PETROLEUMSTILSYNET

Investigation report

Report	
Report title Report of the investigation of gas leaks on Statfjord B on 23 May 2022 - revised	Activity number 001037065

Security grading

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

Involved	
Team T-1	Approved by/date Kjell Marius Auflem/14 February 2023
Members of the investigation team [redacted]	Investigation leader [redacted]

Contents

1 Summary

Two gas leaks occurred on 23 May 2022 on the Statfjord B (SFB) facility while running up after a turnaround. They derived from holes in blowdown lines in the M10T area of the upper north-eastern corner of the Equinor-operated facility. The Petroleum Safety Authority Norway (PSA) decided to investigate this incident on 24 May 2022.

Initial rates from the two leaks are estimated at 0.52 and 0.57 kilograms per second respectively. In different circumstances, the simultaneous gas leaks on SFB from holes in two separate blowdown lines for export-gas metering stations could have had more serious consequences and lives might have been lost.

The direct cause of the hydrocarbon (HC) leaks was external corrosion and consequent loss of integrity in two carbon-steel (CS) blowdown lines. These were used during startup after the turnaround on the facility, and had probably corroded through before the incident.

Underlying causes are complex, with failure to carry out maintenance as a crucial factor. The investigation indicates a number of reasons why the necessary maintenance was not done.

The investigation shows that this incident could have been avoided if Equinor had established a robust system for following up and maintaining control of the integrity for the blowdown lines.

Seven nonconformities have been identified, related to:

- inadequate management of HSE
- inadequate knowledge of weaknesses in barriers and barrier elements
- inadequate marking of equipment
- inadequate maintenance
- inadequate maintenance programme
- lack of maintenance criteria
- inadequate maintenance efficiency.

In addition, seven improvement points have been identified, related to:

- improve assessment of the HSE consequences of manning changes on SFB
- improve assessment of the HSE consequences of manning changes in the onshore organisation for SFB
- improve efforts to ensure competence (training backlogs)
- failure to activate deluge
- improve plans for running up the facility after a turnaround
- improve evacuation measures
- improve efforts to ensure appropriate behaviour.

2 Background information

Equinor has implemented a number of cost-reduction and efficiency-enhancement processes in recent years, and established a field life extension (FLX) business area on 1 April 2020 to run its late-life facilities, which include SFB. The maintenance and technical integrity unit in the FLX organisation has overall responsibility for such work on the Statfjord field.

Through FLX, Equinor has worked to reduce maintenance costs by

- increasing robustness through investment
- customising maintenance work
- digitalising and making greater use of data in maintenance work
- enhancing the efficiency of the maintenance programme and converting experience from maintenance into continuous improvements
- strengthening collaboration with the suppliers
- benchmarking maintenance costs against those in other companies and facilities.

2.1 Description of facility and organisation

Developed with the A, B and C production facilities, the Statfjord field straddles the boundary between the Norwegian and UK continental shelves in the Tampen area of the North Sea. SFB is an integrated drilling, production and quarters platform standing in 145 metres of water at the southern end of the field. The plan for development and operation (PDO) for Statfjord was approved in 1976. SFB came on stream on 5 November 1982.

Image 1 SFB. (Source: Equinor)

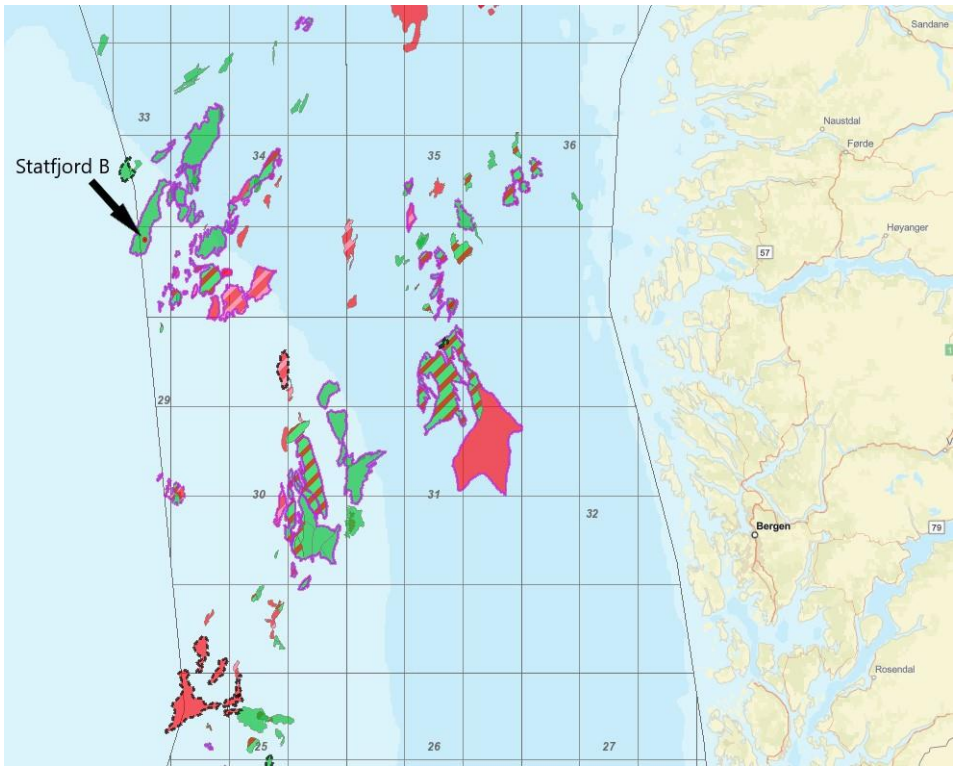

Figure 1 Location of SFB. (Source: Norwegian Petroleum Directorate)

The organisation of FLX is presented in the figure below.

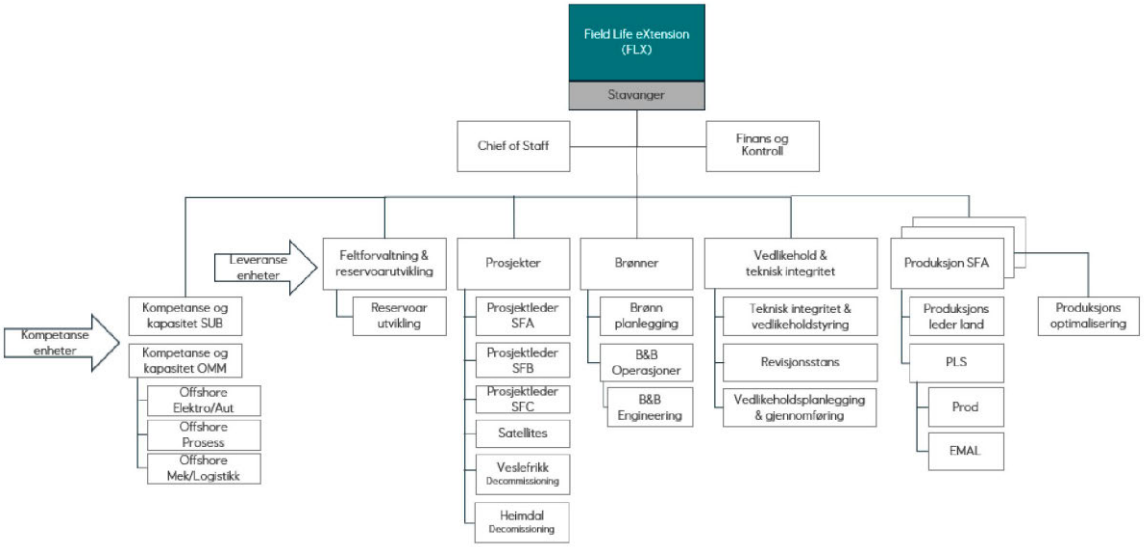

Figure 2 Organisation of FLX. (Source: Equinor)

2.2 Position before the incident

The gas leaks in the process plant occurred in the M10T area at a time when SFB was in a running-up phase after a planned turnaround.

Originally planned for the autumn of 2021, the turnaround was postponed in part because of manning restrictions on SFB imposed by the coronavirus (Covid-19) pandemic. Running down the plant on the facility began on 12 March 2022.

Equinor's Solv surface treatment programme and its GVI programmes had identified over several years that the surface coating on the blowdown lines was degraded and required maintenance work. In its follow-up of the condition of the relevant lines, Equinor had opted for the GVI method rather more resource-intensive CVI, which requires much greater preparation for accessing all parts of the object being inspected.

During the turnaround, repairs were made to identified corrosion on valves and the blowdown line for the Statpipe metering station (the Statpipe pipeline) in M10T. After the work, local pressure testing was performed on the repaired area. The repair did not embrace the location where a leak occurred in the Statpipe line.

Running up after the turnaround was due to start on 4-6 April. A leak test in connection with the startup found leakage problems, and the operation was thereby postponed until 22 May. This delay was extended by a further day to permit rectifications to a pack box valve leak.

Two out of three shifts of production and control room operators had participated in a shutdown seminar as part of the turnaround preparations, and plans initially included stationing an additional person in the CCR during running of the SFB plant down and up. Because of the startup delay, only two operators were present in the CCR. This was to be compensated for by taking extra time during the running up, and by deploying an additional specialist process operator out in the plant. Equinor had not prepared detailed plans for the startup, but relied on a generic procedure.

M10T is the top of the M10 module at the north-eastern corner of the facility, and has natural ventilation. The wind speed at the time of the incident was 15 knots from the south-east (170 degrees).

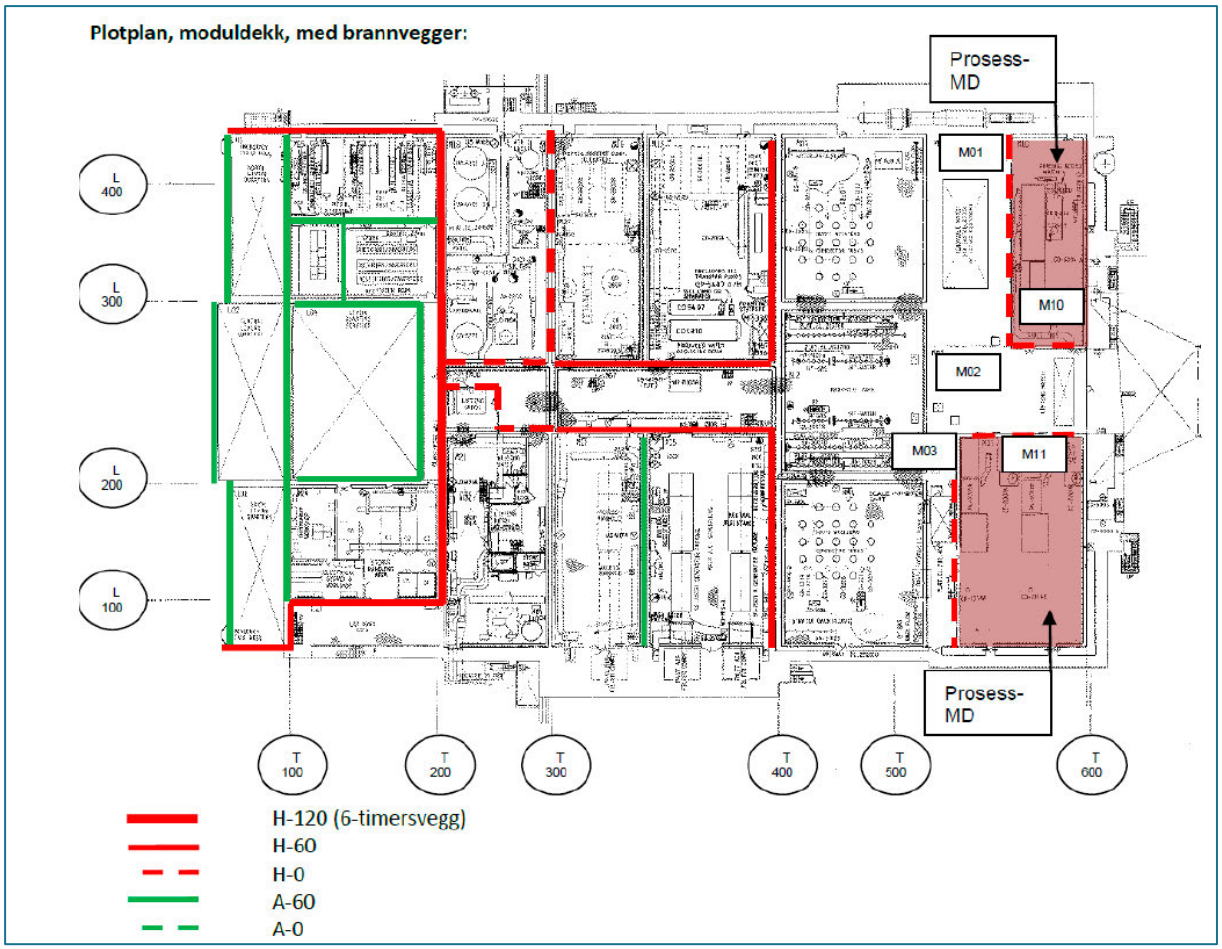

Figure 3 Module overview from the SFB safety strategy. (Source: Equinor)

2.3 Abbreviations

AMU	Working environment committee
ART	Alarm response team
CAP	Critical action panel
CCR	Central control room
CM	Corrective maintenance
CS	Carbon steel
CVI	Close visual inspection
DSHA	Defined situation of hazards and accidents
EPN	Exploration and Production Norway
ESD	Emergency shutdown
ESD2	Emergency shutdown level 2
FLX	Field lifetime extension
GA	General alarm
GVI	General visual inspection
HC	Hydrocarbon
HSE	Health, safety and the environment
LEL	Lower explosion limit
LL	Late life
MIS	Performance management in Equinor
NCS	Norwegian continental shelf
OMC	Organisation, management and control
PDC	Primary discipline contact
PDO	Plan for development and operation
PM	Preventive maintenance
POB	Personnel on board
PS	Performance standard
PSA	Petroleum Safety Authority Norway
RBI	Risk-based inspection
SFB	Statfjord B
Solv	Statoil surface maintenance
Timp	Technical integrity management programme
TR	Technical requirement
TRA	Total risk analysis
TTS	Technical condition safety
VI	Visual inspection
WO	Work order

Table 1 Abbreviations

3 The PSA investigation

The purpose of the investigation has been to identify the direct and underlying causes of the gas leaks on SFB, draw lessons from the incident and contribute to preventing a repetition of such events.

3.1 Mandate for and composition of the investigation team

The mandate was tailored to the circumstances and covered the following points.

a. *Clarify the incident's scope and course of events (with the aid of a systematic review which typically describes timelines 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. *Identify nonconformities and improvement points related to the regulations (and internal requirements).*
e. *Discuss and describe possible uncertainties/unclear points.*
f. *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).*
g. *Assess the player's own investigation report.*
h. *Prepare a report and a covering letter (possibly with proposals for the use of reactions) in according with the template.*
i. *Recommend – and normally contribute to – further follow-up.*

In addition, the investigation team was to do the following.

1. *Assess possible deficiencies related to management preconditions for technical and operational integrity.*
2. *Assess managerial aspects across other relevant incidents in Equinor with similar identified conditions in the causal picture.*

Composition of the investigation team

Name	Title	Discipline
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

Table 2 Composition of the PSA investigation team.

3.2 Investigation of the incident on SFB

The PSA decided on 24 May 2022 to investigate the gas leaks which had occurred on SFB the day before.

The purpose of the investigation has been to establish the direct and underlying causes of the incident and to identify important lessons learnt for SFB in particular and for the industry in general.

Work by the PSA team has been based on inspections on the facility, verifications in management systems, interviews with personnel on land and offshore, and reviews of relevant documents.

Put briefly, the process has involved:

- notice of investigation sent to Equinor on 25 May 2022
- inspections, interviews and verifications on SFB from 30 May to 1 June 2022
- interviews and verifications on land in weeks 23-25 2022
- interviews and verifications on land in weeks 33-34 2022
- meeting on leak calculations and the potential of the incident in week 44 2022
- PSA's internal work on preparing the report.

4 Course of events

The incident is timed at 17.27 on 23 May 2022, when leaks in the corroded blowdown lines for the metering stations on the M10T area were picked up by line-of-sight gas detectors. Since the investigation shows that surface corrosion had developed over time, determining when it began to impair the pipes is difficult.

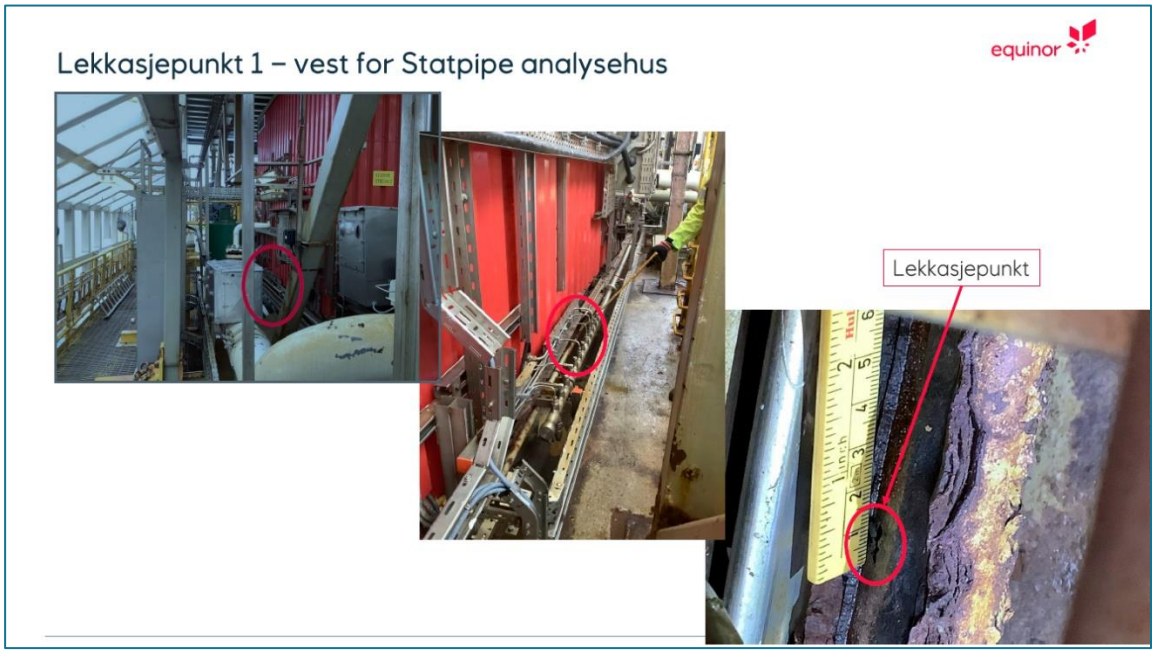

Image 2 Leak point 1, Statpipe metering station. SFB. (Source: Equinor)

Image 2 Leak point 1, Statpipe metering station. SFB. (Source: taken during PSA investigation)

Image 3 Leak point 2, UK metering station. SFB. (Source: Equinor))

Image 4 Leak point 2, UK metering station. SFB. (Source: taken during PSA investigation)

4.1 Relevant conditions

The incident comprises gas leaks from holes in two one-inch blowdown lines for the metering stations on M10T. In the table below, the PSA team has described the chronology for conditions which it believes have been relevant for this incident.

Date/time	What	Comment/assessment
1 Mar 1984	Installation of blowdown lines 01"-VF-33001-MF3 and 01"-VF-33601-MF3 (Statpipe and UK metering stations respectively)	ISO drawing with revision date "Issued for construction" on 1 March 1984.
	Surface treatment of blowdown lines 01"-VF-33001-MF3 and 01"-VF-33601-MF3	Equinor has been unable to confirm when surface treatment was carried out on the blowdown lines since they were installed.
27 Oct 2008	Classification of blowdown lines 01"-VF-33001-MF3 and 01"-VF-33601-MF3	Containment fail consequence is assessed as "extremely high", while function fail consequence-HSE is set as "low". Comment by the PSA team: These lines are shared for each metering circuit. They were inaccurately specified as permanently removed from service in SAP and the Kamfer classification tool.
2008	Solv surface maintenance programme 2008	The 01"-VF-33001-MF3 and 01"-VF-33601-MF3 blowdown lines were reported as condition level 1 (best, 0-3 per cent of surface with degraded protection) on a scale of 1 to 6 where the minimum permitted condition for these pipes is 2 and 6 is the poorest condition.
2012	GVI M10 module	In 2010-2011, the PM text included both the structure and static process equipment. That was changed from 2012 to cover only the latter, with the structure placed in a separate GVI programme.
15 Jul 2013	GVI M10 module	Frequency in the GVI programme for static process equipment and piping in M10 changed from 12 to 36 months.
2014	Solv surface maintenance programme 2014	Pipe 01"-VF-33601-MF3 is reported to have a level 5 condition (40-60% of surface with degraded protection). Data for 01"-VF-33001-MF3 are not received. Equinor informs the PSA team by e-mail

		that such a development in condition is not normal for a six-seven year period, and that the level 1 condition reported in 2008 could have been wrong. Comment from the PSA team: No information is available that action was taken on the assessments in the 2014 Solv review. The same condition was reported in 2018.
5 Jun 2015	Report on updating of RBI and inspection programme for piping on SFB	Recommendations from chapter 5 in the report: "Experience indicates that external corrosion could contribute to a number of piping leaks, depending on the plant's age. External corrosion is not included in the scope of work, but should also receive an RBI evaluation to secure a more holistic risk picture of the plant." Interviews by the PSA team revealed that no RBI was conducted for external corrosion.
2 Sep 2013 and 13 Dec 2016	GVI M10 module	Equinor writes in an e-mail to the PSA team that it assumes GVI inspection of the 01"-VF-33001-and 01"-VF-33601-MF3 blowdown pipes was conducted with an OK result. No documentation of the inspection done (M3 report) is available. The prevailing practice is negative reporting.
31 Jan 2018	Solv study report for job package 4A12 M10 external upper weather deck	The report shows level 5 condition for 1''-VF-33601, with level 2 the minimum permitted. "All conditions in the Solv database are averages for a tag. This means parts of a tag could have worse or better condition. Solv therefore does not replace the need for inspection programmes (PM)." Comment from the PSA team: It is assumed that these assessments from the Solv review were included as part of the

		basis for the surface coating programme in 2020.
19 Sep 2018	Proposal to update GVI module programmes	M5 notification 45405822 established for updating GVI module programmes.
9 Oct 2018	Updating of GVI module programmes	Change in title for inspection programme in M10 from 36M-FV-INSP-GVI, Modul M10 to 24M-FV-INSP-GVI, Modul M10. The maintenance plan frequency was first altered from 36 to 24 months on 7 December 2021, see the item below.
4 Jul 2019	Job package for surface maintenance in M10, external upper weather deck (Solv)	The 01"-VF-33601-MF3 blowdown pipe was placed in condition class 6 - the two job-package images covering detail F1Z do not appear to show where the leak occurred - notifications 45805325 and 46745700 are referred to under detail F1Z. Comment from the PSA team: Since notification 45805325 was established on 29 July 2019, it is assumed that the job package was updated after its establishment date.
29 Jul 2019	GVI M10 module	Work order for 36-monthly GVI at all levels in M10 module was implemented.
29 Jul 2019	Notification 45805325 for 01"-VF-33601-MF3 blowdown line established in connection with 36-month GVI	"Marked locations on attached ISO are recommended for surface treatment." Comment from the PSA team: From the marked locations on the attached ISO, it appears that the leak point was covered by the finding described in this notification. It contained images of several locations with substantial corrosion, but not one of the leak point on the 01"-VF-33601-MF3 blowdown line.
12 Aug 2019	Notification 45805325 for 01"-VF-33601-MF3 blowdown line	Recommendation after VI to coat the pipe within two years.
13 Aug 2019	Notification 45805325 for 01"-VF-33601-MF3 blowdown line	The PDC for static mechanical equipment on SFB recommends removing corrosion to reveal its scope, and replacing the piping if its wall thickness proves insufficient.

		Comment from the PSA team: Residual thickness measures do not appear to have been done prior to the incident.
28 Aug 2019	Notification 45805325 for 01"-VF-33601-MF3 blowdown line	Assessment at finding meeting: "Pipes must be surface-treated within no more than a year".
20 Sep 2019	Notification 45805325 for 01"-VF-33601-MF3 blowdown line	Plans call for the notification to be executed in the 2020 surface programme, with a proposal for its required end to be postponed until 31 December 2020 – in other words, not in line with the finding meeting recommendation of 28 August 2019. The postponement decision was transferred to the finding meeting. Comment from the PSA team: The documentation provided does not reveal whether assessments from the finding meeting were incorporated when the required end was moved. Interviews and verifications in the management system appear to show that the notification was not implemented by the deadline of 31 December 2020. The team has been told that the coating programme was postponed from 2020 to 2021 because of the coronavirus pandemic, but the grounds for this were not found during verifications in the management system.
9 Dec 2019	Notification 45805325 for 01"-VF-33601-MF3 blowdown line	The notification was added to the coating programme for 2020 (WO 24996666), ref action log for the notification.
26 Mar 2020	Risk register when FLX established	Risk factor: "Reduced maintenance programme for safety-critical equipment. Threat of incidents and production shutdowns because of inadequate maintenance". Major accident risk assessed as high with low uncertainty.

		Proposed actions: "Ensure coordination with extended-life programme. Ensure a QA routine for changes by involving the specialist ladder." Deadline 1 April 2020/closed.
26 Mar 2020	Risk register when FLX established	Risk factor: "Dimensioning: reduction of onshore manning" and risk description: "Threat of major accident from errors because of low manning". Major accident risk assessed as low with high uncertainty. Proposed actions: "Establish OMC with description of roles and responsibilities plus associated interface for LL." Deadline 1 April 2020/closed.
26 Mar 2020	Risk register when FLX established	Risk factor "Dimensioning: reduction of onshore manning". Major accident risk assessed as high with high uncertainty. Proposed actions: "Phase 2: plan and execute process for local assessment of adequate competence requirements." Deadline 1 April 2020/closed.
1 Apr 2020	FLX business area established	SFB becomes part of this business area.
11 May 2020	Two identified risks in MIS assessed as relevant to the incident.	1) "SFB PS1 leak caused by degraded surface condition." "Start date 20 April 2020." "Risk description: Big gap between condition and requirement for surface treatment. Even with implementation of the approved surface programme, the average condition of the plant will degrade. Several areas have a condition below the acceptance criteria. Expected

		development: Condition will gradually worsen for all systems in CS. Increasing risk of leaks owing to surface corrosion." "Risk factors: - plant age - much CS - capacity lacking for planning and execution." "Impact description: Lack of execution of surface rectification could lead to leaks." Related measures, both with a due date of 2037: "- follow up execution of surface programme - ensure risk assessment of annual surface programme." 2) «SFB PS1 threat of ignited HC leak as a result of corrosion." "Risk description: Threat of ignited HC leak as a result of corrosion in tanks and piping. The Statfjord installations are elderly and include much original CS and equipment. An increasing threat of leaks is posed by both internal and external corrosion. Much CM is needed on safety-critical static mechanical equipment. This could be an indication that the technical condition of the equipment is poor." "Risk factors: - Age of the facility - Much CS" "Impact description: It is estimated that an ignited leak could result in one-three fatalities and extensive material damage." Related measures, all with a due date of 2099:

		"- Ensure correct handling of findings - Ensure that inspection programme for HC systems is executed as planned - Include proposals for enhancing robustness of HC systems in the technical producing life plan - Highlight specific PS1 weaknesses and ensure communication of their risk - Ensure execution of CM related to rectifying corrosion found in HC systems by the required end." Comment from the PSA team: The measures emphasise the importance of a good and robust process for detecting and correcting corrosion, but they do not add extra actions which could result in improvements to and/or enhancing robustness of the process.
24 Jun 2020	Notification 46220504 for 01"-VF-33001-MF3 blowdown line established in connection with the inspection programme (WO 25085851)	"Heavy external corrosion of pipes and valves" from inspection (radiography) of various M10T lines. Reporter recommends rectification in the 2021 turnaround, later postponed to the first half of 2022." Comment from the PSA team: Given the marked areas on the attached ISO, the leak point does not appear to have been covered by this notification.
26 Jun 2020	Notification 46220504 for 01"-VF-33001-MF3 blowdown line	T_{min3} ($T_{målt}$=2.3 mm, T_{min3}=2.4 mm) is described as exceeded, and residual thickness of the pipe determines the rectification method. Comment from the PSA team: The measured thickness does not relate to the leak point on the Statpipe line.
27 Jul 2020	Notification 45233509 with recommendation to establish surface treatment	Notification established 24 April 2018. "Given the amount of external corrosion, establishing an external programme of visual inspection (VI/GVI/CVI) is recommended to map and keep external

		corrosion under control." Comment 27 July 2020: "Interval change implemented. Tag which has/has had external corrosion entered in the GVI for the flare system."
13 Jan 2021	Notification 46220504 for 01"-VF-33001-MF3 blowdown line	FLX technical safety dept: "We must replace parts of this one-inch pipe run in RS21 because of corrosion."
29 Jan 2021	Notification 45805325 for 01"-VF-33601-MF3 blowdown line	The notification was closed when closing the 2020 coating programme (WO 24996666) without rectifying the finding. Comment from the PSA team: This was acknowledged in interviews to be an error.
15 Feb 2021	Notification 46220504 for 01"-VF-33001-MF3 blowdown line	The technical integrity department "recommends that operations/ mechanical and inspection look at the totality here and recommend a forward-looking replacement scope – ie, are there other parts of VF-33001, from the metering station all the way to the flare, which should be replaced at the same time now that this can be done with cold inspection solutions." Comment from the PSA team: Interviews and verifications have shown that only part of the line was replaced in the 2022 turnaround (RS22). The leak point in the Statpipe line was not assessed and included in this replacement.
11 Jun 2021	Notification 46220504 for 01"-VF-33001-MF3 blowdown line	Proposals for new deadline 15 May 2022. "Consequences/risk: Small, at present the one Statpipe run is shut down and will not be critical in terms of leaks." Comment from the PSA team: Interviews and drawings show that this assessment was wrong, since the blowdown line could be used for pressure equalisation regardless of whether one or two meter

		runs were available.
15 Jun 2021	Notification 46220504 for 01"-VF-33001-MF3 blowdown line	The technical integrity department supported postponing the deadline.
31 Aug 2021	GVI M10 module (WO 25356787)	Description WO 25356787: "Attention to good reporting. Get in touch if anything is unclear. Read through the list below of what is to be looked at and reported after the GVI. See M3 44962837 for an example of OK reporting. Divide the reporting into three parts – one each for the M10/M10M/M10T areas."
31 Aug 2021	Report (M3 notification 46745491) after GVI M10 module (WO 25356787)	"Executed" on 31 August 2021 and "QA in accordance with Aris R-11549" reported "OK" on 7 December 2021. Some of the images in the appendices to the report (M3 notification 46745491) refer to line number 01"-VF-33601-MF3 and that a notification, on the line shown in the image, was established in 2019.  *Image 5 Appendix to M3 notification 46745491. (Source: Equinor)* Comment from the PSA team: Interviews revealed that this was a misunderstanding and that the images depict line 01"-VF-33001-MF3. This corrosion finding was thereby not reported.
7 Dec 2021	GVI M10 module	The frequency of executing GVI was changed for maintenance item 10196823 from 36 to 24 months.
7 Dec 2021	GVI M10 module	M3 report associated with WO 25356787 for GVI in M10 module. M10T: "A quantity of surface corrosion is

		found on piping and structures, many of the pipes are inoperative." Comment from the PSA team: Inoperative pipes can give rise to misunderstandings in relation to GVI of piping systems.
14 Dec 2021	Notification 45805325 for 01"-VF-33601-MF3 blowdown line	"A new GVI was executed on 14 December 2021. No visible development, but should be given surface treatment to avoid development." The notification was reopened. Comment from the PSA team: Holes were probably present in the UK line even before the incident. In the team's view, reporting after the GVI shows that this method was insufficiently detailed to follow up corrosion on the pipes. The report identifies an area with leaks on the ISO drawing, but no images of this area are attached.
16 Dec 2021	Notification 45805325 for 01"-VF-33601-MF3 blowdown line	The action log for the notification shows that its required end was postponed from 23 July 2020 to 23 December 2021.
20 Dec 2021	Notification 45805325 for 01"-VF-33601-MF3 blowdown line	"Recommend that this notification is executed on a separate CM WO since it has been waiting a long time. See text from inspection, so that the CM job is executed during Q1 2022."
23 Dec 2021	Notification 45805325 for 01"-VF-33601-MF3 blowdown line	The action log for the notification shows that its required end was postponed from 23 December 2021 to 23 March 2022.
22 Mar 2022	Notification 45805325 for 01"-VF-33601-MF3 blowdown line	The notification was closed again (the description is dated 16 March 2022) without the finding being rectified. The required end was 23 May 2022.
12 Mar-23 May 2022	SFB turnaround 2022	See section 2.2. The turnaround was originally scheduled for the autumn of 2021, but was postponed. Running up after the turnaround was due to start on 4-6 April, but was postponed to 23 May.
25 Mar 2022	Notification 46220504 for 01"-VF-33001-MF3 blowdown line	Repair of valves, adjacent piping and flanges on the 01"-VF-33001-MF3

		Statpipe blowdown line. A local joint test was conducted after the repair on 26 May 2022. The leak point on the 01"-VF-33001-MF3 line was not covered and pressure-tested in connection with this test.
12 Mar-23 May 2022	SFB turnaround 2022	According to information, no work was done on the blowdown line (01"-VF-33601-MF3) for the UK metering station during the turnaround.
Apr 2022	Feedback on valve positions in the Statpipe metering package	Feedback on HV33003, HV33102 and HV33202 valve positions not available in the trend tool (PI) until April 2022. Comment from the PSA team: Equinor has no history which shows when the 01"-VF-33001-MF3 line was pressurised/used earlier than that.
5 Apr 2022	MIS risk – SFB PS6	Ignition owing to lack of overview of non-electric ignition sources. Start/end date: 20 April 2020–31 December 9999 Due date 31 December 2022: ensure execution of survey Reported 10% complete 5 April 2022
5 Apr 2022	MIS risk – SFB PS6	Ignition owing to fault in intrinsically safe loops (EX-i). Start/end date: 20 April 2020–31 December 9999 Due date 31 December 2022: secure documentation for existing EX-i loops and perform EX-i calculations. Reported 10% complete 5 April 2022 Comment from the PSA team: Given surface corrosion and risk of HC leaks, uncertainty over ignition sources is particularly unfortunate.
19 May 2022	Timp plant assessment for SFB	"The risk level for the platform is regarded as acceptable on the basis of its technical condition." The Timp status gave a D grading

		(substantial deficiencies) on 13 PSs, including PS1 – containment. PS1: "In recent years, a large number of open notifications have existed for safety-critical static equipment, including HC-bearing tags." "Given weaknesses in the original design and that SFB is an ageing installation, it is important to devote attention to quality-assuring priorities for rectifying findings in the HC system, and to rectifying them."
20 May 2022	MIS risk – SFB PS6	Ignited gas leaks owing to heating-cable faults Start/end date: 7 May 2020–31 December 9999 Due date 31 December 2023: secure acceptable condition of heating cables to prevent ignition sources. Degree of completion unspecified.
23 May 2022, 07.00	Regular morning meeting with pre-startup review	The startup was conducted without a detailed running-up plan.
23 May 2022, 08.55	Choke opened on the first well	
23 May 2022, 09.15	Startup meeting in the CCR	Attention in this meeting was devoted to concentrating fully on the running up and on taking time. It was followed by authorisation for the CCR to run the facility up.
23 May 2022, 10.33	Flare ignited	
23 May 2022, 17.09	Recompression train M11B started up after several unsuccessful attempts	
23 May 2022, 17.27	Flare valve HV33004 opened on the Statpipe metering station.	
24 May 2022	Leak point 1 (01"-VF-33001-MF3)	M2 notification 47074220 Hole measured using callipers with the following dimensions: length 7.4mm and breadth 2.6mm.

		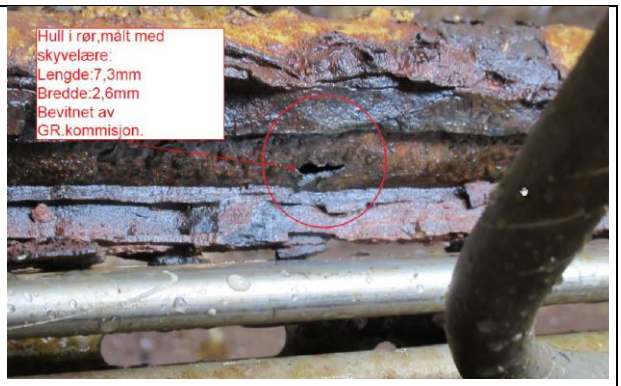 *Image 6 Appendix M2 notification 47074220. (Source: Equinor)*
24 May 2022	Leak point 2 (01"-VF-33601-MF3)	M2 notification 47074214 Hole measured using callipers with the following dimensions: length 6.3mm and breadth 2.0mm.  *Image 7 Appendix M2 notification 47074214. (Source: Equinor)*

Table 3 Conditions of significance for the incident in chronological order.

4.2 Response to the incident

Date/time	Activity/position
23 May 2022, 17.27.25	Gas leaks in M10T – two detectors activated at 100 per cent LEL. Automatic GA and ESD2. Gas detectors alerted almost immediately after the operation to equalise the pressure differential started. Printout from the control system showed that two line-of-sight gas detectors activated at 17.27.25.
23 May 2022, 17.27.30	Ignition source disconnection was activated automatically.
23 May 2022, 17.28.37	Printout from the control system shows that two point gas detectors activated at 17.28.37.
23 May 2022, 17.29.52	Initiated pressure relief (printout shows that this had an immediate effect). Pressure relief was manually initiated from the CCR with a pneumatic time delay which ensures that the time delay functions even with the loss of drive power.
23 May 2022, 17.40	All gas detectors in M10T down to zero per cent. M10T is naturally ventilated. At the time of the incident, wind speed was 15 knots from the south.
23 May 2022, 17.43	POB check, within the requirement for mustering time.
23 May 2022, 17.43.53	Plant blown down.
23 May 2022, 17.52	Search and rescue teams cleared to enter the area with respirators/ personal gas meters to inspect the damage site.
23 May 2022, 18.06	Personnel out of the lifeboats.

Table 4 Response to the incident in chronological order.

5 Potential of the incident

The gas leaks occurred in the open M10T process area at the upper north-eastern corner of SFB, where the gas-export metering stations are positioned. M10T is the top of the M10 injection compressor module. This houses gas turbines and injection compressor trains, which had been taken out of operation before the incident. Wind speed was 15 knots from the south-east (information subsequently received from Equinor corrects the wind direction from 190 degrees in the figure below to 170). The figure shows the activated gas detectors. The two point gas detectors registering 100 per cent LEL were installed inside the Statpipe analysis compartment, while the line-of-sight gas detectors were out in the module.

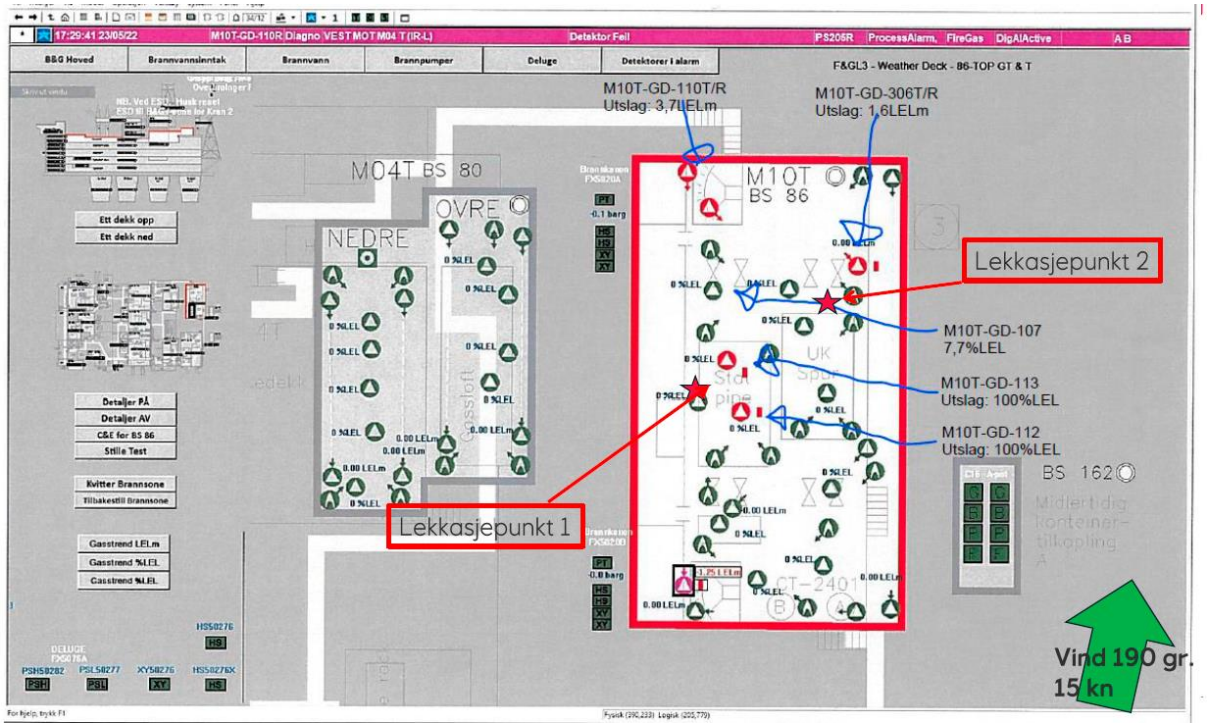

Figure 4 Overview of fire detection on M10T. (Source: Equinor)
Key: Lekkasjepunkt = Leak point; Vind = Wind 190 degrees.

5.1 Actual consequence

The PSA team has based its assessment of leak rates on Equinor's own calculations of these, since geometry, pressure and temperature are verifiable from flow diagrams and process data.

The incident's actual consequence was gas leaks estimated initially at 0.52 and 0.57 kg/s respectively, giving total emissions of about 285 kg of export gas, with consequent shutdown, emergency response mobilisation and a delay of just under two days in restarting the facility. No significant material damage was suffered except to the already degraded blowdown lines. No individuals were exposed to HC gas during the incident.

Initial pressure at the leak point was about 160 bar. Manual pressure relief was activated at 17.29.52, roughly 2.5 minutes after the GA and ESD2. The curves below show when the gas detectors activated and the course of pressure relief respectively.

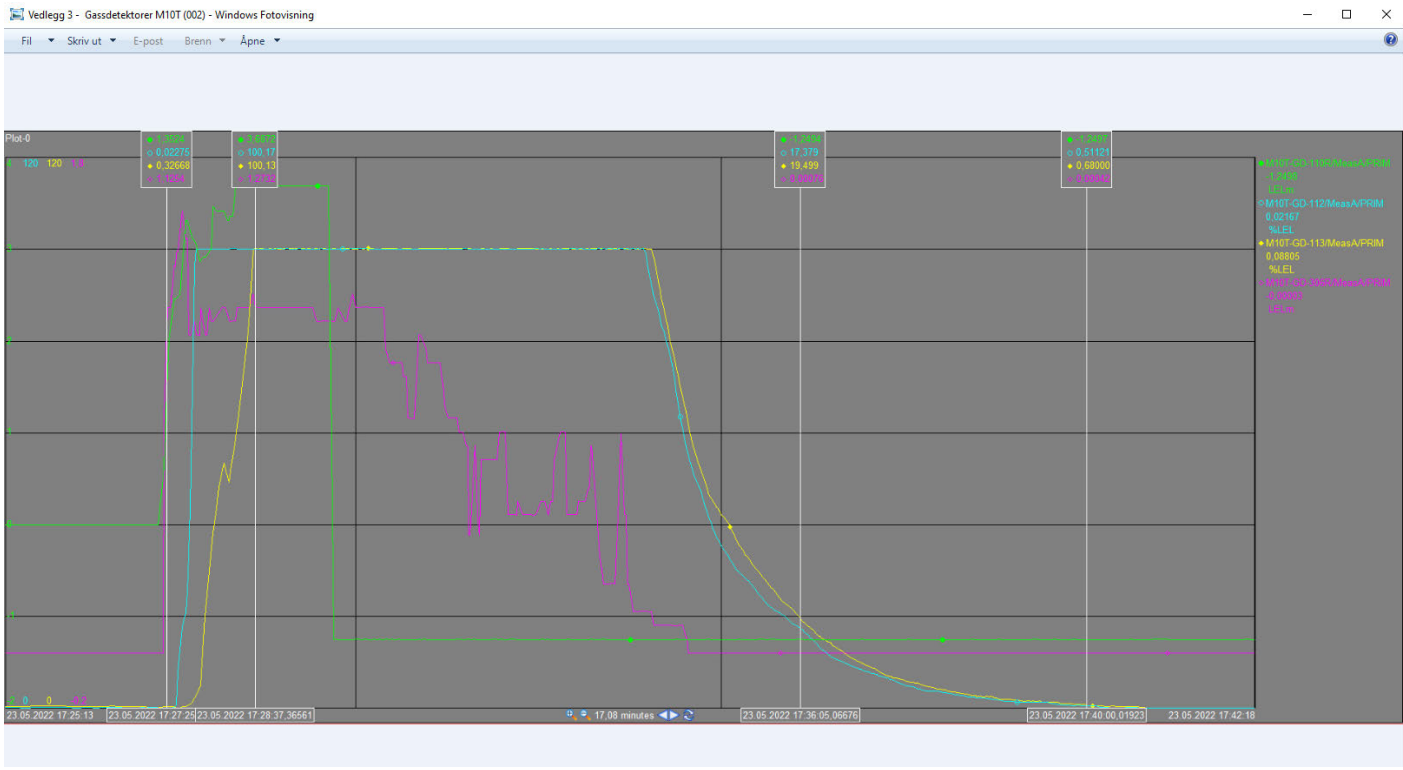

Figure 5 Activation of gas detectors on M10T. (Source: Equinor)

Explanation of figure 5.

- The first marker shows when the first gas detectors activated. These are line-of-sight gas detectors and measure in LEL metres, with one designated as H and other as HH.
- The second marker shows when four gas detectors were activated – two line-of-site and two point.
- The third marker shows when all the detectors were below 20 per cent LEL.
- The fourth marker shows when all the detectors were down to zero per cent (at 17.40).

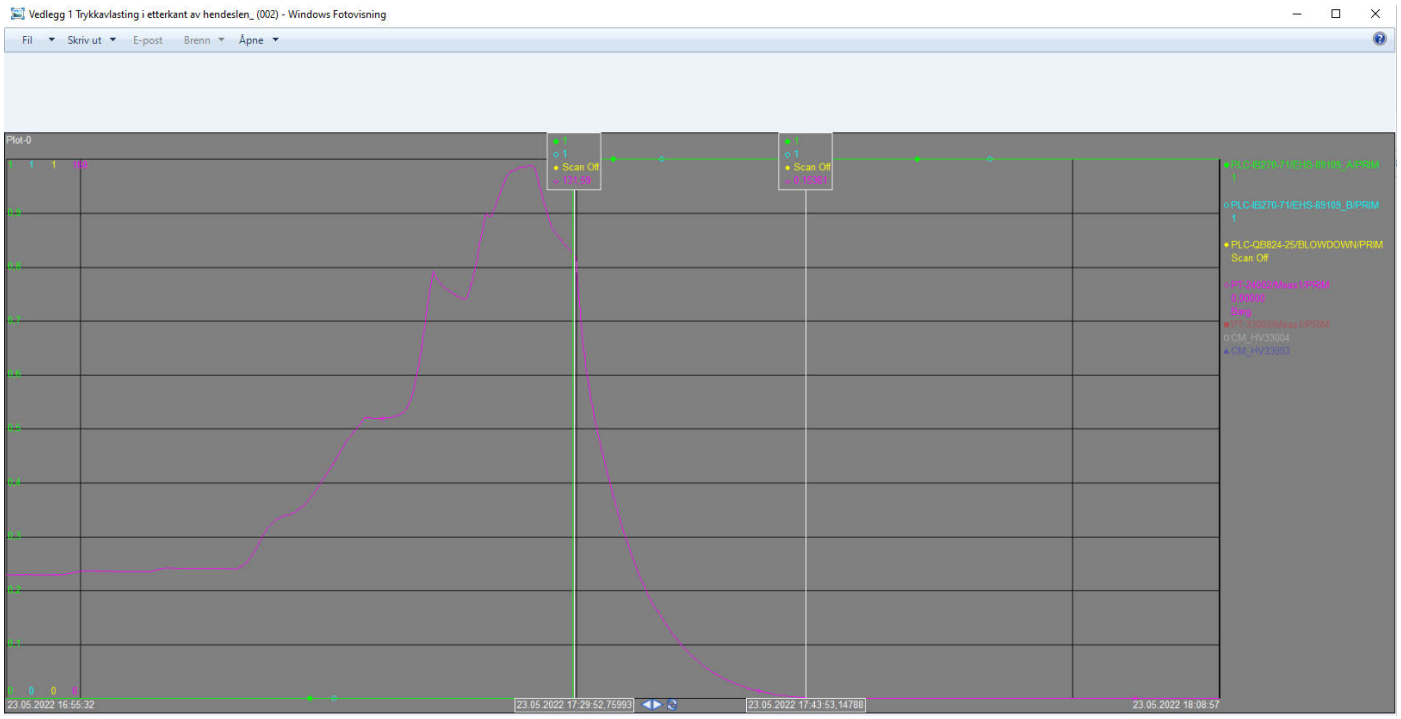

Figure 6 Pressure relief in the wake of the incident. (Source: Equinor)

Explanation of figure 6.

- The figure shows that manual pressure relief (EHS-89109A and B) was initiated at 17.29.52.
- Pressure transmitter PT 24002 on CD2010 (the gas injection suction scrubber upstream from the measurement package) shows that pressure was down to zero at 17.43.53.

After manual relief had been activated, the pressure dropped rapidly. Figure 6 shows that the plant was blown down 14 minutes after relief was initiated. Equinor reported that the segment blown down has a volume of 41 m^3.

5.2 Potential consequences

Potential consequences for people

Activity in the plant was reduced while running-up after the turnaround. Personnel deployed there were charged with looking and listening for signals which might indicate possible abnormalities.

The PSA team has been informed that two people were in the area close to M10T ahead of the leaks, and two were moving in that direction when the leaks occurred in order to investigate more closely. Had the leaks ignited when these people were in the immediate vicinity, the team's assessment is that they could have been seriously injured or killed. Such injuries could have occurred as a result of exposure to fire or of being struck by loose fragments should gas have ignited in the Statpipe analysis compartment. Breathing in gas could also have posed a potential danger of losing consciousness.

Assessments by the team are based on information from SFB's TRA, which describes the probability of sudden death in the incident area as 0.1 and 0.5 respectively for fires with rates of 0.05-1 and 1-10 kg/s. The TRA has also assessed the probability of fatalities when evacuating the drilling area in the event of a fire in M10T with rates of 0.05-1 and 1-10 kg/s. The associated probabilities for sudden death in the TRA are zero and 0.015.

Although the gas leaks might potentially have expanded in size because the holes developed into a full pipe break, the team considers this to be unlikely. It has been told that the gas export line had been pressurised to about 160 bar when the incident occurred, and Equinor has stated that the potential leak rate with a possible full break would have been in the order of seven kg/s. The highest consequence class in the TRA – leaks above 10 kg/s – would thereby have been irrelevant in this scenario.

The TRA assumes that the integrity of the facility and the safety barriers is maintained. PS6 ignition source control receives a D grading (substantial deficiencies) in the Timp overview because of the risk related to the condition of heating cables, and the company has established an extended-life measure to install ignition source disconnection, with an investment decision (DG3) due in 2023. Uncertainty has also been identified over non-electric ignition sources, where the company has established a survey activity with a deadline of 31 December 2022. This indicates that ignition sources represent a vulnerability for SFB.

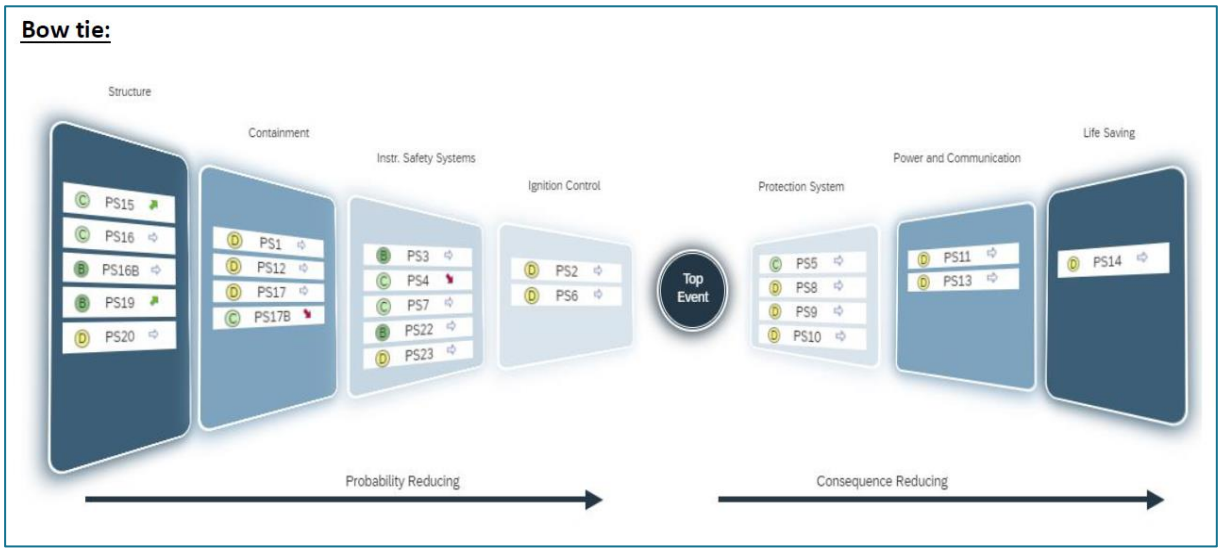

Figure 7 Timp picture SFB. (Source: Equinor)

Wind direction and speed during the leaks are specified as 170 degrees (wind from south-east) and 15 knots (7.7 metres per second) respectively. The leak points were in open areas on M10T, but gas was also detected in the naturally ventilated Statpipe analysis compartment. Natural ventilation is likely to have made an effective contribution to thinning out gas concentrations.

Potential consequences for material assets

Ignition in the analysis compartment could have resulted in major damage there but, based on the TRA, the PSA team does not consider extensive damage outside the M10 module and M10T area to be likely. The TRA indicates that even a fire with an initial leak rate of more than 10 kg/s would not have threatened main safety functions other than evacuating the drilling area.

Potential consequences for the environment

Under different circumstances, the initial leak rate could have been larger and would have led to increased emissions to the air.

Areas of SFB with a greater damage potential

This investigation has uncovered weaknesses in following up external corrosion of process piping in CS, and the PSA team cannot exclude the possibility that the leak could have arisen in an area other than M10T, where the damage potential might have been higher. No further assessment of that possibility has been made in this investigation.

6 Direct and underlying causes

6.1 Direct cause

The direct cause of the two HC leaks in the M10T area was heavy external corrosion of piping in CS.

The surface coating had degraded, and corrosion had been allowed to develop to a serious extent without technical or operational measures being initiated. Rust holes had probably already developed in the pipes when they were pressurised as part of running up.

6.2 Underlying causes

The investigation has identified a number of technical, organisational and operational elements which were or could have been significant for the occurrence of the leaks. These elements are described in the following sections.

6.2.1 Material technology

Verifications on SFB by the PSA team showed that surface protection for the relevant pipes had degraded and that surface corrosion had been allowed to develop. The pipes had not been coated since their installation in 1983. In addition, the team observed that one of the pipes was further corroded by contact with other material which may have created a galvanic effect. The piping in M10T is exposed to the weather, and corrosion will begin once protection against it has been lost. Coating was reported to have degraded to condition 5 in 2014, but this had probably begun earlier. Furthermore, it can be assumed that unfavourable conditions – plentiful moisture combined with salt – could produce a corrosion rate of 0.5 mm/y.

6.2.2 Marking of equipment

The two relevant pipes on M10T were not adequately marked to ensure correct identification and integrity checks.

In addition, equipment permanently removed from service was inadequately marked. That creates opportunities for misunderstandings. See table 3 with comments on the GVI of 7 December 2021 in the M10 module.

6.2.3 General attention paid to corrosion

External corrosion will occur on an older facility like SFB. The challenge lies in distinguishing between serious corrosion and what is non-serious general corrosion. “Surface corrosion” was the term used to describe the external condition of CS piping on SFB.

Equinor had two maintenance programmes intended to follow up the integrity of surface coating and the actual piping respectively. Corrosion protection was

monitored through area-based condition surveys. Grading coating condition formed the basis for programmes to maintain the actual surface protection. Area-based GVI programmes were used to map condition and serious impairment of static process equipment module-by-module.

Equipment permanently removed from service on SFB was not included in the surface maintenance programme. Accepting that such equipment corrodes can make it challenging to devote enough attention to corrosion of equipment still in operation.

a) Control over external corrosion

Surface protection and maintenance are a precondition for sustaining control of the integrity of CS piping over its operating life.

Detailed inspecting with a customised method is essential for being able to follow up developing corrosion.

The challenge for SFB has been the lack of adequate maintenance management, with inspection and surface treatment failing to complement each other so that leak integrity can be ensured.

b) Surface maintenance

The need for surface maintenance on M10T was identified in the 2018 Solv study, but had not been done for various reasons before the incident occurred on 23 May 2022. Upgrading the coating on the relevant pipes was included in the surface treatment programme, but the latter was postponed during the coronavirus pandemic. Challenges are the lack of individual risk management for equipment and piping included in the surface treatment programme and the process for handling risk when rescheduling programmes for surface maintenance.

Grading part of the blowdown line for the UK metering station as condition 6 (the lowest) in 2019 apparently failed to trigger action, and no new follow-up occurred until a GVI of M10T in 2021.

c) Maintenance in the form of inspection

Degraded surface coatings and corrosion were identified and reported after GVI programmes in 2019. The need for supplementary inspections to confirm residual wall thickness on corroded piping was not followed up.

The GVI method for monitoring external corrosion lacks the precision required for following up individual impairment and maintaining control of residual wall thickness.

d) Prioritisation of inspection findings

Reports following GVIs in 2019 and 2021 revealed uncertainty about the technical integrity of the pipes, and the need for further inspection was partly described in the text. That failed to receive the necessary attention and follow-up because findings of impaired pipes were categorised as "unwell" and thereby given low priority.

The result in this case was that the technical condition of parts of the relevant pipes was not known, and that serious weaknesses were first exposed in the form of an incident.

e) Handling of notifications

Notifications of findings from GVIs for the relevant pipes have been entered in the surface treatment programme without knowledge of their residual wall thicknesses. Uncertainty has not been made manifest concerning the wall thickness of individual pipes in a big surface treatment programme. The programme was little suited to handling individual uncertainties for single pipes. Corrosion will continue as long as the surface coating is degraded and not maintained. Notification of findings on the UK line were also incorrectly closed in connection with rescheduling the surface treatment programme because relevant WOs were closed and new ones established. This was described during the investigation as an error. The investigation also showed that corrosion findings on the Statpipe line in the 2021 GVI were erroneously confused with findings from the corresponding line for the UK metering station, where corrosion had already been reported. A new notification therefore failed to be established.

The process for handling notifications is insufficiently robust in the sense that the individual risk for each pipe and the remaining time until integrity is lost are not adequately followed up. Corrosion will continue without surface maintenance. The investigation has found several examples of reported findings of external corrosion which were dealt with late, postponed and incorrectly assessed in technical terms, as well as of closures without findings being rectified.

f) Prioritisation for inspection

No updating has taken place of the RBI analysis for external degradation of the relevant pipes, and the changed probability of degradation as a result of lost surface coating and corrosion reporting is not specified. The pipes are given the "extremely high" (the highest) classification for loss of function, loss of containment and HC leaks.

The incident shows that the process for establishing necessary confirmatory inspection of HC piping is inadequate in exposing and thereby preventing serious corrosion, with leaks as the consequence.

6.2.4 Risk assessment of external corrosion

In its MIS Risk tool for risk management, Equinor has specified external corrosion on HC piping as a risk. Actions related to this risk are hard to measure and take time. That makes it difficult to assess their effect.

Equinor 's Timp tool has given M10T on SFB a D grading for PS1 with a comment on piping corrosion. The D grading permits operation without restrictions, and uncertainty as a consequence of postponed surface maintenance and the unknown condition of HC piping is not discussed.

Equinor calls attention to surface corrosion in its summation of condition after inspections of static equipment conducted during 2021 in M10T on SFB. The summation does not identify serious corrosion or discuss the potential effects of postponed surface maintenance and the unknown condition of piping.

6.2.5 Expectations of production operators

It emerged from several interviews that production operators on SFB were expected to be observant out in the plant and report back if they saw corrosion or other conditions which could threaten the integrity of static process equipment.

The PSA team's understanding is that operators monitor a number of operating conditions, including by observing, smelling and listening for irregularities, but that exposing and assessing corrosion are not part of their primary role.

6.2.6 Capacity offshore for following up corrosion

Inspection resources on SFB have been reduced against a background of projects to enhance robustness which are directed at reducing the need to follow up internal degradation of static process equipment. Confirmatory inspections will demand more capacity than the current GVI-based practice for following up external corrosion as a result of degraded surface coating.

It emerged from the inspection that the workload for handling notifications has been rising. This could mean that the need for individual risk assessment and assessing risk when allocating work has not been adequately assessed.

6.2.7 Capacity in the onshore organisation for following up corrosion

The organisation on land, which is assigned to prepare maintenance plans for static process equipment, follow up the condition of HC piping and assess the risk of HC leaks, has been reduced over time. This investigation has identified vulnerabilities in the onshore organisation's handling of notifications, including in connection with risk assessment of impairments and postponements of work.

6.2.8 Operational and technical assessments

When starting up after the 2022 turnaround, the organisation out on SFB was not aware that the relevant pipes were degraded and could not be used.

The technical specialists on land had proposed a "forward-looking scope" in 2021, whereby the whole Statpipe line should be replaced. Thereafter, they erroneously concluded that the heavily corroded line was out of commission. See the entries for 15 February and 11 June 2021 in table 3.

6.2.9 Own follow-up

External corrosion of CS equipment was identified as a risk in the MIS tool, but associated actions and follow-up have been inadequate to expose and combat vulnerabilities in maintenance management. Equinor had identified handling of notifications as a risk, and the PSA team has been told that it has introduced an self-evaluation activity. However, actions for reducing uncertainty related to competence, processes, systems and tools were not clearly defined.

7 Emergency response

The incident was handled in accordance with DSHA 1 oil/gas leak, and the PSA team's general impression is that the response was good. Presented in section 4.2, the timeline shows that it took about 15 minutes from the alarm sounding until the POB check was completed.

Manual pressure relief was initiated early from the CAP on the orders of the incident commander, and it took about 14 minutes to depressurise the plants. To ensure the safety of personnel, the response management waited a few more minutes after the plant was depressurised and the gas detectors had ceased responding before search and rescue teams with respirators were sent in to inspect M10T.

7.1 Activation of deluge

Deluge is not automatically activated by confirmed gas in M10T.

It emerged from interviews that conditions in the CCR during the incident were viewed as calm and contained, and that the response and communication were seen as good. Nevertheless, the PSA team has heard that the incident commander ordered activation of deluge in the relevant area at an early stage but that this was not picked up in the CCR. It was only in the final phase of the response, when the order to turn off deluge was given, that the failure to activate it was discovered.

Had fire water been automatically activated by a confirmed gas alarm during this incident, Equinor would have avoided the communication failure which occurred and the blast overpressure could have been reduced if the gas had ignited.

7.2 Behaviour when the alarm sounds

The PSA team was made aware that two people undertook the role of an ART on their own initiative during the incident and went to M10T to see where the leak was. This did not accord with the desired behaviour when an alarm sounds, and the people concerned were ordered by the CCR to leave the area immediately. A separate Synergi entry was subsequently written about this action in order to underline the importance of correct behaviour. Important information about an ART and emergency response was also entered after the incident in *New on board*, a presentation given when arriving on SFB.

7.3 Evacuation routes

According to appendix B of SFB's safety strategy, a minimum of two evacuation routes must be available from all permanently or temporarily occupied areas. However, the PSA team was told that an evacuation route from the UK metering

station was blocked during the incident. This had been rectified when the team carried out its inspection on board as part of the investigation.

8 Observations

The PSA has two main categories of observations.

Nonconformities: observations where the PSA *establishes* a breach of/failure to comply with the regulations.

Improvement points: observations where the PSA *believes it sees* a breach of/failure to comply with the regulations, but has insufficient information to establish this.

8.1 Nonconformities

8.1.1 Inadequate management of HSE

Nonconformity
Management of HSE on SFB did not embrace the activities, resources and processes related to controlling degradation of surface protection and corrosion on HC piping which were necessary to safeguard prudent operation and continuous improvement.

Grounds
During the investigation, Equinor presented many ongoing and completed activities to reduce risk associated with controlling degradation of surface protection and corrosion on HC piping in CS. The investigation has shown that these activities have not been adequate to handle serious impairments which resulted in HC leaks. This includes the following.

- Equinor in 2020 identified a risk for leaks as a result of degraded surface protection, and the condition was described as unacceptable with growing risk. Measures for following up surface treatment had an end date of 2037. Measures to ensure correct handling of findings, inspection programmes and the like had an end date of 2099.

- Equinor has not sufficiently followed up vulnerabilities in its own maintenance system for HC piping in CS in order to avoid leaks resulting from external corrosion. It has not sufficiently followed up the vulnerabilities and uncertainties at the interface (detailing and coverage) between programmes for surface maintenance and maintenance in the form of inspecting HC piping in CS.

- GVI in July 2019 reported findings of external corrosion on the blowdown line for the UK metering station, with a recommendation of thickness measurements and surface treatment of the leak point within a year. Thickness was not measured and surface treatment was postponed several times.

- An updating of the RBI evaluation for external corrosion as a basis for the inspection programme was recommended in 2015. This was not done.

- Heavy external corrosion of the blowdown line for the Statpipe metering station was identified by GVI in June 2020. Assessing whether other parts of the line should be replaced was also recommended. This was not followed up.

- The 2014 surface treatment programme specified a condition level of 5 for protection of the relevant blowdown pipes, while the company's lowest permitted level is 2. No rectification was made.

- TR1987 *Preventive activities for static process equipment and load-bearing structures* requires 100 per cent visual inspection of processes and necessary activities to confirm residual wall thickness in the event of corrosion. This requirement was not observed.

- Inaccurate reporting has been a known challenge for SFB. See date 31 August 2021 in table 3, where the desire for more accurate reporting from GVI nevertheless failed to lead to action on identified serious corrosion.

- Equinor noted in its latest annual assessment after inspection (at the end of 2021) that piping in M10T had some corrosion. The uncertainty about the condition was not described.

- Equinor gave PS1 Containment in M10T a condition level of 5 (substantial deficiencies). Uncertainty over the development of the condition for individual pipes and lack of clarity about condition were not described.

- Equinor has not conducted periodic corrosion evaluation as described in governing document OM104.702.02 – *Evaluate and report corrosion risk*.

- Equinor has not followed up adequately the uncertainties created by postponing surface maintenance programmes because of Covid-19 and restrictions on the capacity to execute maintenance.

- A reduced maintenance programme for safety-critical equipment, posing a threat of incidents as a result of unexecuted maintenance and a risk of major accidents, was assessed as a high risk with low uncertainty in FLX S-AMU (case closed 1 April 2020).

Requirement
Section 6, paragraph 1 of the management regulations on management of health, safety and the environment, see section 21, paragraph 2 on follow-up

8.1.2 Inadequate knowledge of weaknesses in barriers and barrier elements

Nonconformity
Equinor had failed to ensure that people knew which barriers and barrier elements on SFB were inoperative or impaired.

Grounds
Equinor has failed to update the RBI analysis for external degradation of piping on SFB, and has not handled the risk of leaks as a result of lost surface coating and corrosion over time.

Handling the integrity of HC piping has largely been assigned to the programme for follow-up and maintenance of surface coating. The investigation has shown that local degradation of surface protection in individual pipes was not handled quickly enough to prevent serious external corrosion.

Equinor uses GVI to identify impairment in HC piping. The investigation has shown that this method is unsuitable for following up the condition of piping and equipment where degradation is partly concealed by corrosion products.

The investigation has exposed weaknesses in the methods for identifying serious and critical corrosion in time.

Requirement
Section 5, paragraph 5 of the management regulations on barriers

8.1.3 Inadequate marking of equipment

Nonconformity
Equinor has not marked HC piping on SFB in a way which ensures safe operation and prudent maintenance.

Grounds
Equinor has not marked the relevant pipes on SFB where the leak occurred in a way which ensures safe operation and prudent maintenance. As a probable consequence of the lack of marking, the company has referred to the wrong line number when inspecting one of the two pipes with serious corrosion and leakage.

Equinor has failed to mark equipment permanently removed from service on SFB so that it cannot be confused with equipment in operation or distract attention from the condition of the latter. See also section 6.2.2.

Requirement
Section 10, paragraph 2 of the facilities regulations on installations, systems and equipment

8.1.4 Inadequate maintenance

Nonconformity
Equinor had failed to ensure that HC piping on SFB was maintained so that it was able to fulfil its demanding function in all phases of its operating life.

Grounds
Equinor had not conducted adequate maintenance of HC piping in CS so that external corrosion could be prevented and/or exposed before it became serious and could lead to leaks, as in this case. See nonconformities 8.1.1 and 8.1.5-8.1.7.

The PSA team takes the view that corroded holes existed in the two relevant blowdown lines before they were pressurised during the incident on 23 May 2022.

Requirement
Section 45 of the activities regulations on maintenance

8.1.5 Inadequate maintenance programme

Nonconformity
Equinor had not ensured that the maintenance programme for SFB included activities for monitoring technical condition intended to ensure that corrosion developing or initiated on HC piping was identified and corrected.

Grounds
Equinor had been unable to identify serious corrosion on HC piping through its maintenance and inspection programmes utilising GVI.

Its programme for surface maintenance had failed to halt corrosion before it became critical.

Equinor has used the "unwell" report code for piping with identified external corrosion without its actual residual wall thickness being known. Criteria (appendix to R-103506) for reporting inspection findings of external corrosion specify use of "unwell" to cover large areas lacking surface protection or with surface corrosion.

Since the latter term is not defined, assessing it becomes subjective. The investigation has found that "unwell" was also used where substantial wall thickness had been lost as a result of corrosion.

Equinor had not identified the need for confirmatory inspection of the relevant pipes, even though it was known that their surface protection has been lost in 2014 (condition level 4) and that their location – exposed to the weather on M10T on SFB – could give a high rate of corrosion.

The company had not upgraded the RBI analysis for external degradation of piping on SFB, and had failed to handle the risk of leaks as a result of lost surface coating and corrosion over time.

Requirement
Section 47, paragraph 2 of the activities regulations on maintenance programme

8.1.6 Lack of maintenance criteria

Nonconformity
Equinor had not defined criteria for setting priorities with associated required ends for executing maintenance activities with HC piping on SFB.

Grounds
Equinor had not followed up the acceptance criterion – condition level 2 – it had defined for surface maintenance in order to avoid serious corrosion developing on HC pipes in CS.

It had not set required ends for executing maintenance, in the form of measuring residual wall thickness so that corrosion was identified before it became serious.

Equinor had not established criteria for conducting detailed and confirmatory inspection of HC pipes in CS when loss of corrosion protection is reported.

Requirement
Section 48, paragraph 2 of the activities regulations on planning and prioritisation

8.1.7 Inadequate maintenance efficiency

Nonconformity
Equinor had not systematically evaluated the effectiveness of maintenance on SFB given the registered data for performance and technical condition of HC piping in CS.

Grounds
Equinor had failed to systematically evaluate the effectiveness of surface maintenance for ensuring that the necessary work was done before serious corrosion developed.

The company had not systematically evaluated the effectiveness of the inspection programme using the GVI method in ensuring that corrosion was identified before it became serious.

Requirement
Section 49, paragraph 1 of the activities regulations on maintenance effectiveness

8.2 Improvement points

8.2.1 Improve assessment of the HSE consequences of manning changes on SFB

Improvement point
Equinor does not appear to have adequately assessed the possible HSE consequences of changes to manning on SFB which relate to inspection and maintenance of HC piping in CS.

Grounds
The reduction in manning offshore and the major accident risk as a consequence of errors attributable to low manning were assessed by the Statfjord AMU (FLX S-AMU case closed 1 April 2020) as high with high uncertainty.

SFB's permanent inspection manning on board has been reduced over time without sufficient account being taken of the need to inspect external degradation on HC piping in CS and associated maintenance.

Parts of the plant in CS on SFB was replaced with more corrosion-resistant materials in recent years to reduce the probability of internal degradation. However, a good deal of piping and equipment in CS remains on board, and the investigation showed that account had not been taken of a growing need to inspect external degradation on HC piping in CS as a result of deterioration in surface protection over time.

Equinor does not appear to have adequately assessed the possible HSE consequences of changes to manning on SFB.

Requirement
Section 14, paragraph 5 of the management regulations on manning

8.2.2 Improve assessment of the HSE consequences of manning changes in the onshore organisation for SFB

Improvement point
Equinor does not appear to have adequately assessed the possible HSE consequences of changes to the onshore organisation for SFB related to inspection and maintenance of HC piping in CS.

Grounds
The reduction in manning on land and the major accident risk as a consequence of errors attributable to low manning were assessed by the Statfjord AMU (FLX S-AMU case closed 1 April 2020) as low but with high uncertainty.

Personnel numbers in the onshore organisation for following up technical integrity, inspection of CS piping and maintenance of surface protection on SFB have been reduced over time. The investigation has shown that several incorrect assessments and errors were made by onshore personnel along the way in handling reported findings on the degraded blowdown lines.

The investigation has shown that the onshore organisation has lacked a detailed overview of degradation in condition and the need for maintenance of the HC blowdown lines.

Equinor does not appear to have adequately assessed the possible HSE consequences of manning changes to the onshore organisation for SFB.

Requirement
Section 14, paragraph 5 of the management regulations on manning

8.2.3 Improve efforts to ensure competence (training backlogs)

Improvement point
Equinor does not appear to have ensured that personnel on SFB at all times have the competence required to pursue activities in compliance with the HSE legislation.

Grounds
A significant backlog had built up in necessary training for personnel on SFB. This was greater than the company's own acceptance criterion for failing to provide training within the specified deadline.

Equinor does not appear to have adequately assessed the risk associated with insufficient training for individual roles or for the organisation as a whole on SFB.

Requirement
Section 21, paragraph 1 of the activities regulations on competence

8.2.4 Failure to activate deluge

Improvement point
Equinor does not appear to have chosen the solutions for barriers on SFB which have the greatest risk-reducing effect.

Grounds
Deluge was not automatically activated on confirmed gas in the M10T area.

No deluge occurred during the incident even though the incident commander had called for manual activation. This message was not picked up by the CCR nor followed up by the response management during the incident.

Requirement
Section 4, paragraph 3 of the management regulations on risk reduction

8.2.5 Improve plans for running up the facility after a turnaround

Improvement point
Equinor does not appear to have drawn up the necessary plans for running up the SFB plant after the turnaround in the spring of 2022.

Grounds
It emerged from the investigation that no detailed plan had been prepared for running up operation of SFB after the turnaround. Operating personnel utilised a generic startup procedure with few details. It emerged from interviews that big changes had been made to CCR operators, and several of these had not been involved in starting up the plant before. For that reason, several of them had expressed a desire for a more detailed startup procedure. It also emerged that simulators for training operators in handling operations were little used.

Requirement
Section 6, paragraph 3 of the management regulations on management of health, safety and the environment, see section 20, paragraph 2, litera b of the activities regulations on startup and operation of facilities

8.2.6 Improve evacuation measures

Improvement point
Equinor does not appear to have initiated measures to correct or compensate for impairments in evacuation barriers on SFB.

Grounds
According to appendix B to the safety strategy, a minimum of two evacuation routes must be available from all permanently or temporarily occupied areas. The PSA team was told that an evacuation route from the UK metering station (north side) was blocked by scaffolding during the incident without compensatory measures having been instituted. The scaffolding had been removed when the team carried out its inspection of the plant as part of the investigation.

Requirement
Section 5, paragraph 6 of the management regulations on barriers

8.2.7 Improve efforts to ensure appropriate behaviour

Improvement point
Equinor does not appear to have ensured that personnel on SFB possessed at all times the competence required to handle hazards and accidents.

Grounds
The PSA team was made aware that two people undertook the role of an ART on their own initiative during the incident and went to the M10T area to see where the leak was. This did not accord with the desired behaviour when an alarm sounds.

Requirement
Section 21, paragraph 1 of the activities regulations on competence

9 Barriers which have functioned

The following are technical barrier elements which have functioned as intended.

Gas detectors: Flare valve HV33004 on the Statpipe metering station was opened at 17.27. The printout shows that two line-of-sight gas detectors activated at 17.27.25, and two point detectors at 17.28.37. This means the gas was detected almost immediately after work to equalise operating pressure began.

Ignition source disconnection: The printout shows that the signal for ignition source disconnection was automatically activated at 17.27.30.

Pressure relief: The printout shows manual activation, which requires a pneumatic time delay which ensures that the time delay functions even with the loss of drive power. Pressure relief was initiated at 17.29.52, and the printout shows this had an immediate effect. The plant was depressurised by 17.43.53.

Isolation: Isolation of the segments to limit the quantity of gas emitted is intended to occur automatically with ESD2 on confirmed gas detection (2 out of N).

Natural ventilation: The M10T area is naturally ventilated. At the time of the incident, a 15-knot wind from the south contributed to ventilation. By 17.40, all gas detectors in M10T were down to zero per cent.

Escape and evacuation: SFB reported POB check completed at 17.43.

10 Discussion of uncertainties

Uncertainty related to historical operation of the two blowdown lines in M10T has been identified by the investigation. The PSA team is aware that the operation history of these pipes is not easily accessible and that the PI tool only provides information from April 2022. It is also aware that repairs to the Statpipe line during the 2022 turnaround did not involve pressurising leak point 2 during post-repair pressure testing. It has not been possible to confirm when the two relevant lines were last pressurised before the startup on 23 May 2022. The operational history of the two lines could have said something about the latest time when the pipes were confirmed to be capable of coping with the expected operational pressure. The team assumes that the blowdown pipes had corroded into holes ahead of the incident.

The investigation has identified some technical conditions which could have been significant for corrosion development up to the leaks, but has reached no conclusions on these.

Where leak point 2 (the UK line) is concerned, it might appear that a support in the form of a U bolt could have been present in the area of the leak. Such a support could have meant that the pipe coating degraded faster at the contact surface between pipe and bolt, and that corrosion there began before 2018 and developed while partially concealed at the contact surface. Movements between pipe and support could have produced abrasion and loss of metal from the pipe, in addition to a reinforced effect on corrosion from the exposure of fresh pipe material as a consequence of abrasion.

Where leak point 1 (the Statpipe line) is concerned, it might appear that this has been covered by marking taped to the pipe surface. Marking stuck to the surface might have caused moisture to accumulate more effectively on the pipe surface and created persistent dampness at the leak point. In addition, the attached marking could have had a reinforcing effect on corrosion by acting as a crevice. It could also have helped to camouflage the developing corrosion.

11 Assessment of the player's investigation report

Equinor concludes that the direct cause of the incident is the admission of gas from production source 14"-PV-33001-MF3 (Statpipe) during startup after the turnaround, and that external corrosion allowed gas to leak from two holes in one-inch blowdown lines, one on 1101-01"-VF-33001-MF3 (Statpipe) and the other on 1101-01"-VF-33001-MF3 (UK).

The PSA team has not engaged with Equinor's consideration of the use of blowdown lines, but supports its assessment that the lines were designed to cope with such use.

In its investigation report, Equinor has identified seven improvement areas after the incident on SFB on 23 May 2022. These seven concern relevant startup procedures and harmonised methods for reaching the desired gas quality, the need to sharpen inspection programmes, ensuring follow-up of corrosion findings, implementing preventive surface maintenance, clarifying the response to corrosion findings on critical piping, awareness of vulnerabilities in maintenance management of critical piping, and learning and improvement areas in emergency response. The PSA team sees many points of similarity between the observations in its report and the improvement areas identified by Equinor.

The company concludes that the incident could not have developed into a major accident. Its actual level of seriousness for personal injury is categorised as "none" and for oil/gas leaks as "red 2". The possible level of seriousness under slightly different circumstances is categorised as "green 4" for personal injury and "red 2" for oil/gas leaks. Where material damage and other financial loss is concerned, Equinor categorises both the actual level of seriousness and the possible level under slightly different circumstances as "none". The PSA team's assessment is that, had the gas leak ignited when people were in the immediate vicinity, they could have suffered serious injury or death. Nor can the team exclude the possibility that leaks from small HC pipelines in CS could have occurred in another area where the potential for harm might have been greater than in M10T.

12 Appendices

List of documents

The following documents have been drawn on in the investigation.

1. Varsel om uønsket hendelse utslipp HC lekkasje mønstring - Equinor Statfjord B - Generell alarm aktivitert grunnet gasslekkasje 23052022
2. Møtereferat 24.05.22 - Gasslekkasje Statfjord B 23.05.22
3. Status hendelse - Gasslekkasje på avblødningslinje gasseksport Statfjord B 23052022
4. BP-000-ZE-124.000
5. Lang saksrapport knyttet til hendelsesforløpet (dokument nr 1 punkt 11 (1999893)
6. Lang saksrapport i synergi for gasslekkasjen – 2000369
7. Rørspesifikasjon MF3 (epost 30.5.2022)
8. OMC20 Field Life eXtention (FLX).pdf
9. ISO VF33601.pdf
10. Tennkilder - 2.pdf
11. Hendelsesforløp i forkant av gasslekkasjen og like et.pdf
12. Tennkilder - 1.pdf
13. Vedlikehold - VF-33601 - Ikke utført.pdf
14. Innsatspersonell - plassering.pdf
15. Personell i området like før hendelsen oppstod.pdf
16. ESD alarmlogg fra gasslekkasje M10T.pdf
17. Beredskapstavler.pdf
18. Fakkellinje P ID - VF33001.pdf
19. Vedlikeholdsordre inkl inspeksjon - historikk - VF33001-33601.pdf
20. Fakkellinje P ID - VF-33601.pdf
21. Skjermbilde B-G SKR - Alarmlogg.pdf
22. ISO VF33001.PDF
23. Overordnet flytdiagram SB
24. SO00134 System PF – Fakkel og avluftningssystemet
25. SO00276 – System PZ – Nød-og avstegningssystem
26. SO00150 System PL – Salgsmåling og gasseksport
27. SO00138 System PH – Gassreinjeksjon
28. OM105.07.01.03 - Tilbakestill isolering og trykksett
29. OM101.05.01 - Oppstart og drift av utstyr / system
30. TIMP oversikt for SFB og detaljert for PS1
31. Plan for oppkjøring av SFB ifm revisjonsstansen
32. Tidslinje for røret
33. MIS risikobilde med tiltak
34. Equinor COA granskningsmandat
35. Utskrift brann og gass logg
36. Brann og gass alarmliste

37. Trykkavlastningslinje via UK – når ble denne sist brukt?
38. Dokumenter tilknyttet Brann og gass logg, alarmliste og trykkavlastningslinje - Trending av gassdetektorer
39. Gassdetektorer UK
40. Trykkavlasting UK run 1
41. Trykkavlasting UK run 2
42. Ny Ombord Drift uke 22 skift 6 + 1 2022
43. Synergi 1885947 - Brann i boliggkvarter
44. Debrief mønstring 16-02-22 - brann i boligkvarter
45. Bemanningsanalyse
46. Utklipp TIMP – PS1
47. Utklipp TIMP – PS10
48. Synergirapport 2007285 – med vedlegg – M11T måleskap: gasslekkasje – detektert av gassdetektor
49. Synerginummer 2007289 – med vedlegg - Diffuse gasslekkasjer ifm oppkjøring
50. Notifikasjon 45805325
51. Vedlegg not 45805325
52. vedlegg 2 not 45805325
53. Notifikasjon 46220504
54. Vedlegg not 46220504
55. Notifikasjonsnummer på ett på hvert lekkasjepunkt -
56. Rapport med lang tekst
    - 47074214 (lekkasjepunkt 1)
    - 47074220 (lekkasjepunkt 2)
57. Tilstandsoppdatering Oceaneering fra 2018 ICMM - M10 Top område
58. Utklipp fra simulering
59. Hele programpakken 4A12 - Vedlagt hele programpakke 4A12. Linje 1»VF-33601 avmerket med grønn farge.
60. Synergisak – Diffus gasslekkasje M10 topp - måleblender
61. Bilder tatt i felt 02.06.22
62. Oversikt over åpne notifikasjoner mot HC rør - fordeling av vurderingene uvel - syk - død
63. EXT-001101 - Inspeksjonsfunnkoder og feilgraderingskoder - statisk prosessutstyr
64. Disp -Kriterie for rapportering av innvendig korrosjon FLX Statfjord
65. Dokumentasjon på trykkavlastning i etterkant av hendelsen
    Bekreftelse på at tennkildeutkopling fungerte
    Bevis for når det ikke kunne detekteres gass i M10T etter lekkasjen.
66. UK Run 1 trykkavlastet til fakkel
67. UK Run 1 trykkavlastet til fakkel

68. Vi ber om ISOer som nøyaktig angir punkter for lekkasje med tilhørende markeringer på P&IDer. Vi ber også om at det aktuelle avblødningsvolumet som ble trykksatt ved lekkasjetidspunktet blir angitt på ISO/P&ID.
69. Utskrift;
    Arbeidspakke 2020 overflate
    Arbeidspakke 2021 overflate
70. Kopi av dokument lastet opp i AO, som skal sikre at Leverandør ser hva som er med i pakken. Dette dokumentet inneholder bilder og kommentarer for detaljer i pakken (4A12-JPK overflate).
71. Utskrift 24996666 – longtekst på arbeidsordre
72. Utvidet studierapport Oceaneering – jobbpakke
73. TR0007 – angi tilstandsgraderinger
74. Klassifisering av tag
75. Kamfer analyse
76. SAP: Utskrift «Maintenance plan NDT» - langtekst
77. Utsnitt; Utfyllende lister / TT_SFB_NDT_UG_40-WF-01 2020
78. Endring av intervall M5 for NDT – langtekst beskrivelse
79. Konsekvensklassifisering rør 33001
80. GVI_program
81. Rapport – 46745491 /Vedlegg dokument
82. M5 45405822
83. PM01 -25245892
84. 46220504
85. 45805325 Action Log
86. Ptil granskning SFB - Dokumentasjonsoversendelse - 14_06_22 (70)
87. FW_ Signert mandat Gasslekkasje på avblødningslinje Statfjord B
88. Oppgavematrise inspeksjon
89. RBI. Vedlagt ligger oppdatert RBI fra 2014
90. Prosess for inspeksjon – Vedlikeholdsstyringssløyfe / Aris 104.702.02 – Evaluere og rapportere korrosjonsrisiko
91. Endringslogg – Maintenance plan
92. FV Standard tekst
93. R-103606 - Kriterier for rapportering av inspeksjonsfunn
94. AO – 253 56787 Langtekst
95. Oppsummeringsrapport M3 - Rapport tekst - 46745491
96. Tennkildeutkoblingsprosjekt – er varmekabler en del av dette prosjektet?
97. BP-000-ZE-163.000 STATPIPEMetering HT M10T
98. BP-000-ZE-166.000 UK SPUR Metering HT M10T
99. BP-000-ZU-209.004 GasInj Comp Seal Oil HT M10T
100. MIS risker på PS 6
101. Aris prosess – etablering av årsprogram
102. Varighet av stoppet overflatebehandling grunnet Covid
103. Skjermbilde dashboard HSE Critical CM Req end date – PM01

104. Egenevaluering M2 - Siste vurdering av SFB
105. Beskrivelse av planeffektivitet
106. Dokumentasjonsoversendelse - 22_06_22 (93-96)
107. Power BI; NCS utklipp tabell kompetanseoversikt – dato 23.05.22
108. Aksjoner fra siste Stabsmøte angående kompetanse SFB
109. MIS – Risker knyttet til kompetanse SFB
110. Begrunnelse for innføring av kompetansekrav innmelder notifikasjon SAP rolle YO002
111. SFB_25085851
112. Risiko og konsekvensmatrise
113. GPS SFB 2021
114. Verifikasjonsplan
115. Assurance activities in FLX
116. FLX review
117. MIS – Drift SFB
118. MIS – FLX nivå
119. AO med langtekst for utskifting av ventil + noe rør på Statpipe-linjen - AO 24649915
120. Reparasjonen av Statpipe avblødningslinjen under stansen i
121. System for aktiv brannbekjempelse på SFB M10T (åpne områder på toppen og inne i målepakkene
122. Utført inspeksjon i henhold til program for begge rørene i perioden fram til henholdsvis
123. Gasslekkasje SFB – Lekkasjestørrelse
124. Referat 01.11.22 - Ptil møte - Lekkasjeberegninger SFB gasslekkasje 23.05.22
125. Simuleringsrapport - Estimert lekkasjerater og prosessteknisk vurdering av utført operasjon
126. Gasslekkasje Statfjord B mai 2022 revidert
127. Tegninger datert når rørene ble «Issued for construction
128. sfb_maintitem_10196823 - mottatt på mail 17.11.22
129. ST-03060-4_VEDLEGG_L_-_BRANNVURDERINGER
130. ST-03060-4_VEDLEGG_K_-_EKSPLOSJON
131. Equinor Graskningsrapport - Gasslekkasje på avblødningslinjer for gasseksport på Statfjord B 23.05.2022
132. TR1987 Preventive Activities for Static Process Equipment and Load-Bearing Structures

Appendix A Overview of personnel interviewed