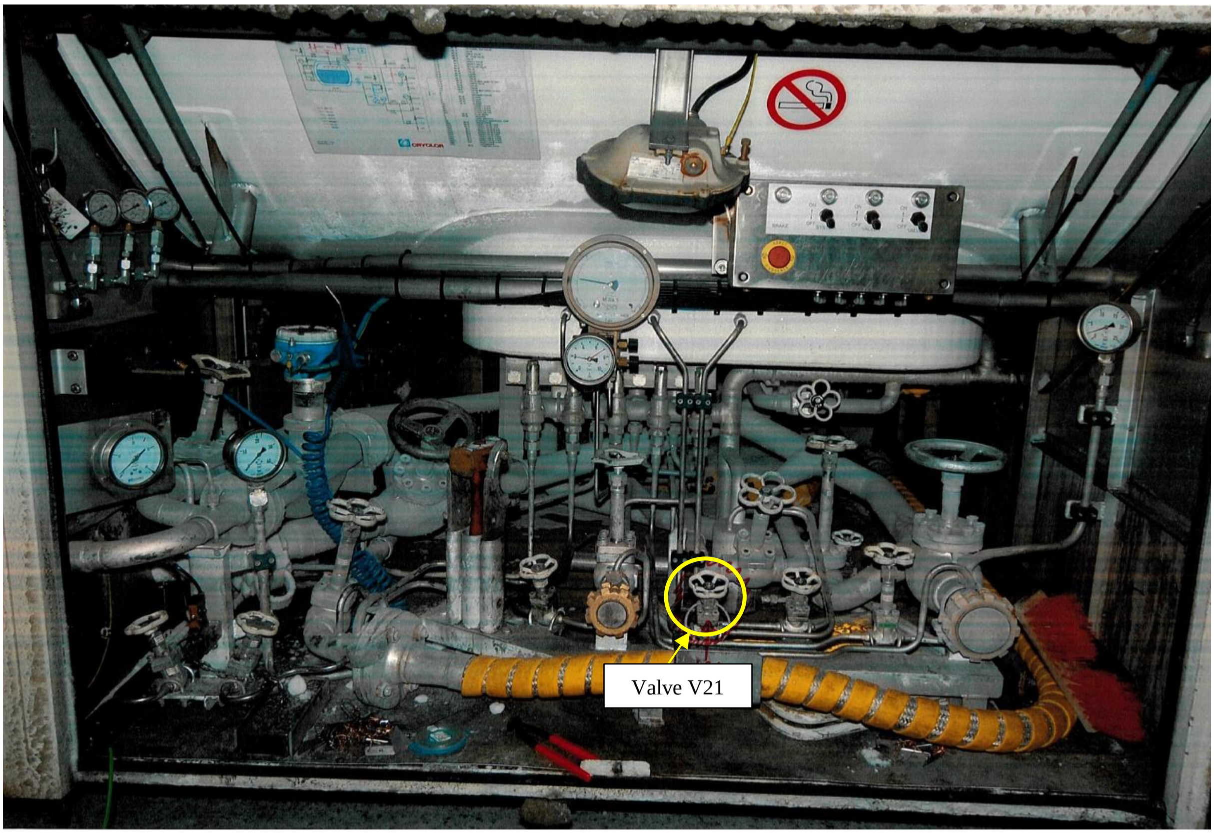

Figure 4 Valve layout on the road tanker. Source: BNG.

6.2 Underlying causes

6.2.1 Method for overloading protection

As described in section 3.4.2, the established method for overloading protection of road tankers involved manual operation of try-cock valves. In connection with this operation, small amounts of LNG will leak out via the vent line at the rear of the vehicle. When the liquid level in the tank is above the measurement level for the try-cock valves, each of these represents the only barrier against a major leak. If they are left in the open position, no opportunity exists to shut off from other locations, and LNG will continue to escape until its level is below the measurement point for the open try-cock valve, or the valve is closed.

The way the system for absolute overloading protection is designed means that discovering and correcting a possible incorrect action is not easy. No position indicator is provided on the valves, nor is it easy to see if they are open or closed – with the exception of those valves which have been open for a while, since they will eventually become “iced over”.

The actual conduct of the level check is based on sound recognition as described in section 4.4.2, which can be challenging if other noise sources are present in the background.

It has emerged from interviews that the indications used for level/quantity loaded used during the loading operation are inexact and can accordingly create uncertainty about whether the tanker is approaching filled condition. The manual test may therefore have to be carried out several times during a loading operation.

The system is described in procedures and a Hazop has been conducted on the chosen system.

6.3 Discussion

6.3.1 Knowledge about and documentation of implemented safety functions

About 50 minutes passed from the first leak detection until the decision was taken to initiate ESD 11i. It emerged from interviews that uncertainty prevailed about the consequences of initiating ESD. Concern existed whether all the segments isolated in an ESD 11i would be secured against overpressure as a consequence of trapped liquid. This concern applied to both the LNG supply vessel and the hose connected to the vehicle, and a SAS duty officer who could reset ESD 11i if necessary was therefore called in. Particular uncertainty prevailed about a connector from the LNG supply vessel to the loading hose. BNG was able to report that the volume between the LNG supply vessel and the road tanker could be blown down via safety valves on the vehicle about an hour after the incident began.

Based on information received in action logs, it appears that the decision to initiate ESD 11i was taken about eight minutes after this ESD level had already been activated by confirmed gas in the filling station.

The challenges faced in securing information on available safety functions during the incident are described below.

<u>ESD 11i</u>
As described in section 3.5, a confirmed gas alarm for the filling station area will initiate ESD 11i. This is documented on the drawing *ESD Field Push Button Actions* [ref 2]. This does not emerge as clearly in other relevant documentation. It was explained to the investigation team that a possible confirmed gas or fire alarm will appear as a common signal for everything which initiates ESD 11i (75-US-1803A/B) in the event log. Confirmed gas and fire alarms are not shown as causes of ESD 11i in the Cause & Effect diagram on the CCR screen like the other causes incorporated in the common signal. Nor do the guidelines for handling hydrocarbon leaks state that an ESD sub-level is initiated automatically with a confirmed gas alarm.

<u>Overpressure protection</u>
It took time during the incident to secure an overview of overpressure protection of the system since the valves are not included in the P&ID, but only referred to in the comment field. No documentation was available for the systems on the vehicle which shows protection of the segment downstream of the isolation valves from the LNG supply vessel.

6.3.2 Assessments related to continued production during the incident

Equinor's guidelines for handling hydrocarbon leaks at Hammerfest LNG [ref 3], describe the expected response to a hydrocarbon leak at the plant, including a figure which shows the expected ESD response based on the leak size.

It emerged from the PSA's investigation that concern existed over whether a plant-wide ESD might cause new incidents elsewhere, since this had previously been experienced. The figure for ESD response showed that shutdown should be considered on a continuous basis with leaks of the size experienced in this incident.

Based on these conditions, shutdown was continuously assessed but no decision was taken at any time during the incident to shut down production at the plant.

6.3.3 Summary of the gas dispersion and fire analysis

The investigation team has not initiated its own gas dispersion and fire analysis for the incident, but has utilised Equinor's analyses. The analyses conducted show that, unhindered, the actual leak would have had a flammable extent of about 3.2m in the open air. On ignition, this could have caused a jet fire with a maximum flame length of about 5m and a thermal load of $45kW/m^2$. A possible boiling liquid expanding vapour explosion (Bleve) cannot be excluded despite its low probability. Late ignition could have caused a weak explosion, with a blast overpressure of < 50mbar.

The team has no comments on Equinor's gas dispersion and fire analysis.

7 Potential of the incident

7.1 Actual consequence

The actual consequence was the release of about 996kg of LNG to the open air, according to Equinor's calculations. No material damage, physical injury to people or production shutdown was caused by the incident.

7.2 Potential consequences

7.2.1 Ignition of the leak

Equinor's investigation reveals that the tractor unit's ignition was not turned off during the loading operation, and that ignition sources in the unit were exposed when the driver opened his door to turn off the ignition. Furthermore, driving of vehicles in the area after the muster alarm sounded could have meant that ignition sources were exposed in the area where the leak occurred. See section 6.3.3 for a description of the possible consequences of igniting the leak.

7.2.2 Personal injuries

According to Equinor's investigation report, ignition of the leak would have inflicted third-degree burns on the driver within two-three seconds. The driver was wearing personal protective equipment in accordance with applicable guidelines. Escape routes were open and easily accessible in the event of possible ignition.

Where risk associated with methane is concerned, the medical assessment concludes that the biggest risk is displacement of oxygen. This reflects the limited information available about methane and its direct toxicity to the lungs on inhalation, and the small likelihood of any toxic effect when the methane concentration is below the explosion limit.

8 Emergency response

Gas detectors in the filling station area gave readings which resulted in activation of the evacuation alarm. Given the location and wind conditions, the decision was taken to evacuate via the north gate. Personnel at the south gate contacted the CCR since they wanted to know whether they should also evacuate, and were told to do so. The count of evacuated personnel showed one person missing. It became clear that this was the loading master on the berthed LNG carrier *Arctic Aurora*. The POB overview was completed after 10 minutes. The loading master remained on board.

Emergency response personnel from Equinor mustered and handled the incident in line with the plans. The emergency services (police, fire and ambulance), BNG and *Arctic Aurora* were notified in accordance with procedure. Personnel from the police, fire brigade and BNG mustered in the emergency response centre at the plant.

The PSA's duty officer was notified by phone at 14.45 on Sunday 17 June 2018, about an hour after the incident occurred.

Communication with the emergency services and the PSA functioned well.

9 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.

9.1 Nonconformities

9.1.1 Deficient knowledge about and updating of operating documentation

Nonconformity
Relevant technical input for dealing with the incident was unavailable or insufficiently detailed. Personnel did not know about safety functions.

Grounds
Technical operating documents must be updated, available and known to operating personnel during operation. It emerged in connection with this incident that:

- uncertainty prevailed about the consequences of initiating ESD
- information about the safety system on the road tanker was not available, nor were the functions known
- guidelines for handling hydrocarbon leaks did not contain information about actions automatically initiated in the event of gas detection
- information on overpressure protection for the LNG supply vessel with associated systems was not known and the documentation was difficult to interpret
- the Cause & Effect diagram did not display actions related to confirmed gas alarm.

Requirement
Section 40, paragraph 2, litera b of the technical and operational regulations on start-up and operation of onshore facilities

9.1.2 Design weaknesses in the system for overloading prevention and deficiencies in ignition source control

Nonconformity
The system for overloading protection is designed in such a way that a single incorrect action can have unacceptable consequences, and the ignition source control system has deficiencies.

Grounds
Equinor's investigation report specifies that some of the vehicles which load at the filling station are designed in such a way that their main power switch cannot be turned off completely since the ignition must remain at 1 to provide power for the tank trailer. The investigation report concludes that this solution is not permitted at Hammerfest LNG since it could potentially be an ignition source.

The chosen solution for overloading protection is not robust with regard to possible incorrect manual action and opportunities for correcting such an action.

This incident displays a combination of:

- deficient follow-up of the condition of vehicles which have access to the plant (vehicles must not be an ignition source)
- the requirement that the vehicle must be completely turned off has not been clearly communicated in the loading procedures
- the manual system for conducting an overloading check is designed in such a way that discovering errors is difficult, while a single error can result in long-term leakage.

Requirements
Sections 10a, paragraphs 1 and 2, and 6, litera c of the technical and operational regulations on ignition source control and on ensuring that a fault in one component, system or a single mistake does not result in unacceptable consequences respectively
Section four of the management regulations on risk reduction

9.2 Improvement points

9.2.1 Lack of follow-up of BNG

Improvement point
Equinor has failed to follow up that BNG fulfils the contractual requirements for equipment and expertise.

Grounds
The service agreement entered into between Equinor and BNG gives the former the opportunity to check that BNG is meeting the requirements for both technical equipment and driver competence.

It emerged from the interviews that Hammerfest LNG has confined such follow-up to checking that the driver has valid courses for HSE24 and access.

Requirements
Section 61 of the technical and operational regulations on transport of hazardous goods
Section 21 of the management regulations on follow-up, see section 18 of the framework regulations on qualification and follow-up of other participants.

9.2.2 Lack of clarity over who should evacuate in the event of a factory alarm

Improvement point
It was unclear to the personnel in the guardhouse at the south gate whether they should evacuate when the factory alarm sounds.

Grounds
It emerged during the interviews that personnel in the guardhouse at the south gate were uncertain whether they should evacuate in the event of a factory alarm. The guardhouse is just outside the fence, relatively close to the leak site and the horizontal path for the gas.

The personnel contacted the first line emergency response organisation after the muster alarm to check whether they should evacuate.

Requirement
Section 67, litera d of the technical and operational regulations on handling hazard and accident situations

9.2.3 The clock in the emergency response centre showed the wrong time

Improvement point
A clock which shows the correct time will contribute to better registration and investigation of the way hazards and accidents are handled.

Grounds
The responsible manager must ensure that hazards and accidents which could cause or have caused acute pollution or other harm are registered and investigated to prevent repetition. Conditions which occur frequently or which have major actual consequences must be investigated. Such investigations should include clarifying the course of events.

In order to establish the actual course of events, it is normally important to produce the best possible timeline for the incident.

The clock on the wall in the emergency response centre being out by 10 minutes would contribute to confusion and unnecessary discussion when the timeline comes to be drawn up.

Requirement
Section 20, paragraph 1 of the management regulations on registration, review and investigation of hazard and accident situations

10 Barriers which have functioned

Process
- ignition source disconnection at single gas detection
- automatic activation of ESD 11i following confirmed gas alarm
- manual shutdown actions coincide with the automatic response.

Emergency response
- In accordance with the philosophy for dealing with an emergency
  - it was decided that no response personnel would be deployed in the plant until the position was clarified and personnel control had been established. Personnel from BNG and the fire brigade were not deployed in order to avoid unnecessary personnel exposure.
- Personnel overview: one person was missing – the loading master on the vessel. He remained on board.

- The shift supervisor asked the vessel master to assess moving from the quay. The master decided that staying put represented the least risk. No decision was taken to remove the vessel from the quay. The second line notified a tug so that this would be ready in the event that it had been decided to move the vessel from the quay.

11 Discussion of uncertainties

Given the information available during the investigation, it has not been possible to determine with certainty which action the driver initiated when he did not hear gas flowing past after opening valve V26. Equinor's investigation report concludes that he initiated "Stop loading".

12 Assessment of the player's investigation report

Equinor established its own investigation team on 25 June 2018 with a mandate to investigate the incident of 17 June 2018. The PSA team received its report on 5 October 2018.

Equinor's description of the course of events largely coincides with the PSA team's description, but deviates on the following main points:

- Equinor states that ESD 11i was manually activated by the CCR at 14.21.31.
    - The PSA team has been told that ESD 11i was triggered at that time as a result of confirmed gas detection (two of 12, with 20 per cent LEL or 2.0 LELm). ESD 11i was not activated manually from the CCR until about eight minutes later, at 14.29.36. Event logs received reflect this course of events.

In addition, Equinor has identified the following points which are not included in the PSA's investigation report:

- ESD valves in the truck filling station closed at 13.44.25 as a result of an HH signal in the gas return line.
    - The PSA team has not been able to read this from the event logs it has received.
- The requirement to turn off main power when loading a road tanker has not been reflected in established practice, and some of the tractor units are also designed in such a way that ignition must be in position 1 in order to operate the pneumatic main valves in the trailer for loading. This meant that ignition sources were exposed in the immediate vicinity of the leak when the driver opened his door to switch the ignition to position 0 as part of securing the workplace.

Equinor's conclusion concerning the direct cause of the LNG leak coincides with the conclusion in the PSA team's report. Information on a failure of ignition source control has influenced the PSA team's original assessment of potential consequences.

13 Documents

The following documents have been used in the investigation:

1. Description of the incident drawn up by the C and D shifts
2. E066-AS-75-PQ-9375-001 ESD Field Push Button Actions, rev L
3. E066-SD-A-KF-0101 Retningslinje for håndtering av hydrokarbonlekkasjer ved Hammerfest LNG, rev 1 status Draft
4. Emergency response log – image of screens in the emergency response centre

5. Photograph of valve arrangement in the road tanker
6. Diagram of valve arrangement in the road tanker
7. Doc ID: 480 Innhold LNG-kompetansebevis LNG-sjåfør, versjon 2, Barents NaturGass
8. Extract from document: Systembeskrivelse av LNG Vessel 42-VS-101
9. Log second-line emergency response from Equinor
10. Doc ID: 1047 Normal lasting av BNG 03-06, versjon 2, Barents NaturGass
11. Operations manual, department 300, revision 6, Hoyer Group Norway AS
12. Log from PCDA for detectors 14AB750101-02/-03/04/05 and 06
13. E066-AN-P-KF-0001 Procedure for Loading of LNG Road Tanker, rev C
14. Doc ID: 479 Prosedyre for opplæring av ny LNG-sjåfør, versjon 2, Barents NaturGass
15. E-mail dated 21 June 2018 07.35, subject: Dokumentasjon PTIL
16. E066-AN-42-PE-2001 Melköya Truck Filling station P&I Diagram 42-XT-103, rev C
17. Presentation of incident of 17 June 2018 at kick-off meeting on Melkøya, 20 June 2018
18. Service agreement for use of the Hammerfest LNG Truck Filling Station, status Draft
19. Confirmation of registered entry to/exist from the plant for the road tanker
20. E-mail dated 29 June 2018 09.27, subject: FW: Info til PETIL
21. E-mail dated 14 September 2018 15.01.40, subject VS: Spørsmål ifm. vår gransking av HC-lekkasjen fra tankbil på Melkøya 17.06.18
22. E066-AN-M-KF-2001 Start, Normal Operation, Stop, Emergency Stop, rev. B
23. Tag history LT2136 and LT2137
24. E066-AN-M-KF-2003 Loading Procedure, rev C
25. C&E diagrams for ESD 11i
26. E066-AN-74-SA-0002-001 Fire & Gas Layout M1 (907/908) 500006, rev 7
27. E066-AN-P-KF-0001 Procedure for Loading of LNG Road Tanker, rev D
28. E066-SD-A-KF-0005 Krav og rutiner for fylling av LNG til tankbil ved Hammerfest LNG, rev. 3 Final
29. EventLogExport sys 74
30. EventLogExport sys 75
31. EventLogExport sys US
32. E066–SD–S–RS–0001 Risk Assessment of LNG Road Tanker Filling Station 42-XT-103, rev A
33. E066-AN-P-RE-0005 Hazop Report, Feb 2009, rev A
34. E066-AN-P-RE-0006 Hazop Close-out Report, Feb 2009, rev A
35. Mandate, Equinor's internal investigation of HC leak HLNG
36. Verification report: Styring av ASU og LNG Tjeldbergodden, 2018-01, status Final
37. E-mail dated 27 September 2018 07.39.31, subject: RE: Oppfølgingsspørsmål etter videomøte 14.09.18
38. A 2018-13 MMP L2 Gransking av: Lekkasje i forbindelse med lasting av LNG til tankbil ved Hammerfest LNG 17.06.2018, status Endelig
39. Presentation: Presentasjon av intern granskingsrapport - Equinor - Lekkasje ved lasting av LNG til tankbil ved Hammerfest LNG 17.06.2018

14 Appendix

A: Participants