

Investigation report

Report	
Report title Report of the investigation of the fire at Mongstad on 3 July 2022	Activity number 001902062

Security grading		
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<input type="checkbox"/> Not publicly available	<input type="checkbox"/> Confidential	

Involved	
Team T-L	Approved by/date Kjell Arild Anfinssen/19 December 2022
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1 Summary

A fire broke out at 05.43 on Sunday 3 July 2022 in the A-1400 reformer plant in the B3 process area at Equinor's refinery at Mongstad. The Petroleum Safety Authority Norway (PSA) decided on the following day to investigate this incident.

The fire arose because of a leak in a two-inch thermowell flange on a 20-inch pipe between the R-1404 reformer column and the H-1404 reformer heater. It was immediately detected by fire detectors in the area, by personnel out in the plant and on CCTV in the control room. The pipe held a mix of naphtha and hydrogen at a temperature of about 520°C, which auto-ignited when the leak occurred. The initial leak quantity is estimated to have been 0.55 kilograms per second (kg/s). Nobody was injured as a consequence of the fire, which caused the shutdown of several process plants for just under three weeks and a substantial loss of production.

Based on observations made under the insulation in the wake of the fire, the leak is likely to have "eroded" its way through the mantled insulation until the oxygen content was high enough for the hydrogen-rich gas to auto-ignite. A jet fire probably occurred at the auto-ignition site, while fires with less flame broke out at several points along the pipe.

Emergency response personnel mustered quickly and opted for a controlled burn-off of the gas from the leak in the reactor column, while cooling down surrounding areas with large quantities of fire water to maintain structural integrity and thereby prevent escalation of the incident. The fire was reported to be extinguished at 11.25.

Normalisation work after the fire included extensive activities to establish the scope of the damage as well a treating equipment and plants with fresh water after their exposure to salt water during the incident.

Both leak and fire occurred without warning in an area where people are not normally present, but the incident might have happened while an operator was conducting routine checks there. In the worst case, that person could then have been exposed to fatally high heat radiation.

The most likely underlying cause of the incident is considered to be loss of tensioning in the bolts on the thermowell flange following erroneous thermal insulation of the latter during the turnaround in 2019. However, it has not been possible to prove this via material technology investigations. Nor can it be excluded that the loss of bolt tensioning was caused by temperature cycling in the bolts when running the plant up and down. To counteract this, the bolts must be retightened after such temperature fluctuations. That was not done for the flange in question.

During its investigation, the PSA team has exposed inadequate communication of risk associated with auto-ignition of hydrogen-rich naphtha. It has also identified weaknesses in the planning, execution and quality control of the surface protection job done on the relevant pipe section during the 2019 turnaround. Furthermore, inadequate follow-up of thermowells in general has been uncovered at the plant.

Three nonconformities have been identified, related to:

- deficiencies in design and maintenance of the plant
- deficiencies in the work process for surface protection
- deficiencies in risk analysis.

Four improvement points have been identified, related to:

- depressurisation during an incident
- notification and reporting of hazards and accidents
- learning from incidents
- securing technical findings and evidence.

2 Abbreviations

AIT – automatic ignition temperature

B3 – process area at the Mongstad refinery where the fire occurred

CAP – critical action panel

CCR – central control room

CMT – crisis management team (third line)

CUI – corrosion under insulation

DAL – dimensioning accidental load

DSHA – defined situations of hazards and accidents

EDP – emergency depressurisation

EMC – emergency medical communication centre

ERT – emergency response team

GL – guideline

HC – hydrocarbons

HMI – human-machine interface

HSE – health, safety and the environment

IMR – inspection, maintenance and repair

IMT – incident management team

ISO – isometric (diagram)

ISS – insulation, scaffolding and surface protection

LCI – life-cycle information

LEL – lower explosion limit

MS – maintenance shutdown/turnaround

NDT – non-destructive testing

NGL – natural gas liquid
OFP – surface protection project
PCS – process control system
PR – performance requirement
PS – performance standard
PS1 – performance standard 1 – containment
PSA – Petroleum Safety Authority Norway
QC – quality control
RBI – risk-based inspection
SAP – maintenance management tool in Equinor
SO – system and operation (documents)
Synergi – system for registering, analysing, processing and following up accidents, near-misses and undesirable incidents
Timp – technical integrity management programme
TR – technical requirement (internal Equinor standard)
TRA – total risk analysis
TTS – technical condition safety
WP – work permit

3 The PSA investigation

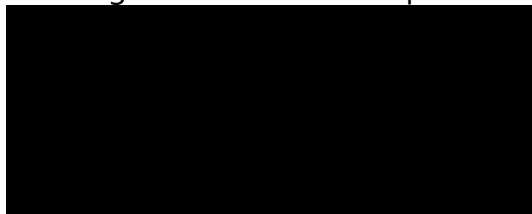
3.1 Mandate and composition of the investigation team

The investigation team has had the following mandate.

- a. Clarify the incident's scope and course of events (with the aid of a systematic review which typically describes time lines and incidents).
- b. Assess the actual and potential consequences:
 1. harm caused to people, material assets and the environment
 2. potential to harm people, material assets and the environment.
- c. Assess direct and underlying causes.
- d. Assess the emergency response to the incident, including relevant decision processes and interaction with external emergency services.
- e. Identify nonconformities and improvement points related to the regulations.
- f. Discuss and describe possible uncertainties/unclear points.
- g. Discuss barriers which have functioned (in other words, those which have contributed to preventing a hazard from developing into an accident or reduced the consequences of an accident).
- h. Assess Equinor's own reviews/assessments of relevant parts of the plant.
- i. Assess the plant's own learning and experience transfer from earlier incidents.

- j. Prepare a report and a covering letter (possibly with proposals for the use of reactions) in accordance with the template.
- k. Recommend – and normally contribute to – further follow-up.

The investigation team has comprised:



3.2 Procedure

The investigation has been conducted through

- interviews with personnel in the Mongstad organisation, covering functions for maintenance (MAIN), process area (PA), offsite (OS), surface protection programme (ISSE) and technical support (TPO), conducted mainly at the refinery with some follow-up using Teams
- verifications and inspections in the process plant at Mongstad
- document reviews of governing and other documents relevant to the incident
- verifications in such systems as Synergi, SAP, and alarm and process monitoring.

Use has also been made of information from analyses by Equinor's material technology lab at Rotvoll and leak calculations by its centre for safety technology.

Questions have otherwise been put to Equinor by e-mail, which have been answered the same way, and the company's own investigation report is assessed in chapter 13.

Assessments made by Equinor in connection with restarting the plant after the fire have not been part of the PSA team's mandate.

4 Background information

A fire broke out at 05.43 on Sunday 3 July 2022 in the A-1400 reformer plant in the B3 process area at Equinor's refinery at Mongstad.

The fire arose because of a leak in a two-inch thermowell flange on a 20-inch pipe running between the R-1404 reformer column and the H-1404 reformer furnace. This pipe held a mix of naphtha and hydrogen at a temperature of about 520°C, which auto-ignited when the leak came into contact with oxygen.

4.1 Description of the plant and organisation

The Mongstad facility in Vestland county comprises an oil refinery with an integrated cogeneration power station and a crude oil terminal. It is Norway's largest refinery, with an annual capacity of almost 12 million tonnes of crude oil.



Figure 1 Overview of the Mongstad facility. (Source: Equinor.com)

This facility ranks as the only refinery in Norway, and its oldest section dates from 1975. After an expansion in 1989, which included the A-1400 reformer plant, processing capacity rose to NOK 10 million tonnes of crude per annum. Pipelines from the Troll B and C platforms and from the Kollsnes and Sture onshore plants arrived in the 1990s. From 2019, crude from Johan Sverdrup was also landed at Mongstad. The bulk of output from the refinery comprises petrol, diesel oil and aviation fuel. About 75-80 per cent of total production is exported. Petroleum coke (petcoke) is also produced for use as anodes in the aluminium industry. (Source: Equinor website).

The Mongstad facility is operated by Equinor and the company's employees there comprise some 900 full-time equivalents (FTEs), including about 310 divided into six shifts responsible for safety, production, first-line emergency response and maintenance. Lab staff also work shifts. Remaining personnel work days and are responsible for planning and development, operational follow-up, labs, engineering and technical information support, maintenance support, stores, workshops, procurement and administration. In addition come roughly 65 apprentices. In normal operation, more than 300 supplier FTEs are utilised annually at the refinery, primarily in maintenance, modification, catering, cleaning, and guard and security services.

Figure 2 presents Mongstad's top-level organisation (MMP OPL MON).

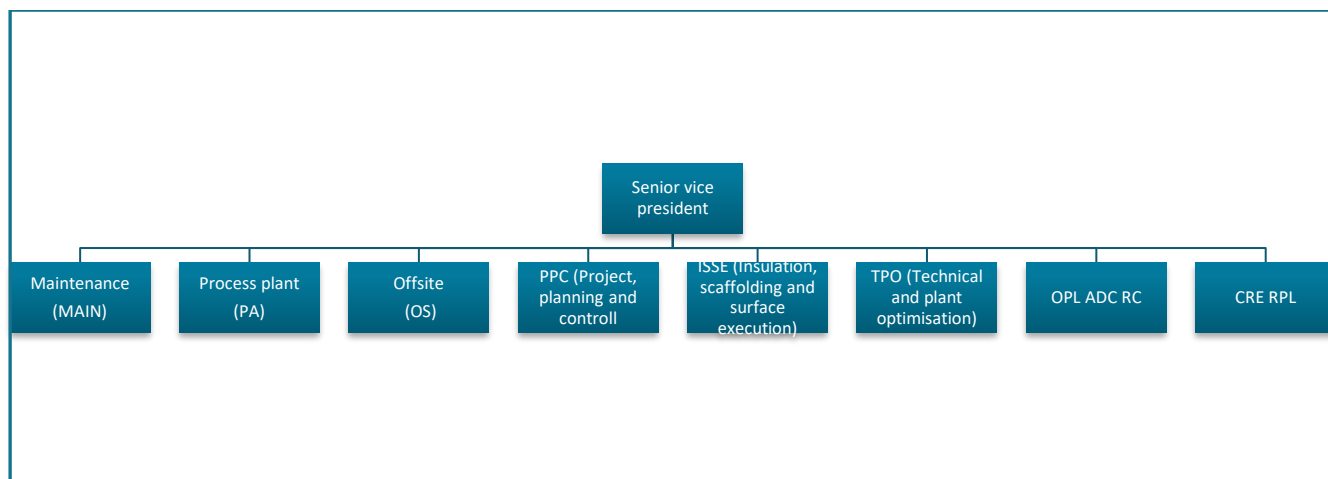


Figure 2 Organogram for Mongstad (MMP OPL MON)

Emergency response organisation

The emergency response department has a permanent staff of 16 in addition to other response personnel as described in appendix E to the *Reference document for the MMP PM emergency response plan Mongstad*.

The department is organised as follows:

- emergency response leader
- leader technical
- consultant emergency response
- 12 people working shifts, six as leader emergency response and six as leader fire
- one person training to serve ultimately as leader fire.

The emergency response organisation is presented in chapter 8.

A-1400 reformer plant

Naphtha is a petroleum fraction obtained from distillation of crude oil. It serves as the starting point for petrol production through reforming, and is also the most important feedstock in Europe for producing petrochemical products.

The A-1400 plant's job is to convert desulphurised medium naphtha from the A-1300 plant to a reformate used in petrol production. A catalytic process is used to increase the octane number of medium naphtha from about 60 to above 100.

Four principal components make up the reformer plant: a reactor, a stabiliser, an LPG recovery section and a regeneration section. The leak arose in the reactor section on a 20-inch pipe (1310-PG-14-0204) between the final stage in heater H-1404 and reactor section four (R-1404). See figure 3. Pressure at this point is normally about

eight bar, with a temperature of roughly 520°C in the pipe. The arrow in the figure indicates where the fire broke out.

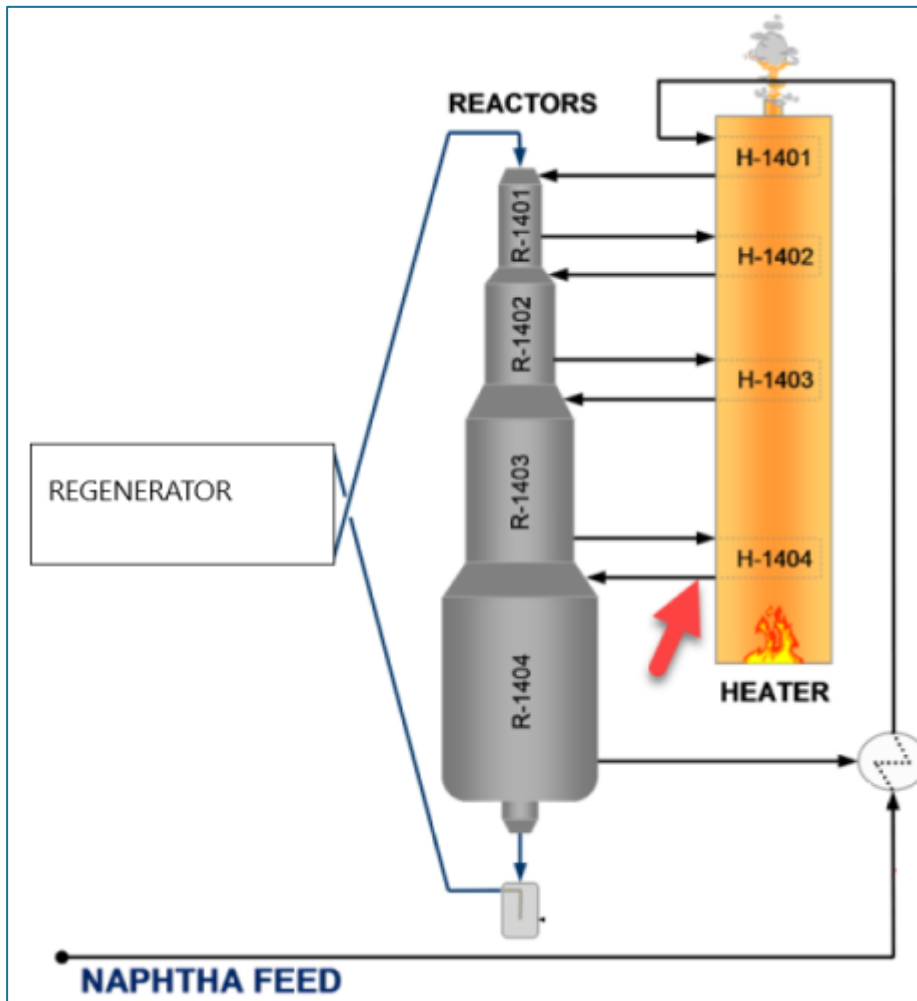


Figure 3 Schematic of reactors and heaters, with the leak site shown. Source: Equinor – presentation at kick-off meeting.

The plant has a real capacity of about 90 tonnes per hour, depending on product quality. Feed to A-1400 is pre-processed in the A-1300 plant for naphtha hydrogenation in order to protect the catalyser. These two plants are interconnected and influence each other.

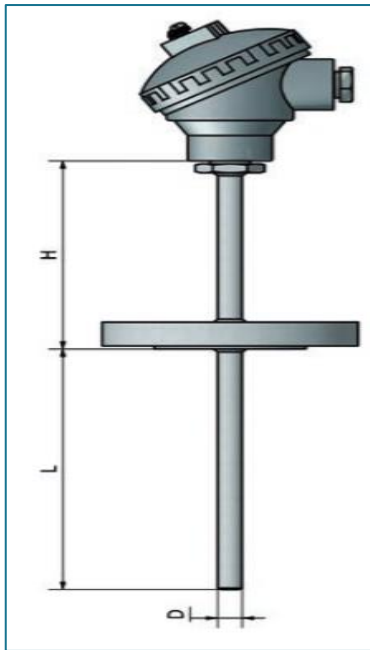
Feed to the reactor contains a mix of hydrogen-rich gas (RC gas, about 90 per cent H₂ by volume) and naphtha (feed). The latter will be partly converted to LPG, H₂ and reformat.



Figure 4 Location of the A-1400 reformer plant – the arrow points for the reformer column. Photo: Finn.no

4.2 Description of thermowell and flange

A thermowell is a temperature sensor protected by a metal tube closed at the inner end and penetrating the medium. The actual well can be attached to the pipe fully welded, by a threaded screw connection or, as in this case, with a flange. It is surrounded by the medium but open to the air, allowing the temperature sensor to be inserted and removed without interfering with the actual process.



*Figure 5 Schematic of the thermowell and photograph of a one-inch thermowell taken from store at Mongstad.
Photo: PSA*

The thermowell on the relevant pipe was a two-inch flanged type with eight ASTM A193 B16 stud bolts, dimensions $\frac{5}{8}$ inch \times 90 mm. A flat spiral-wound gasket installed between the flanges had disintegrated in the wake of the fire and only parts of it were found. According to the applicable specification (TR2000 MDS PG601), the spirals/windings, inner ring and centring ring in this type of gasket must be in austenitic stainless steel (AISI 316/316L) and have graphite between the windings. However, Mongstad has reported that it still uses seals with the centring ring in carbon steel. (Source: *Report on material technology investigations of components involved in the Mongstad fire*).

According to chapter 4.2 of Norsok R 004, 1 February 2009 edition, which is Equinor's reference standard, insulation abutting flanges in piping systems and equipment must be terminated in such a way that bolts can be undone and removed without damage to the insulation. The minimum distance from the flange to the nearest insulated component must be equal to the bolt length plus 25 mm. In this case, the flange was too close in relation to that requirement. The distance between bolts and pipe failed to provide room for insulation and bolt tensioning. In addition, the flange in question was fully insulated. See figure 10.

4.3 Condition of the plant

4.3.1 Technical integrity, Timp

Regular condition assessments (Timp and plant evaluations) identify not only nonconformities from prevailing standards but also weakenings in the physical condition of the facility. Such assessments cover both the individual barrier elements (PS) and each plant section. Results for the individual PSs form the basis for specifying the condition of the individual plant. Timp assessments are supplemented with independent technical condition safety (TTS) reviews, inspections and notifications in the condition assessment.

The process plants at the Mongstad refinery have challenges with both external and internal corrosion, which are reflected in the Timp assessment that PS1, containment, has the lowest E grading overall for the whole facility. PS1 for B3 was graded D in June, but the surface protection project (OFP) has covered 80 per cent of the work scope in this process area without serious findings. The refinery has suffered a number of incidents as a consequence of corrosion, and substantial resources are devoted to inspection and surface maintenance through the OFP. See section 4.4 for more details.

The Timp system assessment for reformer plant 2 in B3 (A-1400) was graded D in August. So was B3 for PS1, 3, 6 and 12.

None of the conditions identified in the plant and area assessments appear to relate directly to the fire on 3 July, but it can be noted that a fire detector was out of action in the area where it broke out. This was compensated for with a CCTV camera directed at the area covered by the detector and noted in the instructions of the day for the CCR operators. Alarm logs show that the fire was detected automatically when it broke out, and the PSA team has been informed that it was simultaneously spotted by CCR personnel via the above-mentioned camera.

4.3.2 Maintenance of thermowell and flange

Maintenance information and history for the flange and thermowell have been requested by the PSA team, but Equinor has been unable to produce this. The team's conclusion is therefore that thermowells and their flanges have not been covered by a maintenance programme. When installation took place in 1989, the torque for tensioning the bolts to was not specified. This requirement was introduced later.

Operation procedure OP-14-01 Start-up of A-1300/1400, version 4, dated 20 May 2021, section 2.13 (hot bolting) states the following:

Retightening of flanges must be carried out in plants 1300/1400 following maintenance work and turnarounds in the plants. The retightening must be done in the period from the temperature passes 150-200°C and until shortly after feed is put into the plants. The following parts of the plants must be retightened:

1. reactor circuit in 1300
2. reactor circuit in 1400.
3. heater circulation in 1300.
4. heater circulation in 1400.
5. in the event of large temperature fluctuations after short operational interruptions, retightening must be carried out on R-1401-4.

Through conversations and document reviews, it has emerged that the two-inch thermowell flange has not been subject to retightening in the same way as the 20-inch flange. The operation procedure does not specify the size of the flanges to be retightened, and the plant has been run up and down several times following RS2019 – most recently in the spring of 2022. Insulation covering the thermowell flange must be removed for retightening. This has not been done.

4.4 Surface protection programme

Extensive inspection and surface work is being pursued at Mongstad, organised by a dedicated ISS execution (ISSE) unit reporting directly to the top executive at the facility. The OFP forms part of this entity.

The framework for the inspection activities is provided by TR1987 Preventive Activities for Static Process Equipment and Load-Bearing Structures, with job packages prepared for area-by-area inspection and surface work.

Plans call for just under 900 000 direct hours to be worked in OFP during 2022. According to plant evaluation, the status for the programme in June 2022 was that more than 80 per cent of A-1400 had been covered without findings which indicated poor condition.

The technical department sets priorities for the work scope, with input from the person with operational system responsibility and the executing sector.

Work flow in the packages is rather different today than it was in 2019, with more field-based verification of data acquired from the various systems now done. Furthermore, routines for marking in the field have been improved so that the specific parts of the job package are documented individually and not just generally. Equinor Mongstad also had a routine in part of 2019 when completion certificates were not signed off after the work packages were finished. An ISS completion certificate for insulation of 20-PG-14-0204 therefore lacks both signatures from

Equinor. Beerenberg and Kaefer have contracts for the ISS work in the OFP, with Aker Inspection responsible for inspection.

4.4.1 Insulation of piping

The scope of insulation in a refinery largely reflects the need to preserve thermal energy and control heat flow. The main reason for insulation at Mongstad is to retain energy in piping and equipment in order to achieve efficient refinery processes. Other reasons also exist for using insulation, as outlined in Norsok N-004 *Piping and equipment insulation* (which replaced Norsok R-004 N *Isolering av rør og utstyr* in 2018), for example. Generally speaking, an insulation system comprises the actual insulating material with external weather protection. Within the insulation is the actual pipe or equipment, with or without surface protection. See figure 6.

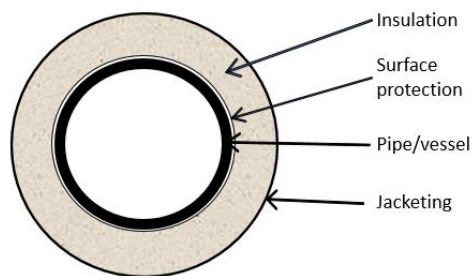


Figure 6 Schematic of an insulated pipe. Insulation on the main pipe involved in the fire was 180 mm thick.

If the insulation experiences moisture intrusion and the temperature is unfavourable, the speed at which piping and bolts corrodes can increase dramatically. This is known as corrosion under insulation (CUI).

The PSA team has been informed that Equinor requires insulation and surface protection jobs to be carried out to TR1660 *Piping and equipment insulation*, addendum to TR 1660 for Mongstad, and to Norsok R-004 *Isolering av rør og utstyr*. In TR 1660 version 6.01 (applicable in 2019) and version 6.02, section 2.5, on *Insulation of flanges and valves*, the requirements are formulated as follows:

SR-32826 - Flanges shall not be insulated if the system contains hydrocarbons above auto-ignition temperature.

SR-32827 - Flanges and valves shall only be insulated if defined on P&IDs [and:]
Insulation is critical to maintain a certain operational temperature in the system.
Insulation is required for safety and working environment.

Section 4.2 on general execution in Norsok R 004, 1 February 2009 edition, states:

Insulation abutting flanges on piping systems and equipment must be terminated in such a way that bolts can be loosened and removed without damaging the insulation.

The minimum distance from a flange to the nearest insulated component must be equal to the bolt length plus 25 mm. Termination of weather protection must be watertight.

The projection for the thermowell was shorter than the depth of insulation. To be correct, the thickness of the latter should be reduced to leave the flange outside such permanent covering so that it is easier to inspect. See figure 10. This was not done in 2019.

The ISS contractor and Equinor report that personnel performing the surface and insulation assignment at Mongstad have received training in TR1660 and Norsok R-004. They are also certified to these in the form of external courses or site-test certificates. According to the ISS frame contract, that was also the case in 2019.

4.4.2 Execution of surface protection

Processes for surface protection have changed in the wake of RS2019. The PSA team has therefore chosen to describe these before and after the changes were made.

4.4.2.1 Job packages for surface protection in RS19

The area packages for A-1400, which includes the pipes between the R-1400 reactor and H-1400 heater, were executed in 2018 while the plant was in operation. Because of the high temperatures in these pipes, however, inspection and surface protection were postponed until the 2019 turnaround. The ISS job was then executed in accordance with job package 21A15.

A first page in the job package provides data on HSE, technical aspects, the pipe surface and insulation. These state that the medium is not auto-ignitable. See also section 4.5 on area risk and the danger of auto-ignition.

HMS:					Tekniske data:				
Fare nivå L: Lav H: Høy	Innspill fra Drift	Tiltak	Inneholder H ₂ S (%)	Selv- antennelig	Linjemedie	Operasjons- temperatur (°C)	Operasjons- trykk (bar)	Steam Out (H/M/L)	Målt temperatur (°C)
0			<100	Nei	NattaH2	516	8,1		

Figure 7 Extract from the first page of the job package for PG-14-0204 in 2019. Source: Equinor

Key: HSE: Hazard level; Comments from operations; Measures; Contains H₂S (%); Auto-ignitable: No.

Technical data: Line medium; Operating temperature; Operating pressure; Steam out; Measured temperature.

The information section on insulation notes that the pipe is 20-inches, has three bends, a 16-metre straight section, must be heat-insulated (insulation class H), and must have 18 mm of three-layer rock wool insulation plus an SS316 mantle. No details are provided about the thermowell flange (zero T joints). However, the drawings in the work package show the thermowell projection (14TRC102/14TIA103).

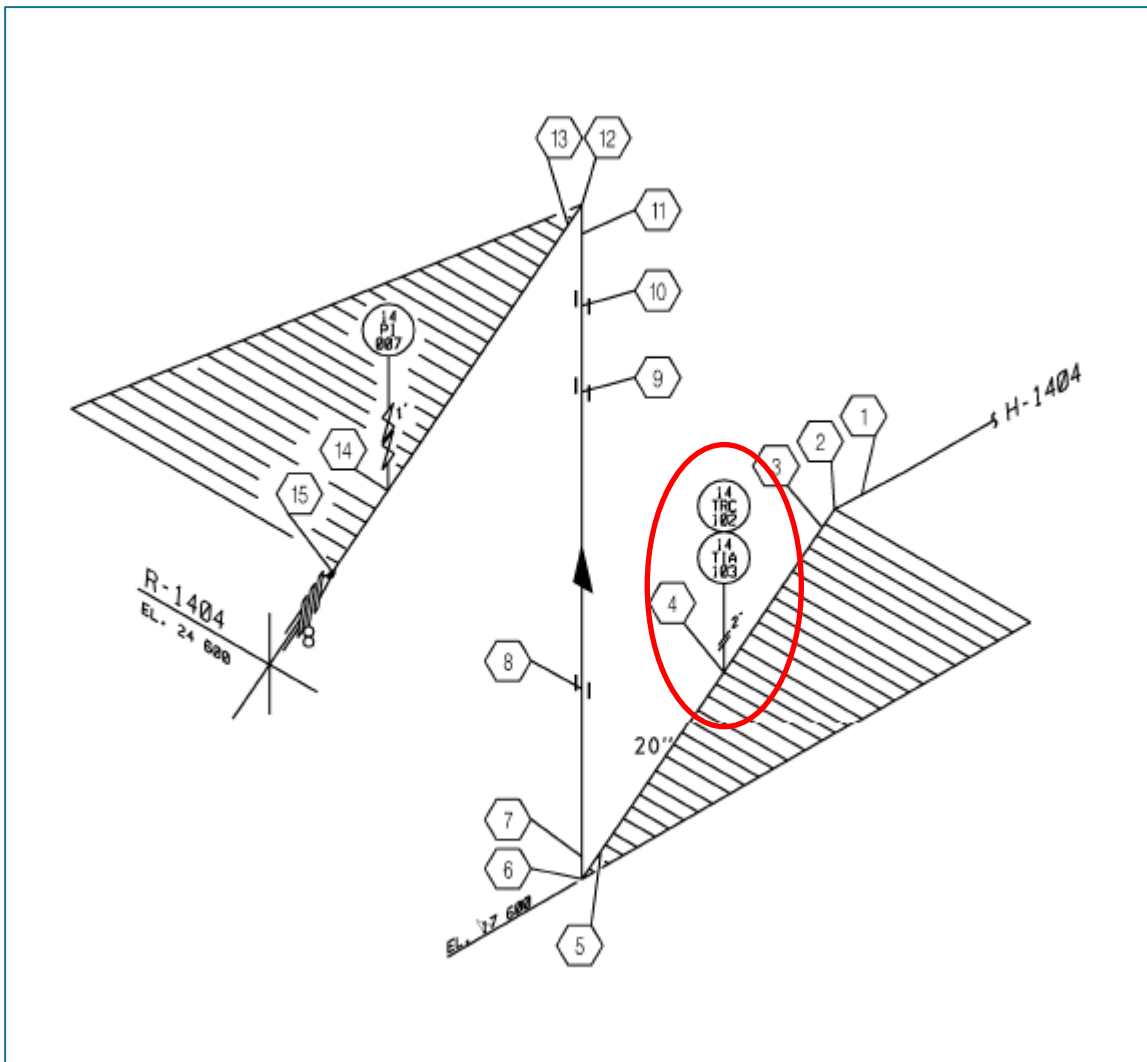


Figure 8 Extract from a drawing in the work package. Thermowell flange marked. Source: Equinor

The workflow for the 2019 job package in the OFP has been described to the PSA team as follows:

- engineering department produces the job package
- ISS contractor quality-checks the job package in the field before execution
- ISS contractor's work team deinsulates the pipe (were the plant operational, an inspector would have accompanied the insulator first on identified highly critical lines to check these before the rest of the area job could continue)
- inspector inspects the pipe
- ISS contractor executes surface protection of the pipe
- ISS contractor's work team reinsulates the pipe
- Equinor's QA function conducts spot checks of the insulation job
- two ISS-contractor representatives (foreman and engineering) and two Equinor representatives (coordinator and QA) review the job and approve it before its completion is reported in SAP.

Figure 9 presents the completion certificate for the relevant job. The PSA team has been told that the duty to sign was dropped for a time but has now been reinstated.

The quality check and the roles involved remained the same, regardless of the “wet signing”.

Statoll		Ferdig sertifikat for Isolering		KAEFER ENERGY	
KUNDE Statoll		Kunde Bestilling nr / PO: [REDACTED]		KAEFER ENERGY Prosjekt Nr : 910382 Mongstad OFP	
Linje nr / Tag :	20"-PG-14-0204	Ao Nr :	24247050	Omr :	21A15B
Linje nr / Tag :		Ao Nr :		Omr :	
Linje nr / Tag :		Ao Nr :		Omr :	
Linje nr / Tag :		Ao Nr :		Omr :	
Linje nr / Tag :		Ao Nr :		Omr :	
Utført arbeid					
Rør, Ventil / Flenser <input type="checkbox"/>		Levelglass, instrument <input type="checkbox"/>			
Ny Isolasjon / Kapsel <input checked="" type="checkbox"/>		Gjenbruk Isolasjon / Kapsel <input type="checkbox"/>			
Annet arbeid : _____ _____ _____					
Isolasjons klasse :	H	Spesifikasjoner :	TR-1660 / IPS / Isol. Håndbok		
Isolasjons type :	Rockwool 856 Pip Section / Mineralull Ventil & Flens	Isolasjons tykkelse :	180		
Kapsel :	SS 316	Kapsel thk :	Ihht IPS		
Festemateriell Isolasjon :	Ihht IPS	Festemateriell Kapsel :	Ihht IPS		
Annet :		Annet :			
Beskrivelse evt annet arbeid : _____ _____					
Vedlegg					
Punch liste :		VEDLAGT	<input type="checkbox"/>		
TA :		VEDLAGT	<input type="checkbox"/>		
FO :		VEDLAGT	<input type="checkbox"/>		
Annet :		VEDLAGT	<input type="checkbox"/>		
[REDACTED]		For Kaefer Energy		For STATOIL	
[REDACTED]		[REDACTED]		[REDACTED]	
Sign	24.11.2019	Sign	24.11.2019	Sign	
Date		Date		Sign	
		Date		Date	

Figure 9 Completion certificate for the relevant job. Source: Equinor

The investigation has revealed that all thermowell flanges on the pipe section between reactor and heater were insulated during the 2019 job. This did not accord with established requirements that flanges should not be insulated. See section 4.4.1, but was not picked up. Photographs of the pipe from before 2019 show that these flanges were not previously insulated.



Figure 10 Photographs showing that thermowells on pipes between reactors and heaters with and without insulated flanges. Photos: Equinor

4.4.2.2 Current job packages for surface protection

Since 2019, the OFP has altered the way it plans job packages. Figure 11 presents a description of the previous position (which prevailed for the 2019 job) and the current position.

Preparation of basis before and now

Before

- **Future scope**
 - HTO taken from drawings in STID, based on package limits in PlantView
 - Establish line list
 - Fetch drawings in STID
- **Operations**
 - Operations info direct in line list (no data reuse)
- **ISS Engineering**
 - Field survey correcting line list
 - Take photos in the field for job basis
 - Compile job basis
 - Mark in the field

Now

- **Future scope**
 - Field survey correcting line list
 - Take photos in the field for job basis, possibly 3D/scan
- **Operations**
 - Operations info in Power apps (data reuse)
- **ISS assignment manager**
 - Method specifier
- **ISS Engineering**
 - Compile job basis received from future scope
 - Mark in the field

Figure 11 Preparing the basis for job packages in OFP. Source: Equinor – English translation PSA

The PSA team was told that current practice after completion is to check each job in the field and confirm with signatures.

4.5 Area risk and threat of auto-ignition

The safety strategy for Mongstad states that, in the event of unforeseen process interruptions or when running the plant up and down, leaks can arise in flanges as a result of significant temperature swings or flange faults. It also notes that immediate ignition can occur on such flanges, particularly if they are in hydrogen or hydrocarbon (HC) service above the auto-ignition temperature (AIT). Flange fires in these systems are usually extinguished by operators with steam (low pressure), using either steam lances if the site is easily accessible or steam rings installed on the flanges in advance for manual activation from a safe distance. Steam can inhibit ignition, have an extinguishing effect and prevent overheating of flange bolts.

Mongstad's total risk analysis (TRA), describes all hazards and accidents which could arise at the facility and the total risk for personnel working there, third parties, the main safety functions and financial risk. The A-1400 plant is located in what the TRA terms fire zone (BO) 240, and the zonal risk for BO 240 is summarised as follows:

The leak frequency in BO 240 is high because much process equipment is located in this area. **Many cases of hydrogen-rich gas are present, but temperatures are not high enough for auto-ignition** (PSA emphasis). Fire frequency and thereby risk associated with immediate ignition are therefore lower in this area than in zones such as BO 230 and BO 350A, which are subject to auto-ignition. Only large leaks (> 15 kg/s) are expected to expose heaters in BO 240, so that the frequency associated with delayed ignition is relatively low. Combined with only moderate concentrations of toxic gas (H₂S) in parts of A-1300 case 2.3 in the area, this means that the risk measured by the zonal fatal accident risk (FAR) is not especially high in BO 240. Risk in the zone is primarily associated with incidents occurring in the area.

The text highlighted above indicates that the risk in BO 240 is underestimated in the TRA, since many examples of auto-ignition exist with leaks in flange connections to reactor R-1400. It emerged from interviews that operating personnel are well aware of the threat of auto-ignition in R-1400.

The threat of auto-ignition is also noted in the system and operation (SO) documents:

- SO01250 version 3, A-1400 Reformer 2, section 2.8: "The hydrogen content in the reactor circuit and the regenerator is so high that leaks to the open air could auto-ignite regardless of temperature."
- SO01250 version 4, OP-14-01 Start-up of A-1300/1400 section 2.1.2: "The reactor section of A-1400 contains a lot of hydrogen in addition to high temperatures. Hot hydrogen contacting the open air could auto-ignite."

Fire-extinguishing philosophy at Mongstad

Extract from Equinor Mongstad safety report ST-16018-4, section 6.2.4 Active fire extinguishing (PS 9):

The refinery has extensive extinguishing systems in the process plants, tank farms, jetty areas and buildings. In addition comes a fire station at Mongstad. Fire extinguishing in refineries is primarily based on using water or foam. Where the process facilities are concerned, the philosophy is to run down the plants and shut off the supply of flammable liquids/gases. Water is deployed in large quantities to cool equipment and structures until the fire has been extinguished. Normal practice when running down is to shut off the supply of flammable liquids/gases. With tank farms, filling racks and jetties, water is applied primarily for cooling, with foam as the extinguishing medium.

Two separate fire water systems cover the industrial area. In addition, potable-water piping is used for fire water in the accommodation part of the work camp. The two different fire-extinguishing systems are divided into the following groups:

- stationary extinguishing systems
- semi-stationary extinguishing systems.

In addition, the heaters and sulphur silos in A-4100 as well as the sulphur sumps are equipped with extinguishing steam systems.

In the event of unforeseen process interruptions or when running the plant up and down, leaks can arise in flanges as a result of significant temperature swings or flange faults. It also notes that immediate ignition can occur on such flanges, particularly if they are in hydrogen or hydrocarbon (HC) service above the auto-ignition temperature (AIT). Flange fires in these systems are usually extinguished by operators with steam (low pressure), using either steam lances if the site is easily accessible or steam rings installed on the flanges in advance for manual activation from a safe distance. Steam can inhibit ignition, have an extinguishing effect and prevent overheating of flange bolts.

From TR2237 – Substitution to TR2237 version 3 - Safety strategy and performance standards for safety system and barriers at Mongstad:

For some fire events, it may not be practical or necessary to provide firefighting systems to extinguish the fire. In addition, extinguishment may create a greater hazard due to an increased potential for an explosion should gas from a release subsequently re-ignite.

At an early stage of the fire, the on-scene commander – in consultation with the response management – decided that it would be safer to let the fire burn out rather than allowing an uncontrolled gas cloud to form. Attention was primarily concentrated on cooling down surrounding structures and equipment.

4.6 Earlier incidents involving ignition of hydrogen-rich naphtha

Several incidents where hydrogen-rich naphtha ignited have occurred at Mongstad. Some of these are noted here, with reference to the case number in the PSA files.

23 October 2019, case 2019/1353: When running up the 300/400 plants, a small leak occurred on a flange into a heat exchanger. The leak auto-ignited and the fire was extinguished with steam after one-two minutes. After the flange was retightened, the leak ceased.

13 March 2018, case 2018/397: Flames reported from two valve pack boxes in regenerator A-1400 at the first grating in the structure. The medium in this part of the regenerator is hydrogen. Two operators were present when the fire was discovered, and were able to extinguish the fire immediately with steam lances.

13 November 2015, case 2015/1281: During maintenance on a closed-off system, a flange was opened in the A-1400 plant. A person was then exposed to a jet flame and suffered burns in the head region.

23 January 2008, case 2008/148: Fire in the A-1400 process plant. To quote the report form: "A report was received at 14.34 via the emergency line (100) of a flange fire up in the reformer plant (A-1400) structure. The fire was in the inlet flange to a reactor (R-1404) about 20 metres above ground level. 'Evacuation alarm' sirens were activated at 14.36. The medium in this part of the plant was a mix of hydrogen and naphtha at a temperature of over 500°C. In the event of a leak, this would ignite immediately, since it was above the auto-ignition temperature. A plant shutdown was initiated immediately, and notification given in accordance with DSHA 12. Firefighters began cooling structures in the fire area. Pressure in the plant was reduced to a little above atmospheric level and the fire subsided to a small jet flame, but it was decided to maintain a controlled flame in order to burn up residual flammable material. The introduction of inert gas (nitrogen) was begun to flush out remaining hydrocarbons in the affected part of the plant. The fire was extinguished at 16.02 and the 'danger over' sirens sounded. No people were injured, and material damage to equipment was limited."

The 23 January 2008 incident has features in common with the 3 July 2022 fire, but involved a 20-inch flange in a main pipe rather than a thermowell flange.

Other incidents involving ignition of hydrogen-rich gas in the same plant have been classified by Equinor as low severity (green 4 and 5). These have not been reported to the PSA:

30 October 2020 Synergi 1634283: Jet flame from inlet R-1401

10 February 2016 Synergi 1464812: Jet flame from flange R-1402

2 August 2015 Synergi 1447104: H₂ leak in outlet-pipe flange R-1404.

4.7 Position before the incident

A turnaround had been conducted in parts of Mongstad during the weeks before the incident, but B3 was not part of this. The most recent turnaround for B3 had been in 2019, but A-1400 had also experienced shutdowns where the main compressor failed three times in 2020, once in 2021 and once in 2022.

The operating status for the seven days before the incident was that A-1400 had operated steadily and normally, without operating disruptions or maintenance activities. The night before 3 July had been quiet, with all plants operating stably. Two burners on H14-4 and H14-2 were cleaned by an operator a few hours before the incident. This operation takes about 15 minutes and was conducted a few levels below the fire site. Three operators were out in the B3 plants during the night, and the night shift was nearing its end when the incident occurred. An operator was making a final tour of the plants to see that they looked fine before handover, while the other operators were in the control room.

Instructions of the day for B3/MHPP on 1-4 July 2022 reported that 30-AX-631 flame detector T-1404 had been overridden in OS6 because of error messages. Compensatory measure: CCTV monitoring.

According to emergency response logs, the weather conditions were favourable during the night before 3 July, with relatively little wind and little rain.

5 Course of events

5.1 Description of the incident

A fire broke out at 05.43 on 3 July 2022 in thermowell flange 14-TW-102 on the pipe between the A-1404 reactor and the H-1404 heater. The pipe held a mix of naphtha and hydrogen at a temperature of 520°C, which auto-ignited on contact with the air. The initial leak volume is estimated to have been 0.55 kg/s.

Based on observations made after the fire, the leak can be assumed to have "eroded" through the mantled insulation until the volume of air allowed the hydrogen-rich gas to auto-ignite. A jet fire probably occurred at the auto-ignition site, while fires with less flame broke out at several points along the pipe. See figure 12.

A plant operator who was at ground level beside a field office near the area concerned observed a flash followed by flames, and immediately alerted the CCR via radio. An automatic fire detector activated at approximately the same time as CCR personnel saw flames on the CCTV camera directed at A-1400. The CCR operators were not sure of the fire's exact location, but saw tall flames up in the reactor area.

Film of the blaze, together with observations by personnel in the area, show that the flames could initially have been 10-15 metres high.



Figure 11 CCTV images of the fire. Source: Equinor

CCR operators at the B3 panel initiated heat off and emergency shutdown from the CAP for A-1400 before halting feed to the blaze and isolating the fire segment. They also initiated pressure relief of the reactor column, but this was done using a control valve rather than by emergency depressurisation via the CAP.

At the same time, the evacuation alarm was activated by a third CCR operator.

Furthermore, action was quickly taken to start fire water since the plant operator who spotted the fire immediately activated a fire monitor and an operator in the CCR ran out and activated the monitors in front of the CCR (south-eastern side of A-1400) and facing B1 (western side of A-1400). He investigated whether liquid was descending from the heaters, since the boiler circulation (liquefied naphtha) was located immediately over the fire site. Since no liquid was flowing down, he was reasonably certain that this represented a gas fire.

The fire response team arrived at the site after a few minutes and was met by the process operator (adviser process) immediately outside the CCR on its southern side. Extinguishing work was then initiated with equipment from fire appliances. A lot of smoke in the area meant it took some time to determine that the fire was coming from the reactor circuit. Because heat was present in the process, it was found to be safest to allow the content to burn out rather than end up with an uncontrolled gas cloud floating about. Attention was concentrated on lowering pressure in the reactor

in order to reduce the potential in the fire, and on cooling plant components with the aid of fire water in order to safeguard the integrity of nearby piping and structures.

The pressure and flames were observed to be declining early in the extinguishing work. About 15 minutes passed before 0.1 bar was confirmed. The fire was then assessed to be under control, but cooling of surrounding pipes and structures continued.

In dialogue with the response management, the team introduced nitrogen to the inlet circuit for the reactor in order to flush flammable media out of the column.

Manual depressurisation was eventually also initiated on both columns – T1305 and T1406.

The fire was reported to be extinguished at 11.25, and the response management decided that the danger was over at 12.56.

Conversations with those involved in the response revealed that they felt it had been implemented well. Rapid response with important and correct initial action meant things constantly moved in a positive direction.

The team also decided to activate the evacuation alarm later in the day when a hand-held gas meter activated. This proved to be a small gas leak from a pump which failed to activate the fixed meters. The position was quickly clarified and dealt with, and is not dealt with by this investigation.



Figure 12 The fire area, with the thermowell where it started in the centre. Source: Equinor.



Figure 13 The two-inch thermowell flange after the fire. Source: PSA

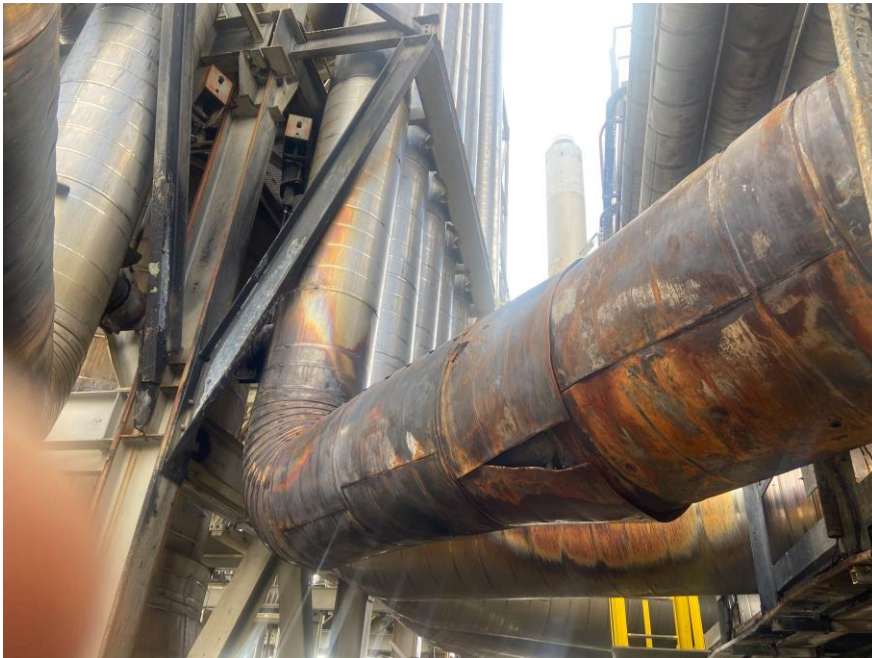


Figure 14 A hole in the mantling where the fire has presumably been more intense, but burning has occurred both inside and outside the mantling. Source: Equinor

5.2 Timeline

Date	Preceding conditions and information relevant to the incident	Comments
1989	Mongstad development project. Process plant B3 installed, thermowell installed with the 14TE102 thermoelement.	No history for the thermowell has been found since its 1989 installation. Requirements for inspection and maintenance of piping with thermowells are assumed to accompany the main pipe. Generally speaking, no maintenance of flanged connections or history of torque tensioning of the bolts are documented.
1994-2015	Inspection of 1310-PG-14-0204 pipe	During this period, inspection intervals for the pipe changed from calendar- to risk-based. Inspection history shows that no corrosion was found on the piping.
23 Jan 2008	Flange fire in R-1404	<p>Fire from 20-inch pipe on the main line. Equinor's investigation report (case 2008/148):</p> <p>Some of the long-term measures in the report are intended to clarify whether the types of gasket, flange and bolts are correct for this service.</p> <p>Based on collaboration with various internal and external specialist groups, the investigation team's impression is that views differ on technical questions related to the integrity of flange connections, particularly for this type of service. That applies, for example, to issues relating to gaskets, flanges, bolts and tensioning torques. The team believes that all the specialist groups must devote more attention to improving the level of expertise in this field.</p> <p>The PSA team believes that attention has been primarily concentrated on large flanges (where leaks have occurred earlier) and not on thermowell flanges.</p>
20 Feb 2008	Recommendation after flange fire in R-1404 on 23 January 2008	<p>After meetings between Shell, UOP and specialist groups in StatoilHydro, changing gasket quality from SPW (spiral-wound) to camprofile was recommended for the following:</p> <ul style="list-style-type: none"> • all 20-inch inlet and outlet flanges for R-1401/2/3/4 • all 24-inch manholes for R-1401/2/3/4 • main flange top R-1401 <p>The PSA team has not found any documentation on follow-up of recommendations concerning gasket quality for thermowell flanges.</p>

2 Aug 2015, 10 Feb 2016, 30 Oct 2020	Minor flange fires in R-1401 and R-1402	<p>Synergi 1447104:</p> <p>Jet flames from 20-inch flange. Controlled cooling of the plant was conducted to change gaskets. Measure 8: 1) Find out if right gasket type has been used at leak site. 2) With reference to the 2008 incident, are there other flanges in the same part of the 1400 plant where gaskets should be changed?</p> <p>Equinor reports that it has been unable to find confirmatory documentation about what type of gasket was used for upgrades, but that it is likely to have been a 20-inch spiral-wound solution.</p> <p>Synergi 1464812, 10 February 2016:</p> <p>Jet flame from flange R-1402, B3 process area, line 20-inch 14-PG-0202. Measure 2) Replace gasket on inlet flange R-1402. Measure 3) Post job for replacing corresponding gaskets in A-1400 in RS16.</p> <p>A SAP printout has confirmed to the PSA team that the gasket on the 20-inch flange inlet R-1402 was changed to a camprofile type.</p> <p>Synergi 1634283, 30 October 2020:</p> <p>Jet flame inlet R-1401: Measure 4) Recommendation to operate the plant until the next opportunity. Measure 6) Recommendation to change gasket in RS24.</p>
1 Jan 2019	OFP established	The goal of the surface protection project is to ensure integrated management of surface maintenance at Mongstad.
Q2 2019, ahead of RS2019	ISS for job package 21A15 was established in SAP as part of work order 24247050	<p>Job package 21A15 describes the following:</p> <p>Auto-ignition: no Line media: naphtha/H₂ Operating temperature: 516°C Operating pressure 8.1 barg</p> <p>In the information section on insulation, no information is provided about the thermowell flange. However, this is shown in the drawings attached to the work package.</p>
Q3 2019	RS2019	Execution of job package 21A15, where the thermowell is erroneously covered by insulation.
24 Nov 2019	Quality assurance	Completion certificate for insulation of 20-inch-PG-14-02-04. Signed only by the contractor, but the PSA team has been told that two representatives for Equinor (coordinator and QC) reviewed the job and approved it.
3 Jul 2022	Fire in A-1400 plant	The fire occurred following a leak in a two-inch thermowell flange installed on a 20-inch pipeline between the R-1404 reactor column and the H-1404 heater.

5.3 Leak calculations

The PSA team has rested its assessments on calculations performed by Equinor's safety department at Rotvoll. These are based on leakage from a distorted flange with a wedge-shaped opening. See figure 16. The Phast programme developed by DNV has been used to calculate leak rate and gas dispersion.

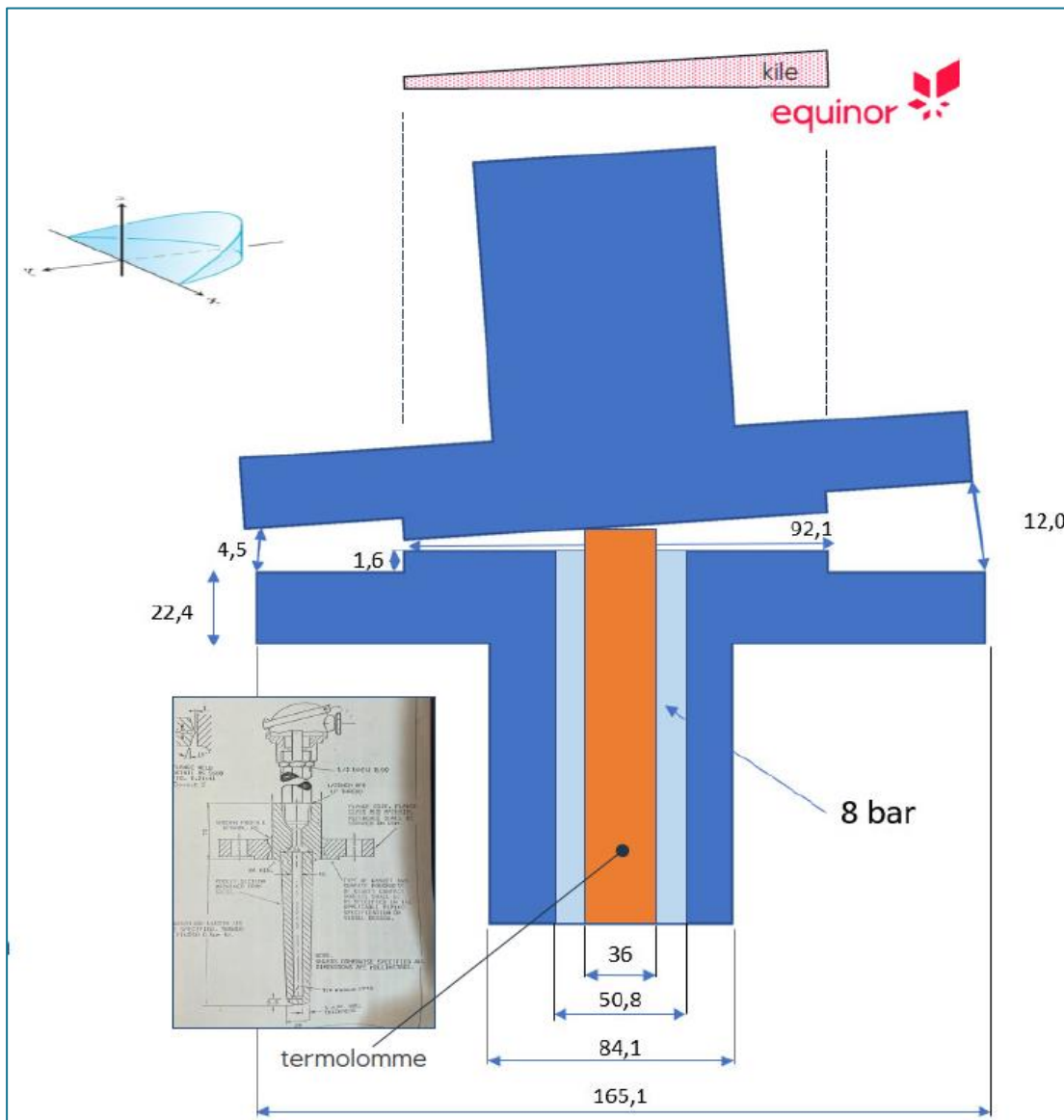


Figure 15 The basis for the leakage calculations. Produced by Equinor's technology centre
Key: termolomme = thermowell

Equinor has not considered the possibility that the bolts failed so that the joint was left fully open. It justifies this on the grounds that the pressure was low (eight bar initially) and would have fallen as soon as the leak occurred. Equinor concluded that the rate may have been a little higher, but that full opening is unlikely to occur. The PSA team supports this assessment on the basis of the report from Equinor's material technology lab at Rotvoll on its investigation of components involved in the Mongstad fire.

5.3.1 Results from the leak calculations

The calculations show that the leak probably had a mass flow rate of 0.55 kg/s. This is based on the largest limiting area, specified as the cross-sectional area of the pipe given a thermowell located in its centre.

An unobstructed jet flame of this size has a flame length of about eight metres. Gasket material (graphite and steel) in the flange at the time of the leak has influenced gas dispersion, and it is not impossible that this material limited the mass flow rate. External insulation on the pipe probably also affected the flow. This has not been taken into account, so the estimated rate is considered conservative.

5.3.2 Results from gas dispersion assessments

Figure 17 presents a side view of the concentration in an *unignited* unimpeded gas cloud. Blue=20% LEL, green=50% and red=100%, where the lower flammable limit of mixing in air is 100% LEL.

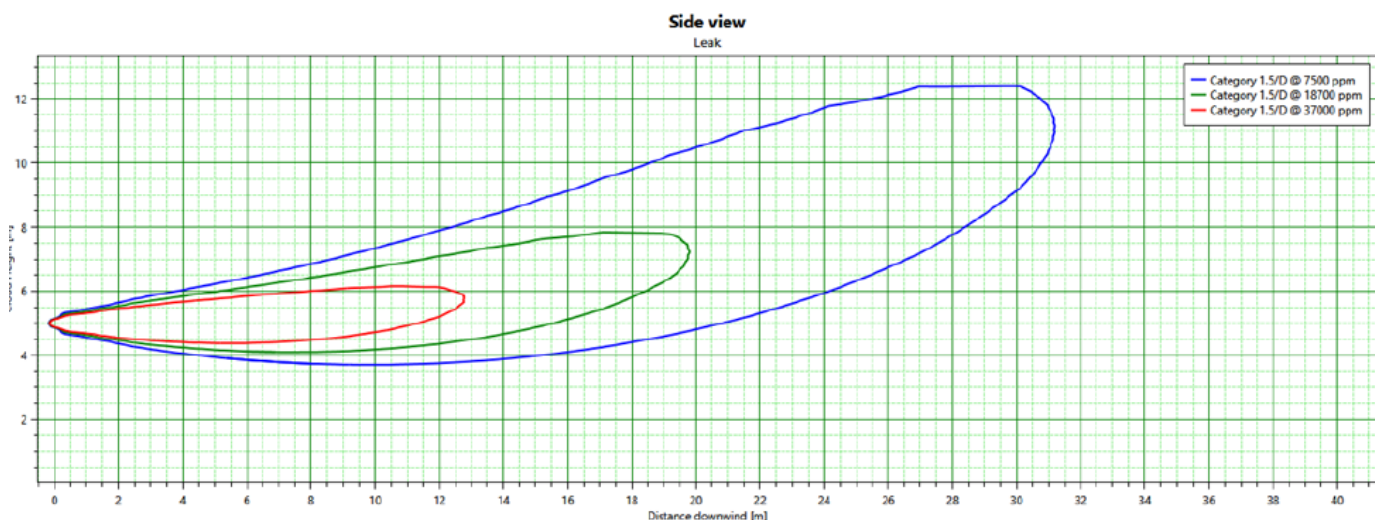


Figure 16 Gas dispersion – for comparison. Source: Equinor technology centre

5.4 Effect of the fire on the PG-14-0204 pipe and surrounding pipes

When stripping off insulation in the wake of the fire, the OFP made an assessment of the thermal insulation's resistance to the fire, and documented this in the *Fire on 20-PG-14-0204 (H-1404), information about the insulation* report.

The 20-inch pipes between reactor column and heaters are insulated with three layers of rock wool, totalling 180 mm. Pipes in the overlying pipe tracks carry naphtha from the base of the T-1305 stripping column and unstabilised reformat from the base of the T-1406 stabiliser column, and have 80 and 100 mm of insulation respectively.

Based on assessments of the various layers of insulation on pipes affected by the fire, the OFP concluded that none of the pipes were directly exposed to temperatures above 1 000°C over time. This assumes that the insulation against the pipe would otherwise have melted, which was not observed.



Figure 17 PG-14-0204 and overlying pipe tracks immediately above the leak point. Source: Equinor



Figure 18 Cross-section of fire-affected thermal insulation on the overlying PL-13-0718 pipe. Source: Equinor

6 Potential of the incident

The process area is segmented into fire zones to reduce the probability of transmission and spreading. Feed and heat in the affected zone were shut off, and blowdown and evacuation alarms quickly activated. The on-scene commander also chose, in consultation with the response management, to let the leak burn out in a controlled way and to flush out flammable gas with nitrogen. Attention in the response was concentrated on cooling down surrounding structures and equipment as long as the fire lasted, rather than extinguishing the flames.

6.1 Actual consequence

The incident caused the emission of hydrogen-rich gas to the air at an initial rate of 0.55 kg/s. The fire began at 05.43 and was reported to be extinguished at 11.25.

Nobody was injured as a result of the fire or the subsequent emergency response.

Equinor has estimated costs associated with the fire at NOK 600-700 million. See chapter 13.

6.2 Potential consequences

The leak and the fire occurred without warning in an area where people are not normally present. But it could have happened while operators were in the area to conduct routine checks, and these could then have been exposed in the worst case to fatally high heat radiation.

In the worst case, ignition of media in surrounding pipe tracks could have escalated the fire with substantial local material damage. However, assessments of the thermal insulation's fire resistance mean that this is considered improbable.

Based on Equinor's assessment of the fire-resistant properties of thermal insulation on the pipe concerned, the overlying pipes are likely to have retained sufficient integrity to avert leaks/fracturing until the fire died out. That assumes the same extinguishing approach followed during the incident, with activation of heat off, emergency shutdown, pressure relief and cooling.

The investigation established that all thermowells on the pipes between the reformer column and the heaters were insulated. Since the temperature is roughly the same for all the pipes, which thermowell leaked appears to have been a matter of chance. The response and potential consequences are likely to have been the same regardless of the thermowell involved. Geometry, insulation, temperature, pressure and medium are comparable when assessing the potential consequences of a leak and fire.

Had the fire been extinguished earlier in its progression, before the column had been pressure-relieved, an uncontrolled gas cloud might have formed and possibly suffered delayed ignition. Not extinguishing the fire was a conscious action to avoid that scenario. The same approach was also taken during the fire on 23 January 2008.

7 Direct and underlying causes

The PSA team has drawn on the investigations conducted by Equinor's material technology lab at Rotvoll, and has also been in dialogue with it over defining the scope of this work. The results are presented in *Report on material technology investigations of components involved in the Mongstad fire*.

7.1 Direct cause

The direct cause of the fire was a leak of auto-ignitable hydrogen-rich naphtha, probably owing to a loss of bolt tensioning on the thermowell flange with consequent opening of the flange for the 14-TE-102 element which measures the temperature in the pipe flow between the H-1404 heater and the T-1404 reactor. See section 7.2.1.

7.2 Underlying causes

7.2.1 Bolt tensioning

The material technology investigations have been unable to identify the underlying cause of the leak and subsequent fire unambiguously. Thermowell, bolts and spiral-wound gasket are considered to have retained their original properties before the leak and fire occurred. No aggressive corrosion and associated reduction in bolt cross-sections were found, and CUI is therefore not regarded as the cause. A probable explanation of the leak, referenced in the report, could be a loss of tensioning and thereby reduced clamping force in the flange. Such loss is probably attributable to a relaxation of the bolts because the temperature of the flange connection was increased by being (erroneously) fully insulated in 2019.

Another possible explanation is a loss of tensioning because of temperature changes in the bolts when running the plant up and down. To combat such loss, the bolts must be retightened after each fluctuation. As described in section 4.3.2, this has not been done for the flange in question.

7.2.2 Quality of planning for job package 21A15

The job package for the relevant pipe was incomplete, and contained errors and deficiencies. See section 4.4.2.1.

No description of the thermowell was provided in the package basis, although the attached drawings show the thermowell projection.

7.2.3 Execution of insulation in job package 21A15

The investigation has shown that all thermowell flanges on the pipe between reactor and heaters were insulated during the 2019 job, which did not accord with established requirements that flanges must not be insulated. See section 4.4.2.1.

7.2.4 Quality control of job package 21A15

Pursuant to the quality assurance procedure, two representatives from the ISS contractor (foreman and engineering) and two from Equinor (coordinator and QC) reviewed the completion of the insulation job and approved this before final reporting in SAP. This check failed to identify that the thermowell flanges had been insulated. See section 4.4.2.2.

7.2.5 High workload

The PSA team was told that inspection and reinsulation of the reactor piping were the final activities to be conducted before the A-1400 plant could be restarted after RS2019. This could have led to pressure of time which undermined the quality of the work by the team involved in the reinsulation job.

7.3 Other conditions

7.3.1 Depressurisation

The reactor is depressurised via the D-1405 separator. Pressure relief during the incident was accomplished from the CCR panel by operating the 14-PV-025 pressure control valve.

Emergency depressurisation was not activated during the incident via the 14-XV-223 valve used for this purpose. CCR personnel said that this was because the fire site was not known initially, and emergency depressurisation could make the position worse. They chose therefore to operate the 14-PV-025 valve, which was opened about 22.5 per cent roughly two minutes after emergency shutdown was activated. The PSA team could see this from a control-system printout (not attached). Thereafter, the valve was operated gradually over 10 minutes to fully open. The printout shows that

pressure sank steadily, and that D-1405 was virtually depressurised at 06.01 when more than 15 minutes had passed since the fire began.

In the PSA team's view, faster pressure relief by fully opening the control valve at once or by activating emergency depressurisation would have reduced the energy in the fire more quickly.

8 Emergency response

Technical emergency response conditions are divided in this report into three sections, providing an overall description of efforts in the various phases as revealed by logs, interviews and inspection of the fire site.

Mongstad's WR-9007 emergency response plan for the first (ERT) and second (IMT) lines describes how the predefined dimensioning accidents (DSHAs) are to be handled in the various phases which follow each other in time, and which will overlap to some extent. The plan is based on official regulations for onshore petroleum operations and enterprises subject to industrial safety requirements, as well as on Equinor's internal requirements.

The emergency response organisation also embraces the third (CMT) line, which is located at Equinor in Forus.

Emergency response duties and efforts, with descriptions of roles, manning and teams, are defined on the basis of analyses for the Mongstad facility. The emergency response department at Mongstad comprises 16 people in addition to other responders, such as firefighters/smoke divers.

The PSA team's overall impression is that the emergency response commitment from the alarm to the normalisation phases functioned well and in line with plans. But it finds a potential for improvement related to pressure relief during the incident under consideration. See section 7.3.1.

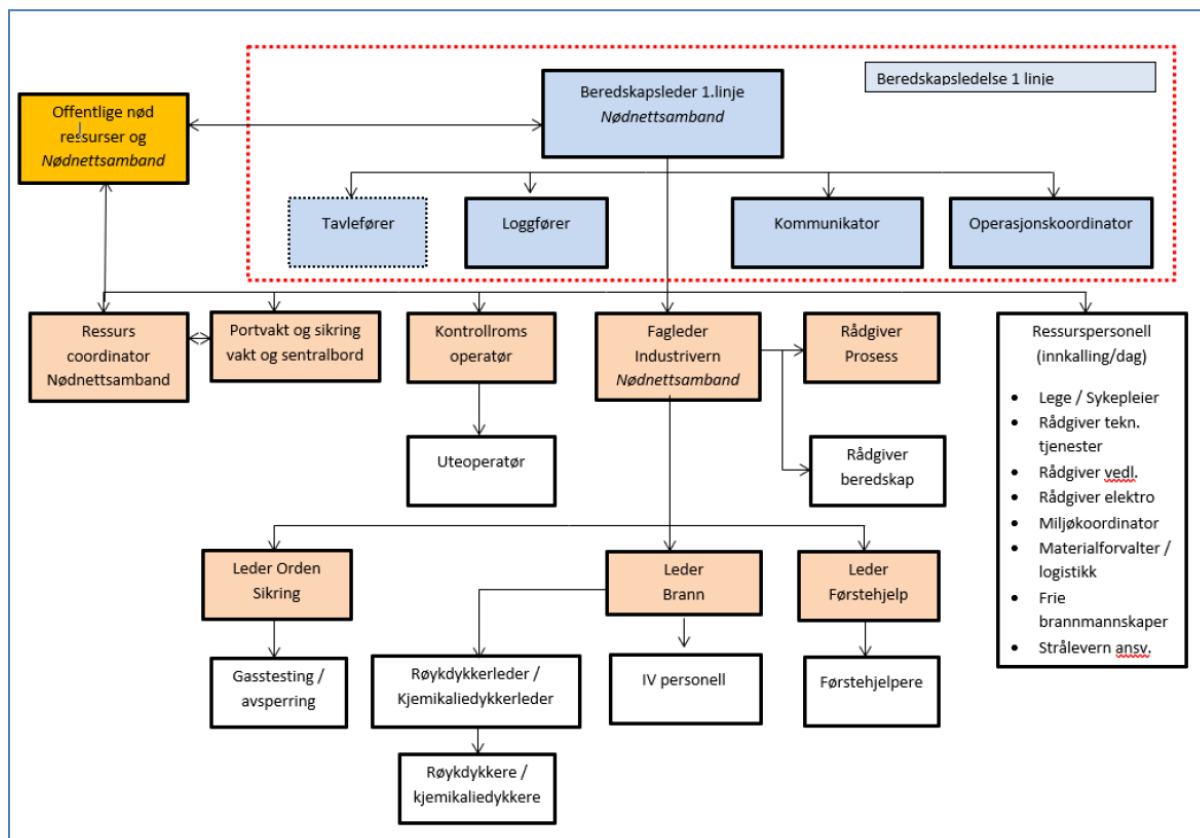


Figure 19 First-line emergency response organisation (ERT) at Mongstad. Source: Equinor/Mongstad

8.1 Alarm – notification and mobilisation

The fire activated flame detectors, and the incident was simultaneously observed by a plant operator who was at ground level near a field office (blue shed) and close to the relevant part of the facility at about 05.43. This person immediately contacted the CCR for the A-1400 area via radio.

At the same time as the CCR for B3/A-1400 received fire alarms from several detectors, its operators observed naked flames on the CCTV camera directed at A-1400.

CCR operators for B3 initiated emergency shutdown, heat off, depressurisation and a number of other measures which they can implement, while the CCR operator for offsite immediately activated the Mongstad-wide evacuation alarm.

Notification of the incident was also provided early in this phase over the radio on all channels. That was repeated regularly during the extinguishing work. Each measure taken and its scope is presented in the response management team/CIM log and other logs.

Item C under DHS 3 Fire/explosion in the Mongstad emergency response plan was followed during the incident.

Furthermore, triple notification of all civil emergency services was activated – in other words, simultaneous notification of the fire to the police, fire and rescue, and the emergency medical communication centre (AMK) with a request for assistance.

According to the CIM log, Equinor internally and external agencies – including the PSA – were notified early in the incident, at about 06.30 (CIM log 030722-06.30).

8.2 Response – rescue and evacuation

In parallel with activating the audible and visual evaluation alarm from the CCR for offsite areas and the subsequent oral alert about the incident over all radio channels from two to 34, immediate steps were taken by personnel at the fire site to activate several fixed fire monitors at ground level alongside A-1400 to spray water towards the fire.

The discipline manager for industrial safety (on-scene commander) was quickly mobilised from his regular post at the Mongstad fire station inside the facility, and the rest of the response personnel in the industrial safety team arrived successively at the fire site at A-1400. Taking the lead there, the on-scene commander gave emphasis to keeping the response team at a safe distance from the fire.

In addition to stationary fire monitors, three appliances from the Mongstad fire station were deployed to the site and two were committed to extinguishing work on arrival. A fourth appliance was also sent to the site after a while and held in reserve.

The application of fire water was eventually concentrated on cooling surrounding piping, equipment and supporting structures. In consultation with the head of the first line ERT, the on-scene commander decided to allow the fire to continue in a controlled manner in order to avoid uncontrolled gas dispersion in the area.

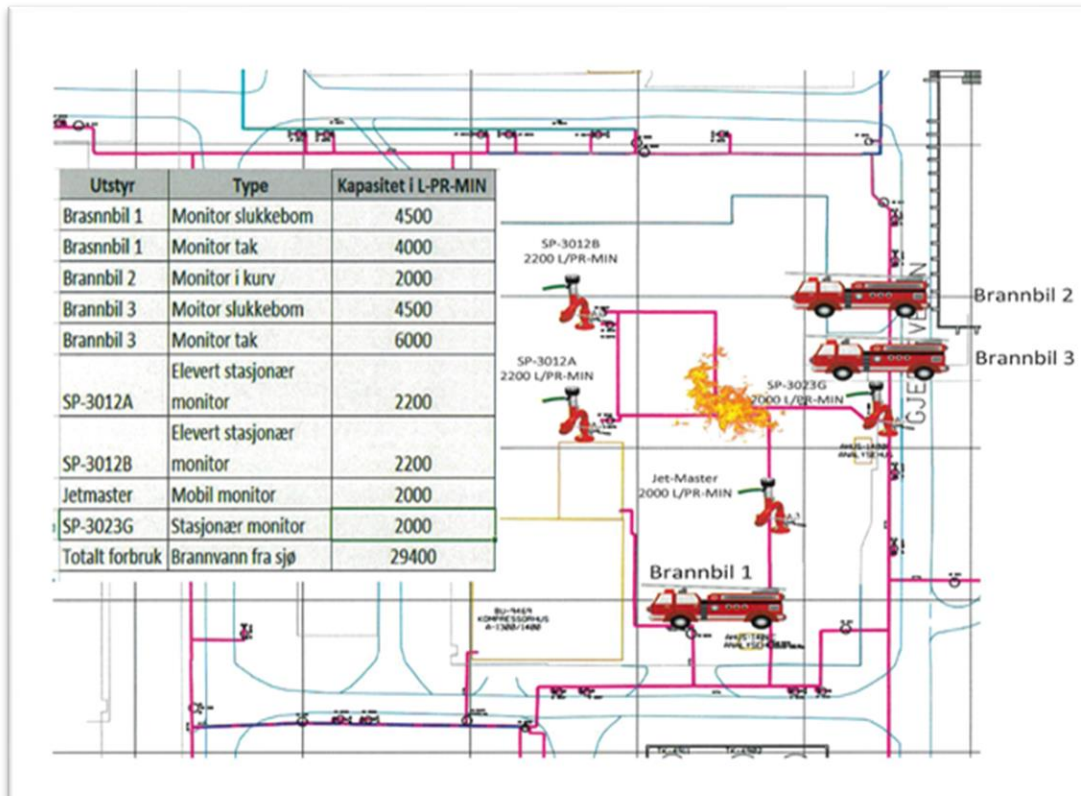


Figure 20 Fire-appliance disposition at the fire site and water capacity. Source: Equinor/Mongstad

The response log confirms that the first of the refinery's own available resources were in place within 10 minutes. Application of fire water from the appliances could start about 15 minutes after the alarm was received (CIM log 030722-05.51) and two refinery appliances were deployed in two positions by A-1400 at about 06.10 (CIM log 030722-06.09).

As time passed, the civil emergency services arrived. They included three police patrols from the western district in Bergen, Nordhordaland fire and rescue, and ambulances from the Bergen health authority. The police and fire services were directed and given access to the fire site, but concurred that Mongstad's own organisation should lead and handle the response effort. These services were kept continuously updated about developments.

A written agreement with Nordhordaland fire and rescue specifies that Mongstad will lead the response to a fire inside the plant unless otherwise decided or agreed.

The weather was favourable, with relatively little wind or precipitation when the incident occurred and during the extinguishing effort. *No visible flames* logged at 11.25 (CIM 0307-11.25), and the *Danger over* announcement was given after consultation between the discipline leader and the response management at 12.56 (CIM 030722-12.56).

Weather data can provide important information for several reasons, including the basis for measures taken during the actual extinguishing work with regard to wind direction and precipitation, and the direction to be taken for safe evacuation of personnel if gas is out of control.

Exact weather data were not logged during the incident, and it has not been possible to acquire or confirm these afterwards.

8.2.1 Personnel overview and performance standard

The response management complied with the measures in item C, DHS 3 Fire/explosion in the WR-9007 emergency response plan for an HC fire in pressure equipment in the process and offsite areas.

According to the response management, an overview of personnel in the facility was acquired relatively early and within the performance requirement for Mongstad. This is 10 minutes for office buildings and 60 for offsite, including the jetty area (PR 14 and the emergency response analysis for Mongstad). The response log shows that the overview was regularly updated.

No individuals were reported to be missing or injured at any point during the incident or the response.

Response personnel involved were debriefed after the incident.

8.2.2 Collaboration with civil emergency services

No use was made of civil fire crews or appliances during the incident, but these were held in reserve at the main gate until shortly after the fire was declared extinguished. They departed Mongstad at about 11.42. (CIM log 030722-11.42).

Similarly, an ambulance was in reserve at the same location until the incident was more or less over. It departed Mongstad around 11.04 (CIM log 030722-11.04).

The police patrol cars and personnel departed Mongstad at roughly 09.40. (CIM log 030722-09.39).

8.2.3 Securing the fire site and evidence

Mongstad's procedures for securing the location after an incident – in this case, the fire site and evidence there – appear to be rather unclear and incomplete. Guidelines exist at an overall level in the response plan, without a detailed description of the procedure and of what is important when securing a site and evidence. This could

mean the loss or degradation of important evidence which complicates subsequent technical investigations.

The PSA team would raise the question of whether the material technology lab at Rotvoll could have provided better analyses if the whole flange had been cut off and sent for investigation. See section 7.2.1.

8.3 Normalisation

The main purpose of normalisation is to return the facility with associated personnel resources to a normal and secure operational condition.

Activities conducted before restarting the plant included:

- securing an overview of the extent of the damage
- fresh-water jetting of structures and equipment exposed to salt water during the incident response
- checking whether more insulated thermowells were to be found in the plant
- repairing damage (new thermowell, insulation and mantling, replacing defective cables and light fittings, and so forth)
- testing safety valves and flame detectors
- sandblasting and re-insulating piping.

Replica tests and hardness measurements were made with the steel in heat-exposed areas, along with a third-party assessment of the fitness for service test which concluded that pipe extensions and flanges were still usable.

Equinor also assessed the resistance of pipe insulation to the fire during insulation removal after the fire. See section 5.4. Bolts and the thermowell were sent to the company's material technology lab at Rotvoll for analysis.

8.4 Practice and exercises

Qualifying response personnel through practice and exercises is based primarily on the DHSAs identified in the facility's emergency response analyses.

Mongstad's emergency response organisation comes across as robust and competent. Based on its investigation, however, the PSA team has nevertheless seen that handling pressure relief for the relevant plant could have been quicker. In the team's view, this did not affect the outcome of the incident but does suggest that changes could be assessed to the training programme with regard to CCR functions. See also section 7.3.1.

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 Deficiencies in design and maintenance of the plant

Nonconformity

The thermowell was designed in such a way that provision could not be made for acceptable maintenance, nor was it maintained.

Grounds

The leak occurred as a result of weakenings in an insulated bolted flange which was not correctly designed (section 4.2).

The flange has not been followed up with regard to selecting the gasket type or retightening its bolts, nor subjected to a maintenance programme (section 4.3.2).

Requirements

Sections 6, litera i) and 58 of the technical and operational regulations on design of onshore facilities and on maintenance respectively

9.1.2 Deficiencies in the work process for surface protection

Nonconformity

The responsible party had not ensured that the work processes for surface protection met the HSE requirements.

Grounds

The job package for insulation work on the relevant pipe was incomplete and contained errors and deficiencies. The thermowell was not described in the basis for the package (section 4.4.2.1).

All thermowells on the piping between reactor and heaters were covered with insulation during the 2019 job. This does not accord with Equinor's established requirements, which were also in force in 2019.

TR1660 *Piping and equipment insulation*, addendum to TR 1660 for Mongstad, and Norsok R-004 *Isolering av rør og utstyr*. In TR 1660 version 6.01 (applicable in 2019) and version 6.02, section 2.5, on *Insulation of flanges and valves*:

SR-32826 - Flanges shall not be insulated if the system contains hydrocarbons above auto-ignition temperature.

SR-32827 - Flanges and valves shall only be insulated if defined on P&IDs and: Insulation is critical to maintain a certain operational temperature in the system. Insulation is required for safety and working environment.

Section 4.2 on general execution in Norsok R 004, 1 February 2009 edition, states:

Insulation abutting flanges on piping systems and equipment must be terminated in such a way that bolts can be loosened and removed without damaging the insulation. The minimum distance from a flange to the nearest insulated component must be equal to the bolt length plus 25 mm. Termination of weather protection must be watertight.

Quality assurance failed to identify that the thermowell flanges had been covered by insulation (section 4.4.2).

Requirements

Section 13, paragraph 1 of the management regulations on work processes

Section 53, paragraph 1 of the technical and operational regulations on risk information during work operations

9.1.3 Deficiencies in risk analysis

Nonconformity

The risk analysis failed to identify hazard and accident situations related to auto-ignitable media in fire zone 240.

Grounds

The overall risk analysis does not take account of the presence of auto-ignitable media in the process plants in fire zone 240, where the naphtha reactor is located (section 4.5).

Requirement

Section 17, paragraph 3, litera a) of the management regulations on risk analyses and emergency preparedness assessments

9.2 Improvement points

9.2.1 Depressurisation during an incident could be improved

Improvement point

The action taken for pressure relief might suggest that the person responsible had failed to ensure that necessary practice and exercises were conducted so that personnel were equipped at all times to handle operational disruptions as well as hazards and accidents in an effective manner.

Grounds

Emergency depressurisation was not run via the valve for this purpose during the incident, but through a gradual opening of a manual pressure control valve (section 7.3.1).

In the PSA team's view, securing faster pressure relief through the immediate full opening of the control valve, or by activating emergency depressurisation, would have reduced the energy in the fire more quickly.

The way pressure relief was implemented indicates inadequate practice with depressurisation scenarios. It emerged from interviews that simulator training had been postponed because of Covid restrictions.

Requirement

Section 52 of the technical and operational regulations on practice and exercises

9.2.2 Notification and reporting of hazards and accidents could be improved

Improvement point

The operator has not notified or reported earlier incidents involving jet flames from flanges in the A-1400 plant to the PSA.

Grounds

Information emerged during the investigation concerning incidents with ignition of hydrogen-rich gas in the same plant, which were not reported to the PSA (section 4.7).

Requirement

Section 29, paragraph 1, litera d) of the management regulations on notification and reporting of hazard and accident situations to the supervisory authorities

9.2.3 Learning from incidents could be improved

Improvement point

The responsible person appears to have failed to ensure continuous improvement in HSE, since recommendations by specialists on changing the gasket type for flanges in R-1400 were inadequately followed up.

Grounds

The gasket type for flanges in R-1400 has been discussed on several occasions as a result of actions after incidents, but the information has been inadequately handled by the specialist team at Mongstad (sections 4.6 and 5.2).

Several flange fires have occurred in 20-inch flanges between reactor column and heaters in recent years, and recommendations have been made by Equinor's specialists to change gaskets in this plant.

The investigation after the 2008 fire noted that gasket and bolt types should be assessed in the relevant line, and a recommendation followed later from the specialists on changing to a different gasket type.

Recommendations from the specialists were first implemented after a fire in 2016, and then only on 20-inch flanges – not thermowell flanges.

Requirement

Section 23, paragraphs 1 and 3 of the management regulations on continuous improvement

9.2.4 Securing technical findings and evidence could be improved

Improvement point

Routines for securing the site and technical evidence after an incident appear to be inadequate and little known among operating personnel.

Grounds

Equinor Mongstad lacks clear guidelines for securing the site and technical evidence after an undesirable incident. That could make subsequent technical investigations more challenging and difficult than if the way a site should be secured is clearly defined, along with what evidence should be secured and how. See section 8.2.

Requirement

Section 20, paragraph 2 of the management regulations on registration, review and investigation of hazard and accident situations

10 Barriers which have functioned

10.1 Fire detection

The fire was detected by detectors 30-AA-630 (R-1404 fire detector, grating 6) at 05.43.50 and 30-AA-636 (E-1401 fire detector) at 05.43.51. It was also observed and reported to the CCR by an operator out in the plant, and through CCTV monitoring by CCR operators in B3.

10.2 Heat off and shutdown

Action was taken in the CCR after the fire was detected. Alarm logs show that the CCR operators turned the heat off switch on the CAP at 05.44.42 (B3 heat off), and the emergency shutdown switch at 05.45.04.

10.3 Pressure relief – partial

Pressure relief via the emergency depressurisation valve was not utilised during the incident. CCR operators began to depressurise the system about three minutes after the fire began. This was not done via the CAP, but through the 14-PV-025 control valve on the control panel. Nor was this valve fully opened at once, but operated by stages over about 10 minutes. That could have extended the duration of the fire at the beginning of the incident.

10.4 Evacuation

The incident occurred early on a Sunday, close to the shift changeover, and few people were present in the plant. The evacuation alarm was activated quickly, and full control of personnel had been secured at an early stage.

10.5 Emergency response

The response organisation mustered as planned and had commenced active extinguishing with its own fire appliances about 15 minutes after the fire began. Fixed fire monitors were activated towards the fire site within a few minutes, but these had insufficient capacity or length of throw to reach the area affected. They were therefore used primarily for cooling nearby structures.

11 Other conditions

11.1 Logging weather data

Specific weather data were not logged for Mongstad in the emergency response log or other available logs during the incident. It has therefore been impossible to retrieve this information in a practical way during the investigation.

Unavailability of weather data can contribute to uncertainty about various conditions related to the emergency response to the incident.

12 Discussion of uncertainties

While it has not been possible to draw any final conclusion about the direct cause of the fire, material technology investigations indicate that the probable reason for the loss of tensioning in bolts was an increase in temperature because flange and bolts had been insulated.

13 Assessment of Equinor's investigation report

Equinor's investigation report is comprehensive, with detailed timelines and causal charts. The company has classified the incident in accordance with its own classification matrix, with actual severity levels of:

- red 1 (very substantial costs/losses for the facility/plant) for the *costs/loss* category because the A-1400 reformer plant was shut down for at least 18 days
- yellow 3 (threatens part of facility/plant) for the *leaks of oil/gas/flammable liquids* and *fire/explosion* categories
- green 5 (individual emission to the surroundings with negligible environmental impact) for *uncontrolled emission* category.

Equinor has assessed the potential severity level under slightly different circumstances to be possibly:

- red 1 for the *costs/losses* category
- red 2 for the *failure of safety functions and barriers* category, because WR9592, its own governing document on requirements for registering and classifying incidents, specifies that "naked flames, sparks or other certain ignition sources in hazardous areas must be classified as 'threatens large areas of the facility or plant'", which corresponds to a severity level of possible red 2
- yellow 3 for the *leaks of oil/gas/flammable liquids* and *fire/explosion* categories, and green 5 for *environmental impact*.

The company has opted not to classify personal injury because of the low probability for personnel exposure.

Its assessment of causes coincides largely with the PSA team's, concluding that one of the most important underlying causes is loss of tension in the flange bolts over time so that the gasket has failed to keep flammable gas at a high temperature inside the pipe. The reason for this points in turn towards the ISS job in RS2019. Equinor also finds that risk management at Mongstad has been inadequate after repeated flange fires, because the facility has concentrated on impact-reducing measures, such as the installation of steam rings, rather than technical measures for reducing the number of such incidents.

The PSA team notes that the technical information on the thermowell and flange is more detailed in the Equinor report than its own investigation has been able to acquire. That is because access to one's own information registry provides an advantage in relation to information, regardless of the amount requested by the PSA. The Equinor investigation therefore goes into greater detail in the gasket and bolt material discussion than the PSA has done, which is a strength for the company's report.

Barrier assessments also coincide, but Equinor has not noted that pressure relief could have progressed more rapidly.

The company's recommendations for lessons learnt call for immediately:

- identifying if the plant contains other fully insulated flanges with auto-ignitable media
- informing other land plants in Equinor about the incident.

Where longer-term action is concerned, the investigation recommends measures related to:

- securing control of flange fires
- ensuring the right classification of future flange fires, including small ones
- avoiding inaccurate information about auto-ignitable media in insulation jobs
- contributing to a corresponding quality of emergency response at other plants.

14 Appendices

APPENDIX A DOCUMENT LIST

The following documents have been drawn on in the investigation.

1. Varsel om uønsket hendelse brann - Equinor Mongstad - Brann i naftaanlegg 03072022
2. OMC04 - Mongstad (MMP OPL MON) - Organisasjon, ledelse og styring versjon 4.02 datert 1.6.2021
3. Organisasjonskart-Equinor-Mongstad 15.06.2022
4. OMC04 - Roller og ansvar teknisk MON - lokalt tillegg til OMC04 TPO Mennesker og ledelse (PL), Organisasjon, styring og kontroll (OMC), OMC04, 1.02, published 03/04/2019
5. Presentasjon - Oppstartsmøte Ptil, Gransking Brann A-1400 05.-06.07.22
6. Presentasjon om beredskap gitt i oppstartsmøtet
7. Sikkerhetsrapport Equinor Mongstad, datert 20.4.2022
8. TR2237 - Substitution to TR2237 ver. 3 - Safety Strategy and performance standards for safety system and barriers at Mongstad, versjon 3.01 datert 8.5.2019
9. TRA Hovedrapport SM-0000-S-RE-183 revisjon C, datert 30.8.2021
10. Områderisikokart – vedlegg P til totalrisikoanalyse – Equinor Mongstad rapport SM-0000-S-RE-183-47 rev c, datert 14.9.2021
11. TIMP-oppsummering juni 2022
12. TIMP-presentasjon gitt av Equinor 31.8.2022
13. Anleggsevaluering A-1400 juni 22
14. Oversikt over synergi-registrerte lekkasjer siste 10 år
15. Synergi saksrapporter for utvalgte hendelser med flensbranner i prosessanlegg
16. Oversikt olje/gass lekkasje Mongstad 2007-2022 kategorisert på faktisk alvorlighetsgrad
17. A-1400 Reformer 2, system- og operasjonsdokument, SO01250, Final ver. 3, publisert 2019-03-12
18. OP-14-01, Oppstart av A-1300/1400 versjon 4 datert 20.5.2021
19. OP-14-02, Nedkjøring av A-1300/1400 versjon 4 datert 10.7.2019
20. OP-14-03, Nødsituasjoner A-1300/1400 versjon 4 datert 10.5.2019
21. OP-14-05, Drift av sikkerhetssystemer A-1400, versjon 5 datert 20.2.2020
22. Safety plot unit 1300 og 1400 SM-0000-S-P-044-01-A
23. WR9007 - Beredskapsplan MMP OPL Mongstad, versjon 7.01 16/12/2020
24. WR9007 - Beredskapsplan MMP OPL Mongstad, Beredskap 1. linje versjon 7.02 datert 16.12.2020
25. WR9007 - Beredskapsplan MMP OPL Mongstad, Beredskap IMT 2. linje, versjon 5.01 datert 16.12.2020
26. WR1920 Beredskap i MMP OPL Ytelseskrav, rev 3 datert 7.6.2021
27. Beskrivelse av beredskapsroller B- og C-skift 3.7.22
28. Logg fra Førstemøte ERT
29. Beredskapslogg ERT_IMT
30. Situasjonsskart og aksjonsliste ERT
31. MT_-_Incident_Brief-04.07.2022

32. ERT_-_Personnel_status-04.07.2022
33. Fokus og aksjoner 2. linje under hendelsen
34. IMT_-_Incident_Brief-05.07.2022, 2. linje incident brief
35. Fokus IMT – hendelse 2
36. Aksjonslogg hendelse 2
37. Equinor Mongstad skiftplan 2022
38. Operation log report dagskift 2.7.22
39. Skiftlogg B3 27.6.-3.7.2022
40. B3/MHPP Døgninstruks 1.7.22-4.7.2022
41. Rundelister B3, for kontrollpunkter for uteoperatørens runder i anlegget
42. Oversikt over arkiverte arbeidstillatelser 13-1400 26-06--04-07-2022
43. Oversikt over aktiv-deaktiv-godkjent-utløpt AT 13-1400 26-6--04-07-2022
44. Utskrift av liste fra SAP over notifikasjoner A-1400 siste to år
45. Oversikt over pågående modifikasjoner i A-1400 datert 7.5.2022
46. M1 A-1400 pre-DG0, oversikt over planlagte modifikasjoner i A-1400
47. M1 45580553 Langtekst, prosjektforslag om bytte/forbedring av branndetektorer i A1400.
48. Vedlikeholdshistorikk A-1400, PM01 og PM02 på H-1404, R-1404, PG-14-0204
49. Pakningsinformasjon fra SAP AO23633890
50. Trendbilder fra kontrollsystemet for B3 for diverse instrumenter/prosessparametre
51. Alarmliste, utskrift fra prosesskontrollsystemet i tidsrommet 22.6.-3.7.2022
52. Bilder av brannområde og brannpåvirkning
53. Bilder fra paneler i kontrollrommet på Mongstad
54. SAP-utskrift av arbeidsordre 25466670 12M kontroll av brannmonitor, sone 240 F, med arbeidsbeskrivelse
55. Plot som viser plassering av brann- og gassdetektorer i anlegg 1300 og 1400
56. Brann A-1400 forbruk av brannvann per enhet og plassering av brannbiler
57. E004-SM-1400-P-C-001- 01 rev H CAUSE AND EFFECT MATRIX
58. E004-SM-1400-P-C-001- 02 rev B CAUSE AND EFFECT MATRIX
59. E004-SM-1300-P-C-001- 01 rev I CAUSE AND EFFECT MATRIX
60. E004-SM-1400-P-C-002- 01 rev A UNIT 1400 RECOVERY PLUS SYSTEM TRIP SYSTEM CAUSE AND EFFECT CHART
61. A-1400-J-P-502-01 rev C Fire and gas field equipment layout cat. reformer 2, unit 1400 fire zone 240
62. A-1400-j-p-501-01 rev D Fire and gas field equipment layout cat. reformer 2, unit 1400 fire zone 240
63. A-1400-j-p-510-01 rev B Fire and gas field equipment layout compressor house fire zone 240
64. A-1300-j-p-501-01 rev A Fire and gas field equipment layout naphta hydrotreater 2, unit 1300 fire zone 240
65. A-1400-P-E-001-01 rev D10 Engineering flow diagram - catalytic reformer no 2 Unit 1400 reactor section
66. A-1400-P-E-002-01 rev E Engineering Flow Diagram Catalytic Reformer 2 Unit 1400 Charge and Interheater Section
67. A-1400-P-P-001-01 rev F Process Flow Diagram Catalytic Reformer 1400
68. A-1400-P-E-004-01 rev P Engineering Flow Diagram Catalytic Reformer no.2, unit 1400 Separator & Recycle Gas Compressor Section

69. A-1400-P-E-009-01 rev P Engineering flow diagram - catalytic reformer no 2 Unit 1400 convection section
70. Oversikt over komponenter i mediet på lekkasjepunktet. Anlegg A-1400-P-P-001
71. MMP PM MON ISSE – OFP prosjektet, beskrivelse gitt oktober 2022
72. TR1660 Piping and equipment insulation versjon 6.01, gyldig fra 08.06.2017 til 10.06.2019
73. TR1660 Piping and equipment insulation versjon 6.02 datert 11.6.2019
74. TR1660 - Addendum to TR1660 ver. 6, Mongstad Piping and Equipment Insulation, rev 1.01 datert 9.5.2019
75. TR1987 Preventive Activities for Static Process Equipment and Load-Bearing Structures rev 6.01 datert 05/03/2019
76. Addendum to TR1987 ver 6 Mongstad, Forebyggende aktiviteter for statisk prosessutstyr og bærekonstruksjoner datert versjon 2 datert 08/09/2020
77. Prosjekter på anlegg i drift – utskrift av ARIS-prosess 1.9.2022
78. Jobbpakke 21A15, A-1400 - Line List Rev 1
79. Jobbpakke overflate 24247040-20-PG-14-0101-H ISO-Jobbpakke
80. Jobbpakke overflate 24247041-20-PG-14-0102-H ISO-Jobbpakke
81. Jobbpakke overflate 24247042-20-PG-14-0103-H ISO-Jobbpakke
82. Jobbpakke overflate 24247043-24-PG-14-0104-H ISO-Jobbpakke
83. Jobbpakke overflate 24247047-20-PG-14-0201-H ISO-Jobbpakke
84. Jobbpakke overflate 24247048-20-PG-14-0202-H ISO-Jobbpakke
85. Jobbpakke overflate 24247049-20-PG-14-0203-H ISO-Jobbpakke
86. Jobbpakke overflate 24247050-20-PG-14-0204-H ISO-Jobbpakke
87. Jobbpakke overflate 24247051-20-PG-14-0301-H ISO-Jobbpakke
88. 24247051 - ISO Ferdigsertifikat
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93. 24247048 - ISO Ferdigsertifikat
94. 24247042 - ISO Ferdigsertifikat
95. 24247050 - ISO Ferdigsertifikat
96. 24247040 - ISO Ferdigsertifikat
97. Service Advisory skriv datert 28.11.2016 angående Platforming-Reactor External Nozzle Rev.1 fra Honeywell UOP
98. Intern e-post i Equinor angående pakningsvalg på R-1401-4
99. Karakterisering av bolter og pakninger fra Mongstad ref. Synergi #2052808, presentasjon gitt av avdeling for material og korrosjonsteknologi (MCT) i Trondheim
100. Møtereferat fra møte om materialundersøkelse av pakning og bolter, Rotvoll (Teams) 25.8.2022
101. E-post med tilbakemelding på funksjon av ESD-ventiler under hendelsen
102. Synergi 2052808 Brann i A-1400 3.7.2022
103. Presentasjon Fire on 20- PG-14-0204 (H-1404), beskrivelse av virkning av varmeisolasjon
104. OFP -prosjektet, presentasjon til Ptil i forbindelse med gransking av brannen i A-1400

105. Pressura-rapport Visual Vessel Design by Hexagon PPM,Ver:20.1 Operator : Rev.:A, 1444-100 - 2IN FLANGE 300 LB_3
106. DnV-rapport Mongstad – Material exposed to fire, Field metallurgical examination and testing Report No.: 2022-5268, Rev. 0 Document No.: 1671427 Date: 2022-07-14
107. Arbeidsordre 25969484 og 25955538 for demontering av termolommer etter brannen
108. Mongstad lekkasjeratevurdering, RITM 2593261, v1 19.9.2022
109. Materialtekniske undersøkelser av deler involvert i brann på Mongstad – MAT-2022082 rev 0
110. Granskingsrapport COA ACC Intern ulykkesgransking Brann i A-1400 anlegget på Mongstad 03.07.2022, rapport nr A 2022-05 MMP L2 datert 20.7.2022

APPENDIX B - OVERVIEW OF PERSONNEL INTERVIEWED