Havtil
Havindustritilsynet

Investigation report

Report	
Report title Investigation of incident involving fire in tank CD2101 (first stage separator) on Statfjord A, 17.04.2024	Activity number 001037079

Classification	
☒ Unclassified	☐ Exempt from publication

Parties involved	
Team A1	Approved by / date 21.11.2024
Investigation group participants [redacted]	Investigation leader [redacted]

1 Summary

On 17 April 2024, a fire broke out inside inlet separator CD2101 on Statfjord A (SFA). The fire was detected at 00.32.

On 23 April 2024, the Norwegian Ocean Industry Authority (Havtil) decided to investigate the incident.

The incident occurred during a planned turnaround on SFA. The processing facility was shut down and emptied of hydrocarbons. One of the turnaround activities was the cleaning and inspection of inlet separator CD2101.

It was someone cleaning the inside of the separator who first discovered the fire. The individual was equipped with fresh air breathing apparatus and quickly escaped from the tank unassisted.
The central control room (CCR) was immediately notified via radio.

The general alarm (GA) and lifeboat muster were initiated at 00.34. The emergency preparedness organisation was then mobilised. At 01.47, the fire was reported as being under control and the area was secured. A POB list was available after 1 hour and 20 minutes; a full overview of all personnel on board was obtained.

The situation was normalised at 02.10 and personnel were demobilised.

Analysis of the contents of CD2101 after the fire showed a high content of iron sulphide in the deposits. The direct cause of the fire was auto ignition of iron sulphide exposed to atmospheric oxygen.

The actual consequence of the incident was that two persons were exposed to smoke from the fire while firefighting. These individuals were not wearing fire-resistant clothing or respiratory protective equipment while extinguishing the fire. They were later followed up by medical personnel on board.

The duration of the turnaround was extended.

Regarding the potential of the incident, it is our assessment that there was limited potential for the fire to spread from this separator. However, there were several tanks in the vicinity (CD9) which were open at the same time as separator CD2101, and we believe that there was a possibility that fire or smoke development could have occurred in several tanks on SFA.

There was a high content of iron sulphide in the deposits in the inlet separator at the time of the incident, and ignition of these deposits together with hydrocarbon residues could have led to further heat and smoke development. The fire could have

damaged the operator's fresh air hose and personal protective equipment and caused burns, and thus placed them in significant danger.

Statfjord's operating unit was aware of information on iron sulphide deposits on SFA. This was documented through samples analysed for iron sulphide content, showing large amounts of iron sulphide. Samples have been taken regularly in recent years. However, SFA had not previously experienced any incidents of iron sulphide auto ignition. However, Statfjord B (SFB) and Statfjord C (SFC) have experienced several iron sulphide fires, the most recent fire occurring on SFC in 2023.

In 2019, an iron sulphide fire occurred the Equinor-operated facility Snorre B. This incident has many similarities with the fire on SFA. After the fire on Snorre B, Equinor updated a number of governing documents to better address and manage the risk of iron sulphide auto ignition.

During the planning of SFA's turnaround, the fact that iron sulphide was known to be present on SFA was not considered, and the risk management measures referred to in updated governing documents were not implemented.
The investigation has identified six non-conformities relating to the incident:

1. Inadequate information in connection with planning of tank cleaning during turnaround
2. Inadequate risk assessment in connection with opening of the manhole cover on the inlet separator (splitting of hydrocarbon systems)
3. Inadequate knowledge of requirements in governing documentation
4. Handling of iron sulphide
5. Inadequate personnel controls
6. Inadequate planning of firefighting measures

Furthermore, four improvement points were identified linked to the incident:

1. Deficiencies in the company's follow-up to ensure that new requirements are implemented
2. Inadequate mustering of the search and rescue team (S&R team)
3. Inadequate radio communication
4. Inadequate emergency preparedness training and drills for work in tanks

2 Background information

In recent years, Equinor has carried out a number of cost-reduction and streamlining processes, and created the business area "Field Life eXtension" (FLX) for late life facilities on 1 April 2020. SFA is part of this business area. The FLX organisation's "maintenance and technical integrity" unit has responsibility for maintenance, integrity and turnarounds of the facilities in the Statfjord Field.

FLX does not apply all technical requirements that apply to the other facilities operated by Equinor. During this investigation, we were informed that FLX applies NORSOK S-001 as regards requirements for technical integrity in preference to TR1055 ("Performance Standards for Safety Systems and Barriers – Offshore"), which Equinor applies as offshore requirements in other operating units.

FLX's organisation is shown in Figure 1 below.

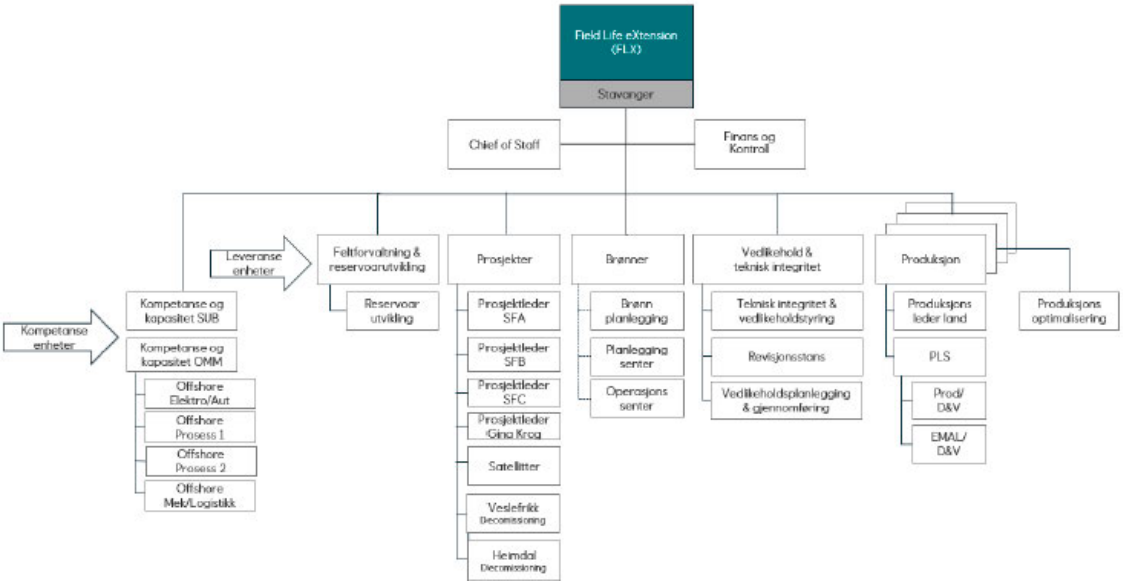


Figure 1 Organisation of FLX (Source: Equinor)

2.1 Description of facility

The Statfjord Field has been developed with production platforms SFA, B and C. The field is located on the border between the Norwegian and British continental shelves in the Tampen area.

SFA is an integrated facility with drilling, production and living quarters which stands at a depth of 145 metres in the southern part of the Statfjord Field, and has been in operation since 1979. The Plan for Development and Operation (PDO) was approved in 1976, with further approval for Statfjord late life in 2005. In 2007, SFA received consent for life extension until 31 December 2027.

Photograph 1 Statfjord A
(Photo: Norwegian Ocean Industry Authority)

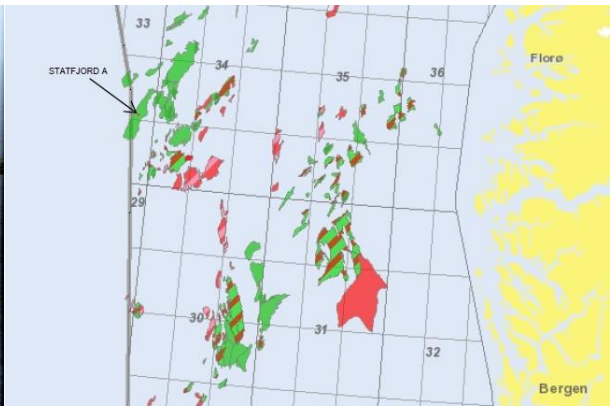


Figure 2 Map of the areas (Source: Norwegian Offshore Directorate)

2.2 Situation before the incident

The turnaround (RS) was originally planned to be carried out in 2022. At the time, the scope of work was considered too extensive, which resulted in the majority of the tank cleaning on SFA being rescheduled to 2023, and later to April 2024.

A separate organisation was established with dedicated responsibility for planning and executing the turnaround activities during RS24. The operations organisation has the main responsibility for emergency preparedness on board during the turnaround, in the same way as under normal operating conditions.

At the time of the incident, turnaround RS24 was underway and 278 crew were on board. In addition to FLX's own turnaround team and operating personnel, personnel from several contractors were also on board.

Production was stopped on 8 April 2024 and the processing facility was isolated and emptied of hydrocarbons.

There was ongoing activity, with planned work including cleaning and internal inspection of inlet separator CD2101 in addition to several other tanks.

The preparatory activities before entering and starting mechanical work inside CD2101 were completed, and the separator was opened by removing the manhole cover on 15 April 2024.

During the day shift on 16 April 2024, removal of debris from mechanical damages to the internals of the tank had to be conducted before removal of deposits could commence. Removal of deposits inside CD2010 started on the night shift on 16 April 2024

The fire was discovered by the night shift, immediately after a new person had entered the tank to carry out cleaning on 17 April 2024.

2.3 Organisation and preparations/planning prior to the turnaround

Planning for RS24 began in April 2023. IKM Testing was awarded a tank cleaning contract on 6 October 2023. IKM Testing personnel were then involved in planning the tank cleaning programme. See Figure 3, where IKM Testing is shown as part of Equinor's core team in connection with planning of the turnaround.

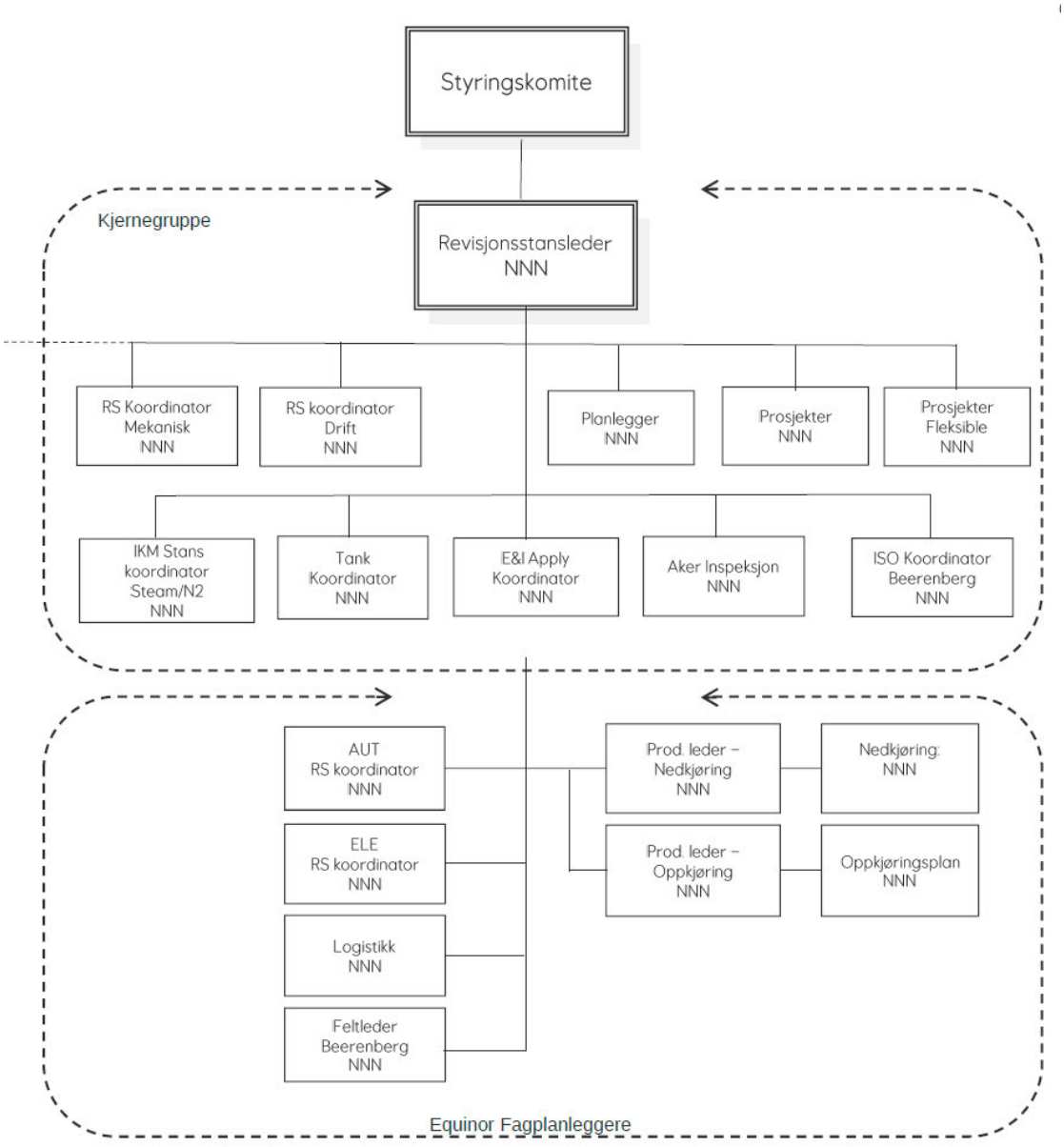


Figure 3 Organisation during the turnaround (Source: Equinor)

Prior to the turnaround, a turnaround seminar (seize and startup of production meetings), during which participants from operations and IKM Testing familiarised themselves with the scope of work for the turnaround, and reviewed experience gained from previous turnarounds.

Challenges related to the handling of iron sulphide were not discussed during the turnaround seminar for this turnaround.

During the planning phase, FLX prepared a tank programme, and IKM Testing prepared a procedure for mechanical cleaning. The tank programme specified the separators that were to be opened and the anticipated scope of work for each separator. As regards CD2101, the planned SOW included cleaning, inspection, replacing/repairing certain components and testing the jet water system.

The procedure for mechanical cleaning referred to governing HSE requirements and operational requirements and included a detailed scope of work for the cleaning job. The procedure included references to work process OM105.02 for entry in addition to a requirement to print out safety data sheets for chemicals/process fluids and put them up in a visible location at the workplace. There was however no information related to the possible presence of iron sulphide in the tanks.

Job cards were prepared for the various sub-activities related to the scope of work in the tank.

As part of the planning for RS24, draft work permits (AT) and a safe job analysis (SJA) were prepared for the planned jobs. These were then reviewed and updated prior to the execution of the jobs. Two SJAs were carried out for work in tanks, for tanks with and without radioactive sources respectively. CD2101 was covered through the SJA for tanks with radioactive sources.

2.4 Description of activity and equipment involved

2.4.1 Separator involved

Separator CD2101 is the inlet separator on SFA. It is a three-phase separator that receives the production flow from the wells and separates oil, gas and water for further processing in downstream processing facilities. The separator has a diameter of approximately 3.3 m and a length (tan/tan) of approximately 14 m.

The separator has centred inlets and outlets at both ends. There is a manhole on the tank. The input essentially consists of an inlet arrangement filled with pall rings, wire mesh in the gas phase, and weir plates upstream of the oil outlet. In addition, the separator has a jet water system for removing deposits during operation.

The purpose of the pall rings, which are collected in a box on the inlet, is to improve separation.

The jet water system consists of a centred separator manifold with oblique nozzles pointing down towards the bottom of the tank.

The separator is physically located in area CD12, which is situated on the cellar deck. A simplified sketch of the separator is shown in Figure 4 below.

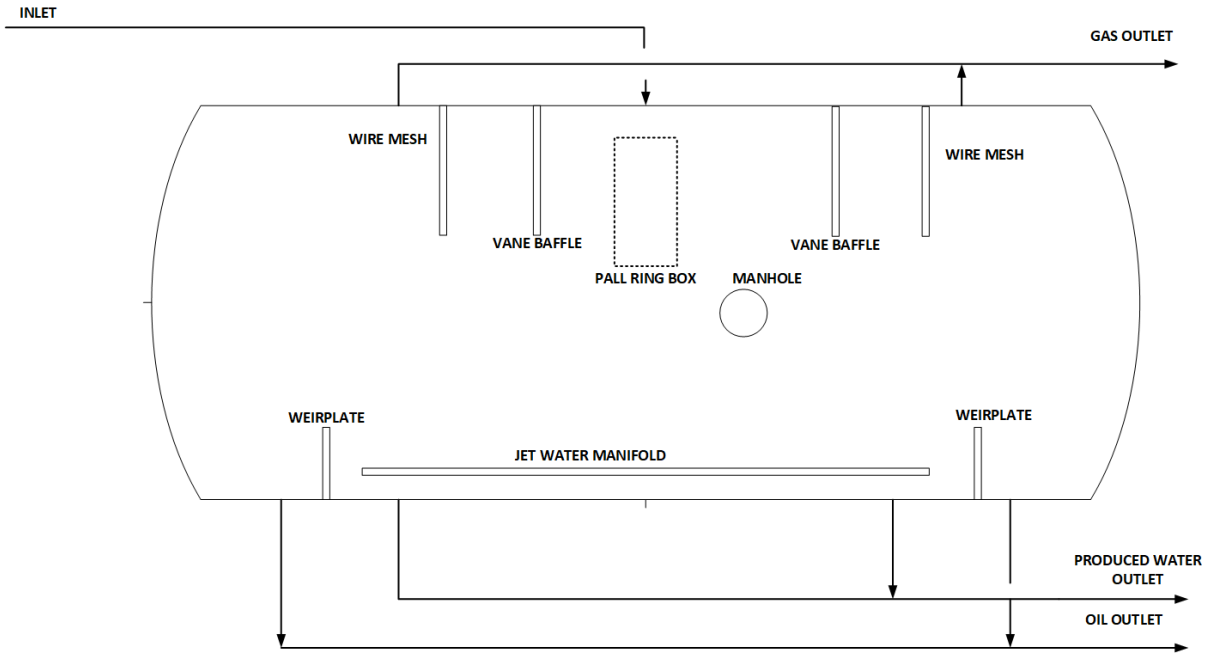


Figure 4 Simplified sketch of separator

Dense smoke made visibility inside the tank poor, and this made it difficult to visually identify the exact location of the flames. The individual that observed the fire described it as being located on a grid structure at normal working height. It may have been on the pall ring box or on the wire mesh.

The separator was last opened for inspection in 2019. In this regard, weaknesses were discovered on the hinged manhole cover, and the cover was therefore replaced. The new manhole cover was not hinged and therefore had to be handled using lifting devices.

The separator has primarily been opened for inspection and cleaning during turnarounds. As and when necessary, the jet water system has been cleaned, and nozzles and parts of the manifold have been replaced. During the period from 2000 to 2019, the tank was opened every two to three years. At the time of the incident, the tank had last been opened around five years previously, because of the turnaround work being postponed.

Table 1 below shows the estimated quantity of deposits from the previous turnarounds where separator CD2101 was opened, as well as a description of the status of the jet water system.

In 2017, samples were taken of the deposits. Subsequent analysis indicated that 15% of the deposits consisted of iron sulphide (approximately 525 kg of iron sulphide). Based on the samples that were collected, the quantity of iron sulphide after the fire on 17 April 2024 was estimated to be between 2,000 and 4,000 kg.

No samples of the deposits were taken in 2019.

Year	Estimated quantity of deposits	Status/work on jet water system
2011	2 m^3	New jetting water nozzles installed; jet water piping flushed.
2014	3 m^3	New jetting water nozzles installed; jet water piping flushed.
2017	3,500 kg	Poor condition of jet water system upon opening, new manifold installed and nozzles cleaned or replaced. It is assumed that the effect of jetting has been poor for periods due to the condition of the system.
2019	2 m^3	Cleaning of jet water system and replacement of nozzles.
2024	7 m^3	Defective brackets/clamping ring were identified on the inside of the flushing pipes inside the tank at both ends. Improved during turnaround. Jet water extraction system cleaned. The box containing the pall rings was damaged and parts of the pall rings were lying on the bottom of the tank.

Table 1 Estimated quantity of deposits

2.4.2 Activity involved

The planned job on CD2101 primarily included the following:

- Preparation before entry
  - Drainage of hydrocarbons/flushing/gas release
  - Steaming
  - Cooling (water filling)
  - Drainage of cooling water
  - Venting (open manhole cover, fit ejector)
- Entry
  - Remove residual products that were not removed during steaming (mechanical cleaning - sludge pumping)
  - Modification work
  - Inspections
  - Jet water test

- Documentation of condition

The incident occurred during removal of deposits inside the separator.

When the manhole was opened, deposits were observed in the manhole. Sludge pumping was therefore carried out from the manhole prior to entry of the tank. Upon entry, it was discovered that the box containing the pall rings was damaged, and that there were pall rings lying on the bottom of the tank. These had to be removed manually before sludge pumping could commence.

Prior to inspection mechanical cleaning is performed to remove residual products that were not removed during steaming (including sludge pumping).

The work team consists of a foreman and six people who take turns to work in the tank. During cleaning of the tank, up to two persons work inside the tank at a time, with one keeping safety watch by the manhole (BES officer). The BES officer is in radio contact with CCR. The people entering the tank normally rotate, with cleaning and flushing being carried out for 1-2 hours before each rotation. At the time of the incident, the work team consisted of two people, with one person inside the tank and one person acting as BES officer.

The cleaning proceeded as planned until the night of 17 April 2024, when the night shift entered the tank and the fire was observed, about 1 day and 8 hours after venting of the separator had started.

The system for work permits (AT) and safe job analyses (SJA) was used during the turnaround in the same way as during normal operation. This is described in more detail in section 2.5.

2.5 Work permits and safe job analyses

Equinor has described the work permit process in the governing document "OM105.01 – Work permit (AT) – Upstream Offshore". The document defines the requirements for AT level for different activities.

The level of the AT determines the person responsible for approval, in accordance with the approval matrix; AT1 (for entry and splitting) is approved by the Platform Manager, while AT2 (for cleaning) is approved by the Production Manager.

The AT system is intended to ensure that risk factors are addressed and that simultaneous activities are coordinated. The principle of internal control means that several independent parties are involved in approval and coordination. The applicant

describes the work, identifies the risks and proposes risk-mitigating measures which are assessed during the approval process.

For high-risk jobs, a safe job analysis (SJA) is conducted prior to the activity in order to identify risks and implement necessary risk-reducing measures. For certain tasks, such as entry, an SJA is required.

For the work on CD2101, several ATs were issued, including an AT for splitting and opening the manhole cover (AT level 1), entry (AT level 1), as well as an AT for work inside the tank (AT level 2). The cleaning job, which was carried out over several shifts, required deactivation and re-activation of the ATs at every shift changeover.

An SJA was prepared prior to splitting and entering, with the involvement of IKM Testing personnel, operations and inspection officers.

The SJA prepared for CD2101 did not include any information regarding the risk of iron sulphide. During the interviews, however, it became clear that risks related to iron sulphide were discussed in the SJA meeting, and some measures for managing the risk of iron sulphide were included in the AT for entry. These measures consisted of the requirement that deposits should be kept wet and that fire hoses should be laid out.

Keeping deposits wet was already included in IKM Testing's delivery in order to prevent the formation of dust from NORM (naturally occurring radioactive material), which is considered to be carcinogenic upon inhalation. A water hose for dampening the deposits was laid out. Fire hoses were laid out, but not all the way to the tank. It was concluded that this was sufficient.

2.6 Governing documentation - handling of iron sulphide

Following the incident on Snorre B (see section 2.8.2), Equinor implemented an adjustment to its internal requirements:

- Entry - The work process (OM105.02) handles preparation of an entry permit and safety preparations before and during entry.
- Guideline GL0378 – Best practice for chemical cleaning.
- TR1055, version 10 concerning PS6.4 regarding the mapping of iron sulphide.

One of the major changes in OM105.02 was related to operating and safety preparations prior to entry, and among other things meant that it must always be assumed that iron sulphide deposits would be present unless such a possibility could be ruled out through testing or analyses. Furthermore, measures were implemented to reduce the risk of auto ignition. Among other things, this meant that deposits

should be kept wet and that the duration of exposure to oxygen should be limited as much as possible.

OM105.02 refers to guideline GL0378. The guideline describes both preventive measures, which must be implemented before the opening of systems with the potential for iron sulphide deposits, and further measures to limit the risk of auto ignition once systems have been opened. In connection with preparations prior to opening, the guideline recommends a two-step steam cleaning method if it is suspected that large quantities of iron sulphide deposits are present. The second steam cleaning step included a chemical pretreatment of deposits which is intended to react with the iron component of the iron sulphide, thereby reducing the amount of iron sulphide present. Furthermore, the guideline stated that work to keep deposits and sediments wet should commence within an hour after the manhole cover on the tank is opened.

In TR1055, version 10, the following is stated regarding iron sulphide: "SR-85881 - The safety strategy shall include information about process segment where iron sulphide may accumulate and pose a threat from auto ignition in connection with maintenance, cleaning or opening of process segment. It should also identify if such an accumulation can be expected during later service life in connection with changes in fluid composition.

During start-up meeting 23.5 with the FLX organisation, the investigation group was informed that TR1055 was not applied as a technical requirement document and that FLX had not carried out the mapping that TR1055 required. Instead, FLX refers to the fact that they apply NORSOK S-001 as the basis for their work.

During the investigation it became clear that updated requirements in TR1055 were not implemented in the safety strategy prepared for any of Equinor's operating units.

2.7 Iron sulphide

Iron sulphide is formed by sulphur reacting with iron in an oxygen-free environment. In oil and gas production, iron will mainly occur in the reservoir but may also originate from the corrosion of ferrous tanks and pipes. The iron reacts with hydrogen sulphide, which is primarily produced by sulphate-reducing bacteria (SRB) in the reservoir. Variations in the concentration of hydrogen sulphide and iron lead to the formation of different types of iron sulphides.

During turnarounds, the facility is shut down and equipment/tanks/pipes are opened up in order to carry out cleaning, inspections, etc.

Some indicators that iron sulphide may be present in a facility:

- Aging facilities with high water production.

- Facilities with water injection.
- Facilities with internal corrosion problems.
- Emulsions in separator, which can be explained by the accumulation of iron sulphide.
- Accumulation of deposits.

2.7.1 Iron sulphide as an ignition source

Experience has shown that ignition can occur if oxygen comes into contact with iron sulphide in deposits, e.g. in connection with:

- Splitting/opening of tanks and pipe systems.
- Following a prolonged period of tank venting.
- Handling of waste.

The reaction between iron sulphide and oxygen is rapid, being of the order of minutes. It causes the particles to glow and leads to substantial heat generation (exothermic reaction). The fumes that are formed are dense and white and can be misinterpreted as water vapour. They contain a high proportion of sulphur dioxide (SO_2). Furthermore, iron sulphide that auto ignites in a tank can also ignite nearby combustible materials, such as hydrocarbon residues.

2.7.2 Iron sulphide on Statfjord

Historically, both SFB and SFC have experienced incidents involving the auto ignition of iron sulphide; see section 2.8. However, this was not the case on SFA.

During the information acquisition and interviews conducted as part of this investigation, it became clear that deposits in the form of "Black Sticky Stuff" (BSS) were first observed around 2000, and that this had been an increasing problem on SFA since 2014. From 2021 onwards, samples analysed for iron sulphide had been systematically taken from wells, tanks and produced water, which documented the presence of iron sulphide in both wells and the processing facility on SFA.

Equinor had prepared a safety data sheet for well deposits on Statfjord. The safety data sheet dated 24 September 2012 states that this type of deposit can contain up to 70% iron sulphide.

Samples taken from tank CD2101 during previous turnarounds also showed the presence of iron sulphide.

During the turnarounds on SFB in 2022 and SFC in 2023, when the separators were also opened and cleaned, specific detailed procedures were prepared which also included the risks associated with iron sulphide auto ignition.

The procedure for SFC in 2023 refers to requirements in the OM105.02 work process for entry, and to guideline GL0378 – Best practice for chemical cleaning. It refers to the incident which occurred on SFC during the same year involving auto ignition during the splitting of PSV. It also refers to the need for detailed and comprehensive measures when splitting pipe systems with hydrocarbons and entering tanks. For example, it stipulates a requirement to maintain overpressure with nitrogen in the tank and to have firefighting water connection points and fire hoses ready in case of heat generation. It also states that the area operator should regularly conduct inspection rounds to check for heat generation. The procedure also states that manholes should be closed in case of heat generation and white fumes.

During the turnaround for SFA, no procedure that included the risks associated with iron sulphide and its auto ignition was prepared.

In connection with the turnaround on SFA in 2019 and cleaning of the test separator and degassing tank ahead of the turnaround in 2024, measures were implemented linked to the installation of connection points for firewater hoses on the separator. These measures were not implemented prior to the splitting of CD2101 during the 2024 turnaround.

SIKKERHETSDATABLAD

Brønnavsetning Statfjord

Sist endret: 24.09.2012 Erstatter dato: 20.09.201(

9.2 Andre opplysninger

Merknad nr.	Kommentar

ANNEN INFORMASJON
Ingen.

10 Stabilitet og reaktivitet

10.1 Reaktivitet
REAKTIVITET
Reagerer med følgende: Oksidasjonsmidler. Ved kontakt med syre utvikles giftig gass.

10.2 Kjemisk stabilitet
KJEMISK STABILITET
Produktet er stabilt når det brukes i henhold til leverandørens anvisninger.

10.3 Risiko for farlige reaksjoner
RISIKO FOR FARLIGE REAKSJONER
Ingen kjente.

10.4 Forhold som må unngås
FORHOLD SOM MÅ UNNGÅS
Ingen kjente.

10.5 Materialer som må unngås
MATERIALER SOM MÅ UNNGÅS
Unngå kontakt med følgende: Oksidasjonsmidler/ Syrer.

10.6 Farlige nedbrytningsprodukter
FARLIGE NEDBRYTNINGSPRODUKTER
Ved brann eller kraftig oppvarming spaltes produktet og følgende farlige gasser kan dannes: Karbonmonoksid og karbondioksid/ Hydrogensulfid (H2S).

Figure 5 From the Norwegian version of the safety data sheet entitled "Well deposits Statfjord", Chapter 10 on reactivity. In the safety data sheet, iron sulphide concentrations are specified as being approximately 70% weight percent (Source: Equinor)

2.7.3 Roles, responsibilities and performance of iron sulphide analyses on SFA

In the production and processing of oil and gas, it is necessary to regularly perform various analyses of production and process fluids. Among other things, these analyses are carried out in order to detect changes in production composition, monitor the effect of the processing facility, and measure compliance with discharge permits.

Based on the analysis results, measures to correct any adverse developments in the processing facility will be considered. When the facility is in operation, such measures may include the addition of chemicals to the process flow (process chemicals), which can help to eliminate or mitigate the adverse effects.

Safety data sheets should generally be available and used to communicate health risks related to the handling of various production products and deposits in the production and processing facility. These data sheets must be established and updated to ensure that they give a relevant picture of factors that contribute to health risks. Analyses conducted while the facility is in operation represent an important source of information in this context.

Responsibility for monitoring, performing the necessary analyses, and proposing any changes or adjustments to the process chemical programme was delegated to onshore engineers. For SFA, this responsibility was delegated to the operations engineer, who prepares a programme which specifies the samples that are to be taken, the frequency of sampling and the analyses that are to be performed. This was carried out in collaboration with the chemical engineer/laboratory technician who was responsible for sample collection and analysis. Some samples were analysed on board, while others were sent to onshore laboratories for further analysis.

Analyses for iron sulphide from deposits and samples on SFA were included in the standard analysis programme from 2021. The proportion of iron sulphide that was detected varied, but high proportions were detected in a number of these samples. We understand that no changes have been made as regards the use and choice of process chemicals as a result of these findings.

Analyses of deposit samples from CD2101 obtained after the incident have confirmed the presence of iron sulphide.

2.7.4 Iron sulphide – IKM Testing's experiences

IKM Testing is a service provider which, among other things, provides services relating to the cleaning of tanks and processing facilities during turnarounds. IKM Testing was the supplier responsible for carrying out tank cleaning during both the

incident involving the iron sulphide fire in the separator on Snorre B in 2019 and the incident in CD2101 on SFA.

During meetings with, and in documentation received from, IKM Testing relating to the investigation, it became clear that the company had established procedures for managing iron sulphide risks.
However, these procedures would only be implemented if the client had made it clear that there was a suspicion or risk that iron sulphide deposits were present. IKM Testing had previously provided cleaning services in order to manage iron sulphide, along with a procedure for further entry and cleaning of tanks for individual customers.

In connection with the planning of the tank cleaning programme during the turnaround on SFA, the provision of two-stage steaming services in order to manage the iron sulphide risk, as described in GL0378, was not included in the scope of work. IKM Testing was engaged in the planning in October 2023.

2.8 Previous incidents involving iron sulphide

The previous incidents referred to below are incidents the investigation team received information about during the investigation, along with incidents referred to in our investigation of Snorre B in 2019.

1. **SFC** 1.4.2023 - During splitting of a Pressure Safety Valve (PSV), fumes emerged from the pipe.
2. **Snorre B** 1.5.2019 - Fire in separator while it was being vented following heavy-duty cleaning.
3. **SFB** in September 2016 - Heat generation in waste from sand trap.
4. **Norne** in September 2012 - Heat generation due to a chemical reaction in an accumulation of iron sulphide.
5. **SFB** May 2012 - Personnel exposed to steam from CD2001 during tank opening.
6. **Kalstø** in January 2012 - Fire in a pig trap upon opening of a door.

The document review linked to these incidents revealed the following experiences and measures:

2.8.1 Incident on SFC, 1 April 2023

The incident occurred during the splitting of a PSV where smoke emerged from the pipe. The smoke development increased until personnel fitted a blind flange on the pipe. The temperature was checked as being 30.2°C on the following day and 19°C two days later. The experience gained through the incident was passed on to all shifts on SFC, and the platform managers on SFA and SFB were informed. On SFC, information has been added to “Ny ombord” (New onboard) and to “Shift Vision”.

2.8.2 Incident on Snorre B in 2019

The fire occurred in connection with preparations for entering the separator. Heavy duty cleaning of the separator was carried out, and the separator was being vented at the time of the incident. Analyses of the contents of the separator after the fire indicated the presence of iron sulphide. It is likely that the fire was caused by auto ignition of iron sulphide in contact with air that further ignited oil deposits still inside the separator.

Equinor revised a number of governing documents and requirements related to the handling of iron sulphide as a result of this incident; see section 2.6.

2.8.3 Incident on SFB in 2016

This incident occurred in connection with the handling of waste from a sand trap from the backflow of scale dissolver. The waste was being collected in an oil drum. Heat generation in the oil drum was discovered during an inspection of the facility. Iron sulphide was suspected to be the cause of the incident.

The experience gained through the incident was passed on to all shifts on SFB in the form of a presentation on *pyrophoric iron SFB* in safety meetings.

2.8.4 Incident on SFB in 2012

The sequence of events is similar to that on 1 May 2019 on Snorre B. Severe heat generation and fumes during venting following a steaming job led the laboratory technician on board to take samples of the remaining material in the bottom of the tank for iron sulphide analysis. The measures implemented after the incident address exposure risk and the use of personal protective equipment (PPE).

One measure describes the transfer of experience to other units. In this regard, it is apparent that the transfer of experience is considered to have been carried out in connection with the Synergi report, along with an experience summary via the turnaround team's final report.

The turnaround team's final report for SFB 2012 refers to problems with iron sulphide in section 5.1 concerning decommissioning. It is stated that tanks should not be opened for venting until blind flanges have been fitted and preparations made for cleaning in order to avoid the oxidation of iron sulphide. No information is provided on the challenges associated with iron sulphide with regard to auto ignition.

2.8.5 Incident on Norne in 2012

On Norne, heat and smoke generation was observed in the slag material (which contained iron sulphide), which had been removed from a pipe bend for produced water. According to the Synergi report, measures were intended to dampen the material with water and prevent oxygen supply to the material.

2.8.6 Incident on Kalstø in 2012

On Kalstø, fire was observed when opening the pig trap. Although iron sulphide was known to be present, the quantity actually present was much greater than assumed. The black dust which fell from the pig trap began to smoulder. A subsequent in-depth study would contribute to the learning effect in order to prevent recurrence of the incident. The study referred to a number of previous cases of smouldering fires in black dust on both Kalstø and Kårstø.

Of the measures that were implemented after this incident, several address the need to change the type of protective equipment in order to provide protection against heat and possible fire, along with technical measures to prevent iron sulphide from being exposed to air.

2.9 Abbreviations

AO	Work order
ARIS	Equinor's process-based management system
ARL	Alarm and response team
AT	Work permit
BES	Fire and evacuation officer
BSS	Black sticky stuff
DSHA	Defined situations of hazard and accident
FiFi	Fire fighting
FLX	Field life extension
GA	General alarm
H_2S	Hydrogen sulphide
HC	Hydrocarbon
Havtil	Norwegian Ocean Industry Authority
LRA	Low-level radioactive waste
NORM	Naturally Occurring Radioactive Material
PA	Public announcement
POB	Personnel on board
PRS	Personnel registration system
PS	Performance standard
PDO	Plan for development and operation
PSV	Pressure safety valve
PPE	Personal protective equipment
RS	Turnaround
S&R team	Search and rescue team
SAR	Search and rescue
SFA/B/C	Statfjord A/B/C
SJA	Safe job analysis

SKL	Incident site manager
CCR	Central control room
SNB	Snorre B
SRB	Sulphate-reducing bacteria
TTS	Technical condition safety
VOC	Volatile organic compounds

Table 2 Overview of Abbreviations

3 Havtil's investigation

The investigation team consisted of six people with relevant expertise. With regard to areas where the team lacked specific expertise, relevant experts from the Norwegian Ocean Industry Authority (Havtil) were consulted.

From Equinor, we have received results of analyses of samples of iron sulphide taken from tank CD2101. These were conducted at Equinor’s laboratory in Porsgrunn.

3.1 Method

The incident occurred on 17 April 2024 and a meeting regarding the incident was held between Equinor and Havtil on the same day.

On 23 April 2024, we gave notice that we intended to investigate the incident, and held a start-up meeting at Equinor's offices on Forus with representatives from the management and the safety service for FLX and SFA. During this meeting, the mandate was announced and it was stated that we did not believe it was necessary to conduct an offshore inspection as part of the investigation. The first interview with the platform manager was conducted after the start-up meeting on the same day.

During the first part of the investigation, priority was given to interviewing offshore personnel who played a role in the incident, the emergency preparedness or the normalisation after the incident, and accessing relevant documentation. The timeline was established based on this.

On 2 May 2024, IKM Testing was notified that the company was required to participate in the investigation, and the start-up meeting was held at IKM-testing offices on Sola the same day. A review of our mandate was conducted, during which we emphasised that the aim of the investigation was to help avoid any further such incidents and assess previous similar incidents.

In addition to interviews with personnel directly involved in the incident, members of the management team in Equinor’s FLX organisation and IKM Testing were interviewed. It was also decided to interview:

- Personnel within the FLX organisation who were familiar with analyses of iron sulphide in wells and processing facilities; see section 2.7.3.
- Administrators/authors of governing documents and guidelines, such as the work process (OM105.02) for entry, guideline GL0378 – Best practice for chemical cleaning, and the requirements of TR1055 regarding ignition control and iron sulphide.

Most interviews were conducted with Equinor acting as an observer. Two of the interviews were conducted with IKM Testing acting as an observer. Relevant documents were received from both Equinor and IKM Testing.

The final interview was conducted on 17 June 2024, and the last information was received from Equinor on 5 August 2024. Equinor's investigation report in which IKM Testing participated was received on 25 June 2024.

3.2 Investigation method

In the early stages of the investigation, a timeline was established based on information obtained from interviews and documentation received. A simplified version of this is presented in Chapter 0. Before the summary meetings were held with Equinor (19 June 2024) and IKM Testing (20 June 2024), the timeline was sent to the participants and reviewed in detail during the meetings. Minor adjustments to the timeline were made after the summary meetings. The timeline in this report differs slightly from that in Equinor's investigation report.

With regards to the incident on SFA on 17 April 2024, the time of the fire was determined fairly accurately as being 00.32. The time at which the hazard situation arose is less certain, but the investigation team decided to define this as occurring when the manhole cover was opened at 16.30 on 15 April 2024 and air entered the separator.

In this investigation, Havtil has emphasised the investigation and assessment of factors which may have influenced the situational awareness, decisions and actions of those involved. It has been important to highlight:

- Safety-related responsibilities.
- Decisions and inadequate performance of tasks.
- Situational awareness or why decisions and actions were taken by those involved.

4 Sequence of events

The main aspects of the sequence of events are described below, while a detailed timeline is presented in Table 3. The table also contains information on events prior to the incident, which may have impacted its development.

In connection with the turnaround on SFA, the platform was depressurised and emptied of hydrocarbons, and the separators steamed as part of preparations for the mechanical work.

At 16.30 on 15 April 2024, the manhole cover for inlet separator CD2101 in area CD12 was opened.

At 20.00 on 16 April 2024, following the shift changeover, visibility inside the tank was reported as being poor, approx. 30-40 cm.

When the separator was entered at 00.32 on 17 April 2024, the tank operator observed a flame of approx. 15-20 cm approx. 40-50 cm directly in front of his face when standing in an upright position.

The BES officer notified CCR of the fire. The tank operator exited the tank and evaluated the module together with the BES officer.

Operator in CCR manually triggered a general alarm (GA) at 00.34. The alarm response team (ARL) started flushing the separator via the manhole, while the S&R teams were preparing for action. The two members of the ARL observed white smoke coming out of the manhole while trying to extinguish the fire. These two individuals did not wear any personal protective equipment and were exposed to smoke before they exited the module and were treated by a medic.

S&R team 1 commenced its response at 00.52 and took over from the ARL. An overview of personnel on board (POB) indicated that five persons were missing. A POB check was carried out at 01.54 and the situation was normalised by 02.07.

Time	What	Comments
Key points concerning the lead-up to the incident:		
2000	First encounter with H_2S in the reservoir at Statfjord.	

Time	What	Comments
2012	Iron sulphide incident on SFB, Norne and Kalstø. Safety data sheet for well deposits Statfjord.	The incidents described in section 2.8. The safety data sheet estimates that deposits contain approximately 70% iron sulphide.
2014	BSS - Black Sticky Stuff discovered on SFA.	
Turnaround 2017	Iron sulphide detected in inlet separator CD2101.	Based on the samples, it is estimated that there are more than 500 kg of iron sulphide present.
20 September 2019	OM105.02 Procedure for entry was updated.	OM105.02 refers to GL0378, Best practice, Appendix H. It should be assumed that iron sulphide is present unless the possibility can be excluded via analyses or samples.
2019	Manhole cover on CD2101.	The hinges were removed so that the cover could no longer be mounted by hand. A lifting device therefore had to be used.
16 September 2020	GL0378, Norwegian version 2.02.	Best practice for chemical and mechanical cleaning, and ref. Appendix H on Risk and mitigation measures. Ref. section 2.6.
18 December 2020	TR1055 version 10, requirements regarding iron sulphide.	Ref. section 2.6.
2022	Turnaround SFA. Certain aspects deferred until 2024.	Most of the tank programme was rescheduled.
2022	SFB RS22 - Procedure for iron sulphide management	Applies to requirements linked to the entry of separators; GL0378 not mentioned in the procedure.
1 April 2023	Iron sulphide incident on SFC.	Ref. section 2.8.1.
Approx. April 2023	Planning of turnaround RS24 commences.	
2023	SFC RS23 Procedure for iron sulphide management.	The procedure applies to the splitting of pipelines, the entry of tanks and the handling of residual waste. GL0378 and the incident on SFC on 1 April 2023 are mentioned.

Time	What	Comments
6 October 2023	IKM awarded contract for tank cleaning during turnaround.	
End of October 2023	IKM Testing commences the tank programme work.	Equinor confirmed to the IKM Testing's tank manager that they had "not encountered any challenges" with regard to iron sulphide on SFA.
Preparations for turnaround:		
February 2020	Turnaround seminar (seize and startup of production meetings).	Two days, time adapted to different shifts. IKM Testing participates. Some area managers were not involved.
March 2024	Advance activity involving cleaning of two tanks.	Fire hoses were laid out and firewater connections prepared prior to entry.
8 April 2024	Production is stopped, decommissioning commences.	
10 April 2024 at 13.15	The facility is depressurised.	IKM Testing commences work to steam the separator.
11 April 2024 at 15.10	Steaming of CD2101 is stopped.	CD12.
14 April 2024 at 01.39	Blanking of CD2101 initiated.	
15 April 2024	SJA is carried out.	Led by IKM Testing. Iron sulphide was discussed, but not documented in the SJA. Iron sulphide risk included in AT1 for entry which included requirements for the connection of a fire hose and wetting of the material in CD2101. Two area managers did not participate in the review due to high workload. Rescue plan prepared in advance, signed on 8 April 2024.
15 April 2024 at 16.30	Manhole cover opened and venting commenced. AT1 for splitting	Solid material falls out upon opening of manhole cover.

Time	What	Comments
15 April 2024 at 16.30	IKM Testing's tank team and area manager review administrative procedures.	AT1 for entry was signed. Review by CCR. They agreed how the tank team and CCR should communicate. Concluded with an inspection of the tank area.
16 April 2024 at 02.26	AT1 for entry activated.	
16 April 2024 at 02.45	Venting of separator.	
16 April 2024 at 07.40	AT renewed and cleaning of CD2101 continued.	The tank operators switch to working inside the tank, approx. 1-2 hours per session before being relieved. Focus on collecting up pall rings at the start; cleaning including removal of the material in the tank. The loose material is removed first before high-pressure flushing.
16 April 2024 (shift changeover)	Unknown odour on board.	Odour detected outside CCR, in the living quarters and elsewhere. Ventilation room was investigated without anything untoward being encountered.
16 April 2024 at approx. 20.00	Entry of separator (personnel changeover).	VOC measurement completed.
16 April 2024 at approx. 22.00	Entry of separator (personnel changeover).	Tank measurement completed half an hour previously: Low VOC, no LRA measured.
17 April 2024 at approx. 16.30	Entry of separator (personnel changeover).	Poor visibility recorded.
Incident:		
17 April 2024 at approx. 00.32	**Tank operator discovered a naked flame.**	**Stood up by chance inside the tank and saw a naked flame, 15-20 cm tall. Chalk-white fumes. BES contacts CCR and reports the observation. Tank operator exits the separator.**
Emergency preparedness and incident management:		

Time	What	Comments
	CCR asks ARL for a "check and reports".	
17 April 2024 at 00.34	Operator in CCR initiated GA manually.	ARL initiated flushing with 1" freshwater hose. (No connections for connecting 2" fire hoses had been prepared prior to the work, as described in AT1).
17 April 2024 at 00.52	S&R team 1 commences its response.	
17 April 2024 at 00.55	Fumes from manhole confirmed.	Filling of CD2101 with water via the manhole commenced. Efforts made to locate connection points for firewater.
17 April 2024 at 01.17	POB overview.	5 persons missing.
17 April 2024 at 01.17	S&R team 2 ready to respond and swaps with team 1.	Team 1 replaces air bottles and is ordered to start filling CD2102 and CD2103 in CD9.
17 April 2024 at 01.35	CD2101 filled with water for the manhole.	The manhole cover cannot be closed.
17 April 2024 at 03.36.	POB	Three persons found following search in the living quarters on the 3rd floor.
17 April 2024 at 01.42	POB	Two persons found in the living quarters.
17 April 2024 at 01.47	Fire under control.	Area is secured.
17 April 2024 at 01.54	POB	All personnel mustered at their respective stations.
17 April 2024 at 02.07	Normalisation.	Awaiting notification of stabilisation of situation.
17 April 2024	Manhole cover is fitted to CD2101.	The separator can be completely filled with water.

Table 3 Timeline of the incident

5 Potential of the incident

5.1 Actual consequences

The actual consequence was a fire and associated smoke inside the inlet separator. One individual from IKM Testing, wearing respiratory protection, was inside the separator at the time the fire was discovered. This person managed to get out and CCR was notified. Personnel from IKM Testing have been routinely followed up since.

When IKM Testing personnel left the separator area, the alarm and response team (ARL) on the platform arrived at the scene and flushed the separator. They were exposed to smoke while trying to extinguish the fire from the manhole. These individuals were not wearing firefighter clothing or other personal protective equipment; see Chapter 7 for more information on the handling of emergency preparedness. Exposed personnel have been routinely checked since.

The turnaround period was extended as a result of the fire.

5.2 Potential consequences

In connection with the turnaround, the processing facility was depressurised, drained and steamed, and it is our opinion that there was limited potential for spreading of the fire from this separator.

We have been informed that it was the S&R/firefighting team that stopped mechanical venting from CD2101. This vented air was routed beneath the platform and the smell of fumes from the fire could be detected at the muster station by the lifeboat. Large amounts of iron sulphide and smoke could have exposed personnel in this area if the venting had not been stopped.

No assessments were made regarding whether the waste was a potential ignition source. However, we were informed during interviews that the waste was being handled as low-level radioactive waste (LRA), which means that it was kept wet. As a result, this helped to reduce the likelihood of iron sulphide in the waste being auto ignited. We consider it unlikely that handling of the waste could have resulted in a fire elsewhere on the facility.

An iron sulphide fire with SO_2 and possibly other harmful components in the smoke could rapidly have had life-threatening consequences without fresh air breathing equipment and protective clothing. The rescue plan prepared for the turnaround did not mention the risk of iron sulphide fire, nor did it cover rescue from a tank filled with smoke and SO_2. FLX estimates that there were initially between 2,000 and 4,000 kg of iron sulphide in the tank, and only limited quantities of deposits had been

removed from the tank by the time the fire started. So, there were large quantities of iron sulphide still present in the deposits in the tank, and ignition of these along with residues of hydrocarbons could have led to substantial heat generation. This could have damaged the tank operator's fresh air breathing hose and thus placed him in significant danger. The S&R team were equipped with fresh air masks which give adequate protection against both SO_2 and other types of fumes and harmful gases.

During the investigation, we were informed that there were several tanks in area CD9 that were open at the same time as separator CD2101 in CD12. This could potentially have led to a fire in two modules on SFA, in both CD12 and CD9.

6 Direct and underlying causes

6.1 Direct cause

The direct cause of the incident was auto ignition of iron sulphide in inlet separator CD2101 being exposed to atmospheric oxygen (see section 2.4.1.).

The exothermic reaction could occur as a result of a combination of:

- Inflow of oxygen/air into the separator.
- The presence of iron sulphide from the wells.

6.2 Underlying causes

The investigation shows that a number of factors contributed to the hazard and accident situation involving the fire on SFA, and had an impact on the scope to manage the incident.

The underlying causes are primarily linked to:

- Deficiencies in governing documents within Equinor and FLX and their use.
- Roles and responsibilities related to iron sulphide analyses and the use and dissemination of the results.
- Planning and execution of the cleaning process.

6.2.1 Governing documents in Equinor and FLX

Following the incident on Snorre B (see section 2.8.2), Equinor revised the internal requirements for confined space entry in the work process (OM105.02), guideline GL0378 – Best practice for chemical cleaning and introduced new requirements in TR1055 for the mapping of iron sulphide; se section 2.6.

It emerged during the investigation that the aforementioned adjustment in OM105.02 was communicated onwards, but was considered to be a minor adjustment in relation to the previous requirement. This requirement was also unknown to several of the people we interviewed during the investigation from both Equinor and IKM Testing.

In guideline GL0378, Annex H, various preventive measures are proposed based on the levels of iron sulphide that have been detected/mapped in the process flows/facility. However, the measures seem unclear, as they do not specify specific element levels for the various approaches.

Also described in GL0378 is the implementation of a two-stage chemical steaming process if high levels of iron sulphide have been detected. None of the Equinor personnel we interviewed as part of the investigation were aware that a method or chemical package had been established which could be used in order to follow this guidance. GL0378 was also not made known to IKM Testing as the service provider for tank cleaning on SFA.

6.2.2 Knowledge of iron sulphide concentrations in the processing facility on SFA

Information on the presence of iron sulphide in the facility on SFA was not actively communicated to or used by those responsible for planning turnaround RS24.

Lack of awareness among both operating personnel and the turnaround team that iron sulphide had been detected in the production and processing facility on SFA appears to be the most likely reason why this was not taken into account during the planning of the turnaround in 2024.

6.2.3 Planning and execution of tank cleaning

As described in section 2.6, the presence of iron sulphide is significant when assessing the choice of cleaning method and in the establishment of measures to prevent and manage auto ignition.

There was no discussion of the risk of iron sulphide or possible measures to manage this risk during the planning phase.

During the planning phase, the scope of work and expected resource requirements were defined for the work for each individual separator. The turnaround team's lack of awareness of the presence of iron sulphide resulted in essential measures to manage iron sulphide not being considered when determining the cleaning method, the resource requirements and possible time limitation regarding venting of separators. At the time of the incident, several separators were to be vented. Updated

requirements in OM105.02 for venting were not known to those who prepared the procedures for the tank-related work.

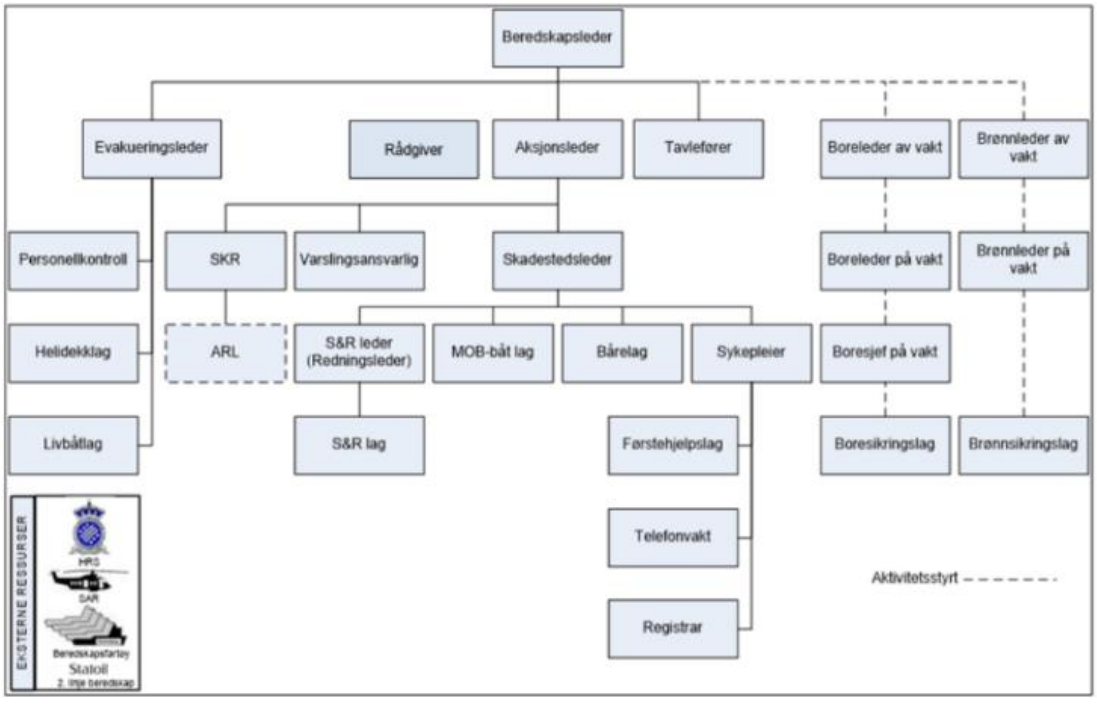
Cleaning of the separator tank is carried out continuously day and night and involves executive personnel from IKM Testing and area operators who are responsible for follow-up/measures within their respective areas. The risk of iron sulphide was discussed during the SJA prior to the job. It was decided to include certain measures in the AT for entry, even though the probability of iron sulphide problems was considered to be low. However, this was not documented in the SJA, which meant that the risk of iron sulphide in the tank was only communicated to a limited extent.

7 Emergency preparedness

The regulations require licensees and others who participate in petroleum activities both on the Norwegian continental shelf and on land to maintain effective preparedness at all times in order to manage situations of hazard and accident that could result in loss of human life or personal injury, environmental pollution or substantial material damage.

7.1 Emergency preparedness organisation

The emergency preparedness organisation, roles and tasks for the emergency preparedness organisation on SFA are described in a supplement to: *Beredskap på norsk sokkel – Beredskap på norsk sokkel - Statfjord A (Emergency preparedness on the Norwegian continental shelf – Statfjord A), Final Ver. 14, published 3 April 2023*.



7.2 Figure 5 The emergency preparedness organisation on SFA. Emergency preparedness management of the incident

In this section of the report, our description of the emergency preparedness and response is based on interviews with technical personnel who were present in the control room during the incident, the alarm response team, emergency preparedness personnel involved at the scene of the accident out in the field, managerial personnel and emergency preparedness managers, in addition to emergency preparedness plans and logs from the incident.

We describe the emergency preparedness measures that were activated from alarm and notification, until evacuation and emergency response were implemented, through until the normalisation phase after the situation had been clarified and the fire extinguished.

7.2.1 Alarm, notification and mobilisation

Immediately after the naked flame was discovered in the separator, the tank operator alerted the BES officer, who in turn reported the fire to CCR via radio. The tank operator immediately exited the tank.

At 00.34, the general alarm (GA) was activated by CCR, which involved all personnel without any emergency preparedness tasks mustering at lifeboat stations. In addition, personnel with emergency tasks were required to muster at their respective muster stations. The operators in CCR responded in accordance with the emergency preparedness plan, using **DSHA no. 03 "Fire or explosion"** as the basis for further actions.

The weather was logged: NE wind, 10 kn, gusting to 13 kn. Visibility was good, with a significant wave height of 1.9 m.

7.2.2 Firefighting and rescue

The ARL, which consisted of two process operators, was immediately sent to area CD12 to verify the status – check and report back to CCR.

ARL asked the accident scene manager (SKL) if they could start extinguishing the fire, which was interpreted as being the go-ahead to commence firefighting. At this time, SKL was convinced that firewater connection points had been installed at both ends of the tank, but this subsequently turned out not to be the case, as the connection points concerned had not been readied for use.

ARL immediately began work, wearing protective equipment in the form of overalls, helmet, safety shoes, gloves and goggles, rather than firefighter clothing suitable for

the task of firefighting in a tank. This was initiated pending the search and rescue team (S&R/firefighting team) becoming operational.

ARL then started applying water using handheld water hoses inside the tank via the manhole. However, the fire hoses that should have been ready before the work was commenced in the inlet separator had not been laid out, in breach of the requirement stipulated in the entry permit AT1.

During the firefighting process, fumes were coming out of the manhole, which resulted in two members of the ARL team being exposed to toxic fumes to some extent before they withdrew from the area.

The platform manager arrived in the emergency preparedness room to direct the emergency preparedness effort immediately after the alarm had been raised. Two SAR helicopters, one ordinary helicopter, and one emergency preparedness vessel with FIFI (firefighting system) were immediately requisitioned.

The rest of the emergency preparedness management mustered in the emergency preparedness centre on an ongoing basis, and measures and actions were carried out in accordance with the emergency preparedness plan and DSHA No. 03 “Fire or explosion”. Other crew members mustered in accordance with the alarm instructions.

An initial meeting was held in the emergency preparedness centre and an accident scene management centre was set up in CD14. The rescue leader arrived at the accident scene management centre, where SKL was located.

The S&R teams mustered at the scene of the accident and were operational by 00.45. At this point, one person was missing from one of the two S&R teams. The missing person had mustered at the lifeboat station and claimed they had not been informed of their role in the S&R team. The person concerned was quickly collected from the lifeboat, so that both teams had a full complement. An emergency hospital was set up and the S&R team was cleared for operation and then took over from the alarm response team.

S&R team no. 1 then entered CD12 and began filling the separator with water via the manhole using fire hoses. The radio communication between the S&R team and SKL did not work optimally with regard to confirmatory communication. In addition, there were a number of interruptions in the radio link (known as ‘radio clipping’), in that the radio link kept dropping out and returning, and did not work continually. At the same time, efforts were made to locate connection points for firewater directly on the tank. Connection points for fire hoses were eventually located, but these had not been

readied for use. Later that night, couplings for fire hoses were fitted to the connection points by the mechanical engineering department.

The two members of the ARL team who had been exposed to fumes were taken to the hospital for follow-up and health checks. The medic was in contact with the duty doctor on land. We were subsequently informed that it was not believed that the two members of the ARL team had suffered any injuries.

7.2.3 Personnel overview

SFA normally uses a system involving personal registration clocks (PRS clocks) for POB counts. Due to the helicopter company having insufficient PRS watches, some of the personnel onboard had no PRS watch upon arrival on SFA. It was therefore decided at an early stage to instigate manual counting in the event of an emergency preparedness situation. This resulted in the POB count taking longer.

At 00.34, the general alarm (GA) was activated in order to initiate mustering. At 01.17, five persons had still not been accounted for, and a search for these persons was started in the living quarters.

Between 01.36 and 01.40, five persons were found asleep in the living quarters: three persons on the 3rd floor, one person on the 2nd floor, and one person on the 4th floor.

After 1 hour and 20 minutes, everyone was mustered at their respective stations. No evacuation from SFA was carried out.

7.2.4 Normalisation

The main purpose of the normalisation phase is to restore the facility and its associated personnel resources to the normal, reliable state.

The S&R team eventually checked whether there were any signs of fumes or fire in the tanks, CD2102 and 2103 (CD9), with a negative result. These tanks were then filled with water.

At 01.35, it was reported that tank CD2101 was so full of water that water was flowing out of the manhole. The S&R team then withdrew, and at 01.47, it was reported that the situation had been clarified and the area secured. Normalisation commenced at 02.07 and a safety watch was established.

The manhole cover that had no hinges was fitted to tank CD2101 by the mechanical engineering department on the same night. No fire watch was established, as it was

not considered necessary given that the tanks were continually being filled with water.

8 Observations

Havtil's observations are generally divided into two categories:

Non-conformity: Observations where we *prove* the existence of a breach/non-compliance with respect to the regulations.

Improvement point: Observations where we *believe we have seen a* breach/non-compliance with respect to the regulations, but do not have sufficient information to be able to prove it.

8.1 Non-conformities

8.1.1 Inadequate information in connection with planning of tank cleaning during turnaround

Non-conformity
Equinor failed to ensure that the requisite information concerning the possibility of iron sulphide was obtained, processed and communicated to relevant users in a timely manner prior to the planning of tank cleaning on SFA, and in connection with the handling of waste on SFA.

Rationale
Through various analyses, it has been discovered that iron sulphide is present in wells and the processing plant at SFA.

The interview revealed that the first observations of H_2S from production on SFA were recorded around the turn of the millennium. The presence of H_2S in the reservoir or processing facilities is associated with an elevated risk of iron sulphide formation. Challenges relating to well deposits and Black Sticky Stuff (BSS) were recorded as a growing issue around 2014. BSS is also associated with a significant risk of iron sulphide formation.

The safety data sheet concerning well deposits in the Statfjord Field states that the well deposits may have contained 70% iron sulphide as far back as 2012, but does not include any information on physical or chemical properties or concerning the reactivity of iron sulphide; see section 2.7.2. This could have contributed to a better understanding of the risks for the personnel involved.

During the turnaround on SFA conducted in 2017, samples were taken from deposits in inlet separator CD2101 which indicated the presence of iron sulphide.

From 2021 onwards, samples were systematically taken from wells, tanks and produced water which documented the presence of iron sulphide in both wells and the processing facility on SFA.

However, knowledge of the presence of iron sulphide and the risks involved was not communicated to the personnel who were planning turnaround RS2024 and the work in CD2101.
Thus, the likely presence of iron sulphide was not taken into account in the planning process.

It was also not ensured that supplier IKM Testing was given information so that they could adapt their work practices to account for the possible presence of iron sulphide in the deposits they had to handle in the tank.

No procedures have been developed as regards preparations for entry or the entry of separator CD2101 which mitigate the risk of iron sulphide ignition concerning, for example, the choice of cleaning method, time of venting and the need for additional resources in order to keep the deposits wet.

Requirements
The Management Regulations, Section 15 on information, second paragraph, cf. the Activities Regulations, Section 29 on planning, first paragraph

8.1.2 Inadequate risk assessment in connection with opening of the manhole cover on the inlet separator (splitting of hydrocarbon systems)

Non-conformity
The safety clearance prior to opening of the manhole on the inlet separator did not include measures to manage the risk of iron sulphide

Rationale
The task of opening the manhole on inlet separator CD2101 did not take into account the risks that the opening entailed.

Via interviews and other documentation, we have ascertained that the manhole cover was opened on 15 April 2024 at 16.30 There is a specific AT1 for the opening/splitting of the tank. There were no requirements for measures linked to iron sulphide, as there were in AT1 for entry.

During the period while the separator was being vented, Equinor did not take into account the risk that the manhole cover could not be closed rapidly.

It is somewhat unclear exactly when air (oxygen) was supplied to CD2101, but it occurred long before the fire was discovered just after midnight on 17 April 2024 (32 hours later). During the interviews, we were informed about an unknown odour (see Chapter 11), while the personnel who entered CD2101 also mentioned poor visibility in the separator. It is possible that a reaction between oxygen and iron sulphide may have started before the personnel entered the tank, or when the personnel were working in the tank during the day and night shift on 16 April 2024.

Requirements
The Activities Regulations, Section 30 on safety clearance of the activity

8.1.3 Inadequate knowledge of requirements in governing documentation

Non-conformity
SFA/FLX personnel were unaware of the requirements stipulated in the governing documentation concerning the handling of iron sulphide.

Rationale
Following the incident on Snorre B involving the ignition of iron sulphide, the governing documentation was updated to prevent similar incidents. The following requirement documents were updated: ARIS process for entry (OM 105.02), as well as best practice for cleaning (GL 0378). Performance requirements for ignition source control in TR1055 were also updated. However, it is understood that FLX/SFA do not use TR1055 as a technical requirement document.

Through interviews, we have learned that, although owners and authors of technical requirements within Equinor are responsible for disseminating information about new requirements among the various operating areas, there is no further follow-up from the requirement owner afterwards. The operating areas must then carry out a gap assessment of new operating and technical requirements and are responsible for implementation within their own organisation.

In this case, changes to governing documentation, linked to the requirement to take account of the presence of iron sulphide if the presence of iron sulphide cannot be excluded through sampling or analysis, were not known or being followed in connection with the planning of tasks (mechanical cleaning of CD2101). See also non-conformity 8.1.1.

Requirements
The Activities Regulations, Section 20, second paragraph, letter b

8.1.4 Handling of iron sulphide

Non-conformity
Equinor has failed to ensure that GL0378 concerning the handling of iron sulphide is formulated in a way which fulfils its intended purpose.

Rationale
Some of the measures described in guideline GL0378, Appendix H are unclear. In the guideline, various preventive measures are proposed based on the levels of iron sulphide that have been detected/mapped in process flows/the facility. However, the guideline does not specify specific element levels for the different approaches.

GL0378 describes a two-stage steaming process for use if high iron sulphide levels have been confirmed. The first step included the use of water vapour with added chemicals to react with iron sulphide and form less flammable compounds. Through interviews, it was confirmed that Equinor has not identified which chemicals should be used in the chemical handling of iron sulphide, nor has it previously used this approach for its facilities and installations.

In connection with the turnarounds on SFB in 2022 and on SFC in 2023, separate detailed procedures were prepared for iron sulphide; see section 2.7.2. During the turnaround on SFA, no corresponding procedure was prepared which included the risks associated with iron sulphide or its auto ignition.

Requirements
The Activities Regulations, Section 24 on procedures, second paragraph

8.1.5 Inadequate personnel controls

Non-conformity
Equinor failed to ensure that the personnel on board SFA could be located and rescued as quickly as possible.

Rationale
The head count system during mustering did not work satisfactorily within the applicable performance requirements. The performance requirement for mustering on SFA is 25 minutes; ref. WR1156, section 3.2.2. As a result, it took more than an hour and eight minutes to complete the POB count.
It took one hour and 20 minutes before everyone was mustered at their respective stations.

Personal registration watches (PRS watches), which are normally used on SFA for POB controls during mustering, were not distributed in sufficient numbers for all passengers at the heliport prior to departure because the supplier did not have

sufficient watches in stock. This meant that a manual POB count had to be instigated, which took longer. During some of the interviews, it also emerged that the general alarm (GA) was terminated somewhat prematurely, and this may have been a factor in not everyone realising that they needed to muster in the lifeboats.

Requirements
The Activities Regulations, Section 77 on the handling of hazard and accident situations, letter c, cf. d.

8.1.6 Inadequate planning of firefighting measures

Non-conformity
Equinor failed to ensure that firefighting measures were implemented as soon as possible in connection with the fire in the inlet separator.

Rationale
Important fire prevention measures, as described in the AT (the entry permit) included keeping the iron sulphide wet/damp. The AT for tank entry included a requirement for connection points on the tank to be prepared and fire hoses laid out, so that water could readily be applied if heat generation was observed.

During interviews, it emerged that the fire hoses had not been laid out or readied for use before the work in the inlet separator began.

Requirements
The Activities Regulations, Section 77 on the handling of hazard and accident situations, letter b

8.2 Improvement points

8.2.1 Deficiencies in the company's follow-up to ensure that new requirements are implemented

Improvement point
Equinor does not appear to have followed up to ensure that the new requirements in the management system concerning the handling of iron sulphide were functioning as intended.

Rationale
In the updated TR1055, version 10, the following is stated concerning iron sulphide: "SR-85881 - The safety strategy shall include information about process segment where iron sulphide may accumulate and pose a threat from auto ignition in connection with maintenance, cleaning or opening of process segment. It should also

identify if such an accumulation can be expected during later service life in connection with changes in fluid composition.

We have been made aware that the new technical requirements of TR1055 have been disseminated in many contexts, e.g. in specialist network meetings. In addition to information on new requirements, Equinor has dedicated verification groups to follow up the requirements in TR1055 through Technical Condition Safety (TTS). The TTS groups carry out their verifications with the aid of checklists, which must then reflect the requirements stipulated in TR1055. We have been informed that the new performance requirement for ignition source control and iron sulphide mapping was not added to the TTS checklist.

During the start-up meeting with FLX held on 23 May, the investigation group was informed that TR1055 was not used as a technical requirement document and that FLX had therefore not carried out the mapping that TR1055 required. Instead, FLX notes that they apply NORSOK S-001 as the basis for their work.

During the investigation, it emerged that, as FLX did not pick up on the changes to TR1055, it has neither updated its safety strategy nor become aware of this issue in any other way. It therefore appears that Equinor did not follow up to ensure that the risk that the changes in TR1055 was intended to address was also taken into account in governing documents as a basis within FLX.

Requirements
The Management Regulations, Section 21 on follow-up

8.2.2 Inadequate mustering of the search and rescue team (S&R team)

Improvement point
Equinor does not appear to have ensured the necessary transfer of information to members of the S&R team concerning mandatory tasks within the emergency preparedness organisation in connection with shift and crew changeovers.

Rationale
The S&R team was established with six members, but the team only mustered with five people when the general alarm (GA) was sounded**.** One member of the S&R team claimed that he had not been informed he had been assigned to the S&R team and had therefore mustered at the lifeboat station. The person concerned had to be taken off the lifeboat.

As a result, it took a very long time for the S&R team to be fully staffed, although this did not lead to any demonstrable delay in fire-extinguishing.

Requirements
The Activities Regulations, Section 32 on the transfer of information at shift and crew changes; cf.
The Activities Regulations, Section 75 on emergency preparedness organisation, first paragraph

8.2.3 Inadequate radio communication

Improvement point
Equinor does not appear to have ensured that the necessary internal radio communication between the personnel in the S&R team, SKL and CCR was safeguarded at all times during the emergency preparedness response in connection with the fire in the inlet separator.

Rationale
Radio communication between the S&R team, SKL and CCR did not work optimally with regard to confirmatory communication. In addition, there were a number of interruptions in the radio link (known as 'radio clipping'), in that the radio link kept dropping out and returning, and did not work continually. Among other things, this meant that CCR believed that the connection points for the fire hoses on the inlet separator had been found, which subsequently proved not to be the case.

Requirements
The Activities Regulations, Section 80 on communication, first paragraph

8.2.4 Inadequate emergency preparedness training and drills for work in tanks

Improvement point
Equinor appears not to have ensured that the necessary emergency preparedness training or drills were carried out for work in the tank/inlet separator in question, to ensure that the personnel concerned could have managed a fire in the tank/separator efficiently.

Rationale
During interviews, it emerged that insufficient training and drills were carried out concerning the rescue plan relating to work in the tank/inlet separator concerned.

Among other things, this meant that, prior to the incident, the response personnel were unaware that there were no connection points for fire hoses on the tank/inlet separator, and that the cover over the manhole had been removed.

Before the incident, it was also not known that the fire hoses that should have been laid out were too short to reach the site of the fire, or exactly where these hoses were located in relation to the inlet separator.

This meant that it took a long time to find the right fire hoses, which then had to be prepared and joined before they could be used.

Requirements
The Activities Regulations, Section 23 on training and drills, first paragraph; cf. The Activities Regulations, Section 77 on the handling of hazard and accident situations, letter b

9 Barriers that did function

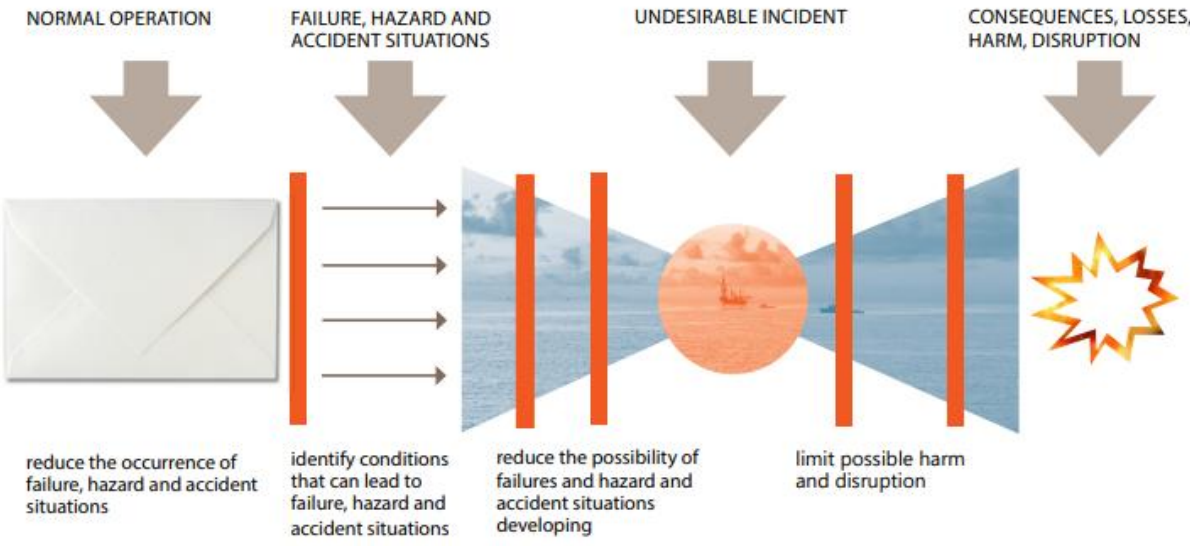


Figure 6 Traditional barrier diagram – From PSA barrier memorandum 2017

The incident was managed in accordance with DFU03 "Fire or explosion". The breaches of barriers primarily occurred on the left-hand side of the Bow-tie diagram, particularly with regard to the inadequate identification of the likelihood of damage/injury, fault, hazard and accident situations occurring.

On the right-hand side of the diagram, the following barrier elements worked:

- CCR was notified of the fire by the tank team's emergency preparedness duty officer (BES) over the radio and followed up by activating the general alarm

(GA). ARL was dispatched to the area and verified the presence of fumes in the tank.
- Emergency preparedness teams and first-aid personnel mustered in accordance with the relevant instructions and performance requirements, but one member of the firefighting team mustered in a lifeboat.
- The emergency preparedness management immediately requisitioned two SAR helicopters, one ordinary helicopter and an emergency preparedness vessel with FIFI.
- The emergency preparedness management mustered in the emergency preparedness centre on an ongoing basis.
- The accident scene management centre was set up in CD14 and the rescue leader and accident scene leader arrived at the accident scene management centre in accordance with the relevant instructions and performance requirements.

The emergency preparedness circumstances that had errors and deficiencies are described in Chapter 7.

10 Learning and follow-up of previous incidents involving the auto ignition of iron sulphide

As part of the mandate for this investigation, the follow-up of measures and learning following similar events on Snorre B, SFB and Kalstø must be considered.

Work process OM105.02 (OM – Operation and Maintenance) linked to entry has one owner and one author. The same applies to technical requirements in, for example, TR1055 and best practice documents such as GL0378. During interviews, we were informed that changes to these documents are made after input from specialists, incidents, standards or other experiences. Changes to OM105.02 and TR1055 following the incident on Snorre B in 2019 were communicated to the various operating units. Further follow-up of the requirements will be handled in these. For example, after the incident on Snorre B, a learning package was established for OM105.02 and the issue was also included in the agenda for the turnaround team's experience transfer meeting in 2019. An "extra option" was also added to the templates for the work permits linked to iron sulphide with regard to entry.

During conversations, it emerged that, in connection with the turnarounds on SFA in 2019 and 2022, some measures were established for the handling of iron sulphide. These included the installation of connection points for firewater on the separators prior to entry. This was also carried out in connection with the entering of two separators prior to the turnaround in 2024 (test separator and degassing tank). For reasons that are unclear, the measures were not continued for the turnaround in 2024.

As described in section 2.8, incidents involving iron sulphide have occurred previously on SFB and SFC. Specific procedures for the handling of iron sulphide have been established on these facilities.

No active measurements were taken to disprove the presence of iron sulphide on SFA in connection with the turnaround. However, as described in non-conformity 8.1.1, samples were collected from production segments on SFA which indicated the presence of iron sulphide.

According to information obtained during the investigation, it may be that the change to the work process for entry linked to handling of the possible presence of iron sulphide (OM105.02) did not result in any change in the way in which the cleaning and inspection of the inlet separator on SFA was planned or carried out.

11 Discussion concerning uncertainties

11.1 Uncertainty as to why previous measures were not implemented in turnaround RS2024

In connection with the turnaround on SFA in 2019 and cleaning of the test separator and degassing tank ahead of the turnaround in 2024, measures were implemented linked to the installation of connection points for firewater on the separator. It is uncertain as to why these measures were not implemented prior to the splitting of CD2101 during the turnaround in 2024.

11.2 Uncertainty associated with a reaction between iron sulphide and oxygen before the fire in CD2101 was discovered

During interviews, it emerged that many people were aware of a new “unknown” odour prior to the fire. Many people were already aware of this odour as far back as the shift changeover on the evening of 16 April, and the ventilation room on board was investigated in order to determine the source of the odour. The investigation team is unsure whether the odour can be linked to an early reaction between iron sulphide and oxygen.

During interviews, it emerged that visibility inside the separator was somewhat limited during the night shift that discovered the fire. The procedure for handling iron sulphide on SFC during turnaround RS2023 notes that it is easy to confuse fumes from an iron sulphide fire with steam. The investigation group is unsure whether the “steam” in CD2101 was actually fumes originating from a reaction between iron sulphide and oxygen.

11.3 Estimated quantity of iron sulphide in CD2101

It has been reported that approximately 7 m^3 of material has been removed from CD2101. Analyses indicate that the samples from the bottom of the tank contain between 32 and 36% iron sulphide. The density of the material is approximately 2,000 kg/m^3, equivalent to 14 tonnes, i.e. about 5,000 kg of iron sulphide. Equinor has concluded that the volume of 7 m^3 of material, the water content and the iron sulphide concentration in different parts of the separator are likely to be subject to some uncertainty. It is believed that the content is actually between 2 and 4 tonnes.

11.4 The timing of events is uncertain

During the summary meetings with Equinor and IKM Testing, we noted that there was uncertainty as regards when the personnel entered the separator. We have received feedback that this first took place on the morning of 16 April. If the personnel had entered the separator earlier, it would have had no impact on the incident.

12 Assessment of the company's investigation report

Equinor set up a separate investigation group on 18 April 2024 with a mandate to investigate the incident which occurred on 17 April 2024. The investigation was placed on level 3 of Equinor's investigation category.

We received your investigation report on 25 June 2024. The sequence of events and causal factors are essentially consistent with our investigation report. We consider the description of the actual planning phase on land prior to the turnaround to be very brief. Equinor's report did not include a central work permit which covered opening of the separator (AT1 for splitting of the HC system); see the description in our report, section 2.5.

In our report, we also considered a number of factors linked to inadequate planning and handling of emergency preparedness.

As regards the more underlying causes, the discussion in our investigation report placed greater emphasis on the fact that there was insufficient sharing of information concerning the risk of iron sulphide in FLX and, to some extent, Equinor, even though the organisation was in possession of this information. For example, in 2012, a safety data sheet was already available for well deposits on Statfjord which stated that such well deposits could contain 70% iron sulphide.

Equinor decided to investigate the incident at level 3, where the operating unit is responsible. We believe that other levels could have been chosen. This was partly based on the following considerations:

- Central work process in the ARIS (for entry), updated in 2019, but did not result in any change in how the cleaning and inspection of the inlet separator on SFA was planned and carried out.
- The guidance concerning the ARIS requirement (GL0378) seems unclear.
- Several barriers with regard to emergency preparedness were not in place.
- It took a very long time for all personnel on board to muster.

Technical requirements in TR1055 for the mapping of iron sulphide quantities were not being fulfilled on any facilities after the requirement had been introduced following the update in 2020.

We believe it is an advantage that Equinor's investigation includes measures for FLX, Equinor and IKM Testing, because failures and improvements in planning and execution can be linked to a number of parties.

13 Other comments

13.1 ARL personnel started firefighting not wearing firefighter clothing

The two members of the alarm response team (ARL) who were the first to arrive at the scene of the accident after the alarm had been activated by CCR, immediately started applying water into the tank via the manhole in order to extinguish the fire. After a short time, toxic fumes began emerging from the manhole, and both members of the team were exposed to these fumes to some extent and had to be monitored by the medic on board.
We understand that this did not lead to any personal injuries.

The ARL personnel were not wearing firefighter clothing for firefighting, only ordinary workwear for work outdoors on the facility.

The primary task of the ARL team is to verify the alarm - check and report - and to provide the fastest possible feedback to CCR, so that necessary emergency preparedness measures can be implemented.
In this case, the primary task of the S&R team was to extinguish the fire wearing firefighter clothing.

13.2 Missing hinges on manhole cover

In 2019, the manhole cover on inlet separator CD2101 was modified through the removal of its hinges. This meant that the cover had to be moved into position using lifting equipment and could therefore not be closed manually, as is possible on other tanks. This reduced the scope to manage the incident effectively.

The incident on SFC 1.4.2023 shows that isolating pipe segments or tanks is an effective measure, and if it had been possible to close the manhole cover easily, this may have helped to choke/extinguish the fire in the separator. This view is also supported by the procedure for the handling of iron sulphide which was prepared for the turnaround on SFB in 2022, which recommends that manholes are closed and water is applied into the tank in the event of heat generation and white fumes.

The fire in CD2101 was located above the manhole level. Applying water into the tank without closing the manhole would therefore not have prevented the incident from occurring. The manhole was not closed until after normalisation, when a team was able to plan and carry out the lifting operation.

13.3 Deferred tank cleaning and technical problems with the water jetting system

As described in section 2.4.1, the tank cleaning of CD2101 was originally planned to be carried out in 2022, but was postponed, initially until 2023 and then until 2024. One consequence of this was an increase in the amount of deposits that had accumulated in the separator by the time the tank was to be cleaned in 2024. In addition, the water jetting system was found to be in poor condition when it was inspected in connection with previous tank cleaning operations in the form of blocked nozzles, among other things. See Table 1. The investigation team has not included any assessments of whether the system has been able to perform its intended functions in operation.

14 Annexes

A: Documents used in the investigation.
B: Overview of personnel from IKM Testing and Equinor who participated in interviews and meetings.