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Abstract

This study is based on information from internal GDF SUEZ E&P Norge AS (GDF SUEZ) documents. This includes system books, P&ID's and external journals regarding Environmentally Critical Elements (ECE). The scope of the thesis is to research parts of the Gjøa offshore installation and identify if there are any environmentally critical elements that have been overlooked during the identification of safety critical elements. To reduce the risk of acute discharge to sea the equipment/tags that are identified will be listed into a checklist. The checklist system will be as similar as possible to the already existing safety critical elements (HSE). The checklist will contain the classified criticality of production, HSE (safety) and the environment to compare them with each other.

There are four system that have been analyzed to find ECEs.

System 44, Produced Water: In this system there were identified six Environmentally Critical Elements. When comparing the criticality for production, HSE (safety) it was clear that the environment was not represented and there was given a new criticality for the identified ECEs in relation to the environment.

System 56, Open Drain: in this system there were identified four Environmentally Critical Elements. In this system when comparing the criticality between production, safety and environment two of the four ECEs had the same criticality for safety and environment.

System 38, MEG Regeneration: in this system there were identified ten Environmentally Critical Elements. In this system the classified criticality for HSE (safety) had excluded the environment and just based the criticality on safety. All the then ECEs got a new criticality based on the environment.

System 65, Hydraulic: in this system there were identified eight Environment Critical Elements. When comparing the criticality for production, HSE (safety) and environment it was clear that the environment was left out of the classification of the criticality.

Acknowledgement

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Anette Seldal

Contents

1. Introduction

1.1 Background

Today there are more and more focus on protecting the environment and that is why the oil and gas industry have a larger focus on this. Because of the accident in the Gulf of Mexico in 2010 (see chapter 2.2) and the large media coverage of this accident people are more aware of what damage the oil and gas industry can do if there are lack of rules and safety procedures.

In 2013 one of the priorities of the Petroleum Safety Authority Norway (PSA) was to prevent accidents that could lead to acute discharges. Operating oil companies are expected to have a good overview over earlier accidents and learn from them; also they need to work towards a safer and more environmentally friendly oil business. To be able to do this they must have a proactive and systematic way of working, to get control over operational risk and the factors that are contributing to the risk of discharge. The operators must also create or find measures that can prevent acute discharge.

The authorities have a clear idea of what they want and expect, but as of this day there are no industry standards that claim how this should be done, so this result in confusion and problems. Although there are no industry standards that require identifying the components that can lead to discharge; it must be done to survive in the business market. Customers and society are more and more focused on a safe and environmentally friendly world. There is therefore a drive to find the equipment also called environmentally critical elements (ECE), whose failure can lead to discharge and prevent this from happening. The drive for the identification of ECEs has become stronger because of accidents that have happened but could have been avoided if there had been systematic procedures in place. To improve the future performance identifying and managing the known and latent environmentally risk is key.

1.2 PSA regulation

The PSA has regulations that are contributing to the interest in finding the ECEs, these regulations must be followed by all oil companies to prevent and reduce the discharge to the environment. There are several different regulations for various part of the operation; risk reduction, barriers, managing health, environment, safety, maintenance, classification and planning and prioritizing, maintenance efficiency and maintenance program. The regulation from the Petroleum Authority, Management and Activity Regulation states that:

Regarding risk reduction regulations say that; the operation must choose technical, operational and organizational solutions that will reduce the probability that there will be failures, harm and accidents, in addition there must be established barriers that will prevent things from happening. The barriers and solutions that will contribute the most to risk reduction will be chosen from a single and overall assessment. If there are solutions that will benefit a larger group this should be preferred as to solutions that will benefit individuals.

Regarding barriers the regulations say that the barriers should reduce the probability for failure, harm and accident happening and also reduce possible damage. If there is a need for several barriers they should be independent. The operator is responsible for the barriers and that they are developed in a proper way so that both use and maintenance of the barriers are correct and the function of the barriers are in good shape and will function through the fields lifetime. The operator must know which barriers that are developed, and what they should protect. The operator must have an understanding of what is required of the technical, operational and the organization to keep the barriers functioning optimal. If a barrier were to fail, there should be a system in place so that this is noticed and fixed.

The section from the regulations regarding managing health, environment and safety says that the responsible should make sure that the HSE covers the activities, processes, resources and the organization necessary to secure proper activity and continuous improvement. The responsibility should be defined and understood at all times, there should also be guiding documents and reporting arrangements established.

The section from the regulations regarding maintenance is also important background for finding the ECEs. The regulations for maintenance say that the operator must make sure that equipment is maintained so that it can function as intended in all phases of the operation.

The section from the regulations on classification says that equipment should be classified with regard to the consequence for health, environment and safety if a failure were to occur. If a failure with large consequences were to happen, the operator must identify the failure and the reasons for the fault, also calculate the probability for every single component. Classification should be assumed on maintenance activity and maintenance frequency.

The maintenance program section from the regulation is clear that a failure that can affect HSE should be prevented by the use of a maintenance program. In the program there should be monitoring of the performance and technical condition to reduce the risk of failure and the possibility to identify, correct and fix it as early as possible.

The planning and prioritizing section from the regulation says that there should be developed a plan for execution of the maintenance program and corrective maintenance. There shall be criteria’s for prioritizing the equipment with associated deadlines, the criteria’s should be in relation to the classification.

The section from the regulations for maintenance efficiency says that the efficiency of the maintenance should be evaluated systematically based on registered data on performance and technical condition. The evaluation shall be used to continuous improve the maintenance program. All these regulation from the petroleum authorities are a part of the background for this thesis.

1.3 Scope

The scope of the thesis is to research parts of the Gjøa offshore installation and identify if there are any environmentally critical elements that have been overlooked during the identification of safety critical elements, called HSE in COMOS , GDF SUEZ' management and maintenance system. To reduce the risk of acute discharge to sea the equipment/tags that are identified will be listed into a checklist. The checklist system will be as similar as possible to the already existing safety critical elements (HSE). The checklist will contain the classified criticality of production, HSE (safety) and the environment to compare them with each other.

The scope of this thesis is connected to the background of the thesis. Because of all the focus on the environment, and the lack of procedures to manage and identify ECEs this thesis will try to identify environmentally critical elements of the Gjøa offshore installation and make a check list of the equipment that are environmentally critical.

The scope will be on the day-to-day operation and not the major accidents e.g. blow-out and rupture of pipelines. The focus ECEs for the thesis are the ones that discharge to sea, the ECEs that discharge to air are not included.

1.4 Methodology

Because identification of ECEs is a new way of thinking and it has not been done before with focus on environments, just focus on safety, there were very little resources to base the work on. To collect data I started using the database of GDF SUEZ and found system and operation book for all the systems I was going to analyze. I used them to understand the technical aspect of the different system. For my analysis of the systems; produced water, open drain, hydraulic and MEG regeneration I started to look at the P&ID/system drawing of the main components in each system and checked if they were already in the safety critical equipment database; COMOS and from that point I gave my tags the criticality they should have according to the danger to the environment, and put the tags into a checklist.

1.5 Limitations

When starting on the thesis there had to be set some limitations/focus areas. For this thesis there will only be focus on the topside of the installation, the subsea equipment and modules will not be included. The focus area for this thesis is acute discharge from the installation to sea, so the acute discharge to air will not be a part of the analysis. Because of time limitation there are several systems that could lead to discharge that have not been included, in the thesis there are only included four systems; produced water, open drain, MEG regeneration and hydraulic.

1.6 Structure of the thesis:

The thesis is structured into different sections:

Section 2: The second section includes the theory, oil and gas industry, accident that caused environmentally consequences and theory on environmentally critical elements. The oil and gas industry is a paragraph that explains general problems in the industry concerning the environment. The accidents that caused environmentally consequences is the Deepwater Horizon, Exxon Valdez and Eirik Raude accident, the paragraph includes some information on how the accidents happened, the environmentally aspect. These accidents created a chain reaction for companies to research their own methods and management procedures. The theory on environmentally critical elements explains a basis for how to find the ECEs and implement them into the maintenance and management system.

Section 3: The third section is a section that cover the case description, GDF SUEZ as a company, Gjøa field and environmentally practice on Gjøa. The GDF SUEZ as a company explains briefly what GDF SUEZ stand for and who they are as a company. The Gjøa field is an explanation of the field in general. The environmentally practices on Gjøa explain their practices with regard to the environment today.

Section 4: The fourth section is the analysis and result part that covers the system description of all the four system, the ECEs in the systems and the checklist.

2. Theory

2.1 The oil and gas industry

The oil and gas industry are constantly addressing the environmentally aspects and making sure that the environment is taken care of.

The oil and gas industry's many activities impact not just the sea, but also land and the seabed. In the industry there are several phases and the impact stretches from exploration to development of fields, drilling, production and decommissioning (Norwegian Environment Agency).

The oil and gas industry are expanding and the rise of new offshore installation are growing. As the industry is growing the amount of discharge of different substances including drill cuttings are rising and the benthic fauna all over are affected. Because there are so many studies on the affect the discharge have there are now much more regulation than there were before, the oil companies are not allowed to discharge the amount and various types of drilling fluids they want any more, like they could before. Before oil based mud was discharged to sea, this is not allowed any more. The only permitted drilling fluids to discharge are much less harmful then the drilling fluids discharged before, and this will help preserve the environment (Norwegian Environment Agency).

During the exploration phase there are often used seismic surveying to find out where oil and gas are located. The seismic surveying can be harmful for the organisms living under, they can be harmed or they can be frightened so before doing seismic there must be assured that there are no organisms and fish that can take harm from the operation, and it should be performed with care (Norwegian Environment Agency).

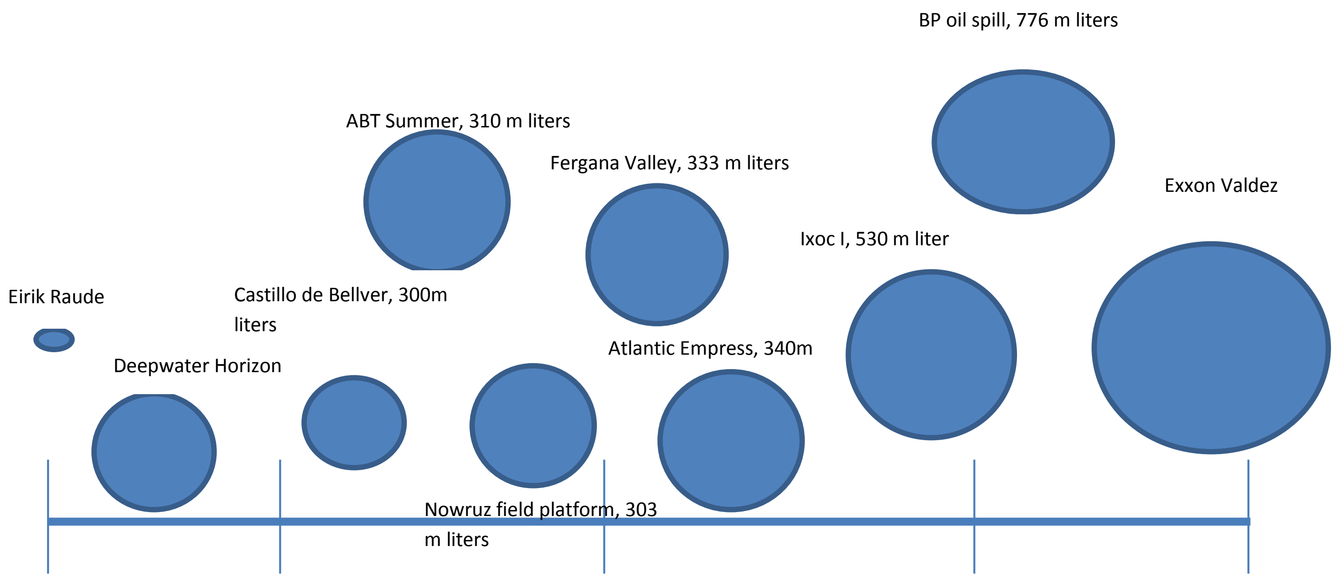
In the production phase and drilling phase, the discharge can be high. Also there might be work on the sea bed before installing a platform, leveling, trenching and dumping of rock waste. All this can affect the environment and prevent organism from reproducing and destroying the sea bed. After production the fields close down, the platforms are sent to shore and another interruption on the sea bed can occur, and there can become disturbance on the seabed (Norwegian Environment Agency).

Impact on the North Sea in combination with offshore activities has been looked at as minor because the area was much polluted from other European countries. Because of this there need to be quantified pollution load to be sure that the total load is not too high. The oil and gas industry is one of many sources to pollution in this area, regardless of the source all the pollution add up to the cumulative effects. There is being developed methods to monitor the marine ecosystems because it can be difficult to find the exact effect the pollution has on the environment (Norwegian Environment Agency).

The need for energy when producing hydrocarbons is huge. The reason for this is both drilling and the treatment of hydrocarbons when it leaves the reservoir. Also transporting hydrocarbons from offshore installations to shore requires much energy. The energy is produced in diesel engines and gas turbines. The diesel engines are mostly used for mobile drilling rigs; these rigs are most often used for exploration and production drilling. Also there are energy production using fossil fuel and gas flaring, this contribute to forming the ground level ozone because it generates emission of $CO2$ (Norwegian Environment Agency). Since there is a huge need for energy when producing and transporting hydrocarbons there have been developed new ways to get energy. Many new installations are powered or plan to be powered by electricity from shore. Gjøa is one of the installations that use this form of energy.

2.2 Accident that caused environmentally consequences:

The graph below shows large discharges to sea from different accidents through the oil and gas history. The larger the circles the larger the spill was. All accidents that have happened through the history are reasons for why the environment is a focus area for the oil and gas industry today.



Deepwater Horizon

On April 20th 2010 the blowout from the Macondo well happened and eleven people lost their life when the Deepwater Horizon rig sunk. Oil from the well discharged to sea for 87 days before the well was under control, BP was the operator on this well. When the accident happened Deepwater horizon was about to drill an exploration well on 1500 meter depth in the American part of the Mexico gulf. In the evening April 20th hydrocarbons came into the riser and reached the installation and caused the explosion, and subsequent fires. It kept burning in 36 hours before the installation sank. There were done multiple attempts closing the well in without luck before and after the explosion, until May 20th 2010 when all interventions with subsea equipment were stopped. Housing was installed and the well was closed July 15th 2010. The well was later killed and cemented, September 16th a relief well confirmed that the well was dead (OljeIndustriens Landsforening (OLF)).

Technical main causes:

1. Well integrity not established or failed.
   a. Annulus cement barrier did not isolate the hydrocarbons
   b. The casings bottom barrier did not isolate hydrocarbons
2. Hydrocarbons came undetected into the well and the well control was lost
   a. Negative pressure test was accepted although there was not established well integrity.
   b. Was not aware of the flow in before the hydrocarbons had reached the riser
   c. Measures to regain well control failed
3. Hydrocarbons were ignited on the Deepwater Horizon
   a. Diverting the mud gas separator resulted in gas venting over the rig.
   b. Fire and gas system did not prevent ignition of hydrocarbons.
4. Blowout preventer did not seal the well (OljeIndustriens Landsforening (OLF)).

All these four causes were the main reasons for this accident. It was not just the technical equipment that failed; there was also a lot of human failure during the accident.

The reports on environmentally impact during and after the accident show that microorganisms break down oil components much faster than expected. On about 1000 meter depth, close to where the wellhead was located and there had been shown large amount of hydrocarbons, the natural decomposition happened with a temperature of 4 degrees Celsius, like on the continental shelf.
The research show that the plankton population show great resistance. The fishing activity in the Gulf of Mexico was closed after the accident due to the risk of polluted sea food. The accident had big consequences for the fishing industry's economy, but the population was not negatively affected. In Norway there are more waves and wind which result in faster natural decomposition (OljeIndustriens Landsforening (OLF)).

This accident have had a major effect on the global oil and gas industry offshore including the authorities, oil companies and the public. The oil companies and contractors have found it necessary to go through their operation and management practices.
This accident is one of the reasons that GDF SUEZ has decided to be proactive and come up with a checklist for environmentally critical elements to prevent accidents from happening, the check list will not involve major oil spills, but day to day work that could lead to acute discharge if not handled properly.

Exxon Valdez

The accident that happened after midnight on March 24, 1989 is one of the biggest oil spills in the US history. A 987 foot tank vessel, Exxon Valdez hit Bligh Reef in Prince William Sound, Alaska (Skinner & Reilly 1989).

The vessel was operated by a captain, an Alaska state pilot and monitored by the U.S Coast Guard Vessel Traffic Service (VTS). The vessel was enroute to Los Angeles and was loaded with 53094510 gallons of crude oil. The vessel was a two year old tank ship with eleven cargo tanks. Right before the hit, the captain informed that the pilot had departed, and that the ship would take a new route to avoid ice, so the ship reduced the speed. Damage survey showed that eight of the eleven cargo tanks were torn open, three salt water ballast tanks were pierced (Skinner & Reilly 1989).

The oil from the vessel spread over 3000 square miles and onto over 350 miles of beach. The problem with this accident was that it was in a remote location and the preparedness and response capabilities were too low. The industries attempt to get equipment on scene were very slow and once the equipment was in place the equipment was not designed to cope with this amount of spill. Also the management failed to plan and the different departments plans did not have a contingency so there were no structure in the work, this resulted in confusion and delay (Skinner & Reilly 1989).

From this accident there are eight point that were highlighted as procedures that should have been in place and that can be learned from.

1. Prevention is the first line of defense
2. Preparedness must be strengthened
3. Response capabilities must be enhanced to reduce environmentally risk
4. Some oil spills may be inevitable
5. Legislation on liability and compensation is needed
6. The United States should ratify the International Maritime Organization (IMO) 1984 Protocols
7. Federal planning for oil spills must be improved
8. Studies of the long-term environmentally and health effects must be undertaken expeditiously and carefully

The accident was stated as an "environmental tragedy". The location of the accident had a broad diversity in ecological systems that were harmed in both short and long term. It was not only the biological life that was harmed, also the people of Alaska (Skinner & Reilly 1989).

This accident happened many years back and still people are talking about it as a major catastrophe. This accident is also a contributor to the focus there are on keeping the environment safe today.

Statoil Eirik Raude

In 2005, in the Barents Sea, a hydraulic hose on Eirik Raude burst and caused discharge of 1000 liters to sea. The hydraulic hose that burst was placed under the platform and was connected to the BOP carrier (Tjelta, Vik, Vikheim, Leistad, 2005).

The incident report only involve the incident itself, technical installations and management system directly related to the incident, so the deviation on other equipment are not analyzed regarding this incident (Tjelta, Vik, Vikheim, Leistad, 2005).

The investigation show that there are two deviations and eight observations.

Deviation 1: maintenance system gives different priorities for work on the BOP carrier that is classified as critical equipment.

Deviation 2: the maintenance system allows corrective maintenance order on critical equipment are put into the system without giving it a criticality.

Observation 1-3: the design of the chain that holds the hydraulic hoses are weak. This was not discovered during commissioning and use.

Observation 4: the maintenance program is not developed and adjusted to the design of the equipment

Observation 5: corrective maintenance is not done according to the plan

Observation 6: risk analysis have not identified a risk of mechanical wear on the hydraulic hoses

Observation 7: unclear use and understanding of standing instruction and safe job analysis when use of the BOP carrier.

Observation 8: unclear understanding of procedures relating to the use of isolation certificate for opening and closing of hydraulic system using the BOP carrier (Tjelta, Vik, Vikheim, Leistad, 2005).

The investigating team concludes that the incident happened as a result of a combination of deficiencies in technical design and maintenance systems.

This incident is not the same scale as Deepwater Horizon and Exxon Valdez but still it has had a large impact on the industry to be more aware of the environment, and also contribute to the investigation of ECEs.

2.3 Environmentally Critical Elements

The Theory behind this thesis is based on the findings of the Energy Institute, Guidelines for the Identification and Management of Environmentally Critical Elements, 2012. The environmentally critical elements will be different in all phases of a project, for the Gjøa field which is a production field, the focus will be the production phase since it is already built and constructed.

The reason these guidelines were developed was to help the industry control the environmentally critical elements. Figure 1 shows the process of finding ECEs, this process is based on the impact a failure can cause. When the process is made the performance should be monitored and measured on a regular basis. (Energy Institute, 2012)

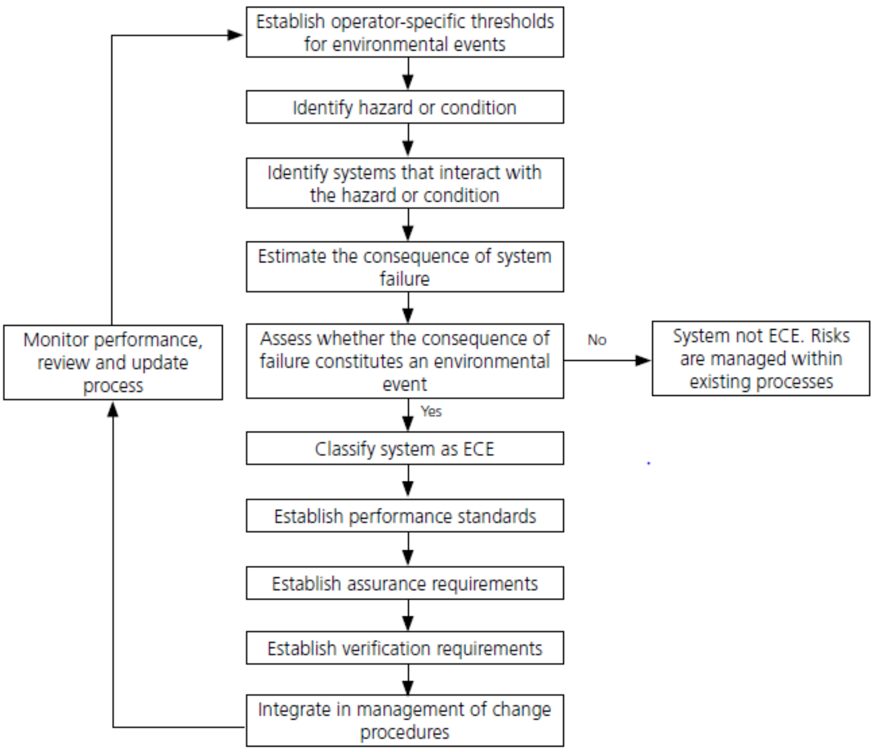


Figure 1: The process of identifying and measuring ECEs (Energy Institute, 2012)

Ideally the process of finding the ECEs should start before operation, for Gjøa this is not an option as they are already operating.

"ECEs are any part of the facility, plant or computer programs whose failure will either cause or contribute to an environmental event, or the purpose of which is to prevent or limit the effect of an environmental event" (Energy Institute, 2012).

This definition is from the Energy Institute and explains what ECE is and the purpose of why they should be defined. To use an example of a system that can be critical, produced water is one of them. Within this system there are several subsystems that should be divided into equipment and then analyzed to find if failure of equipment can cause harm to the environment. In the definition the term environmental event is used, with this they mean a big event that is hazardous to the environment and where there must be measures made to take control over the situation and reduce the risk. The purpose of defining environmental event is to be aware of all the different situations that can occur and have a clear understanding of what needs to be done to eliminate and/or reduce them (Energy Institute, 2012).

When an ECE is identified there should also be a performance standard associated with it. The performance standard is a standard that shows what a system/equipment should be able to perform to be able to fulfil its purpose and keep the risk found as low as reasonable possible (ALARP). When implementing ECEs the system should be as similar to the safety critical elements as possible. (Energy Institute, 2012).

ISO 14001 is a standard for environmental management systems. A part of this standard says "the organization shall identify and plan those operations that are associated with the identified significant environmental aspects consistent with its environmental policy, objectives and targets, in order to ensure that they are carried out under specified conditions" (Energy Institute, 2012). So it is very important that there is a clear understanding of the company's policy and objectives regarding the environment to be successful in planning operations to be safe and risk free.

For the Gjøa installation the environmental aspects have been identified according to ISO 14001.

The identification of ECEs is a form of extension to the already existing identification of environmental aspects. The environmental aspects are a general list that says something about which systems that affect the environment, while the ECEs should say something about what equipment should function to avoid/control the discharge. The ECEs are much more detailed and a lower level of identification.

Approach to find ECE's

The approach to find the ECEs should be done in several steps, find the companies threshold for environmental events, go through the facility and identify all systems and subsystems that can be a risk to the environment, like in figure 2. When the first identification is to take place it may be useful to analyze P&ID's and let this be a part of the environmental impact identification result (Energy Institute, 2012).

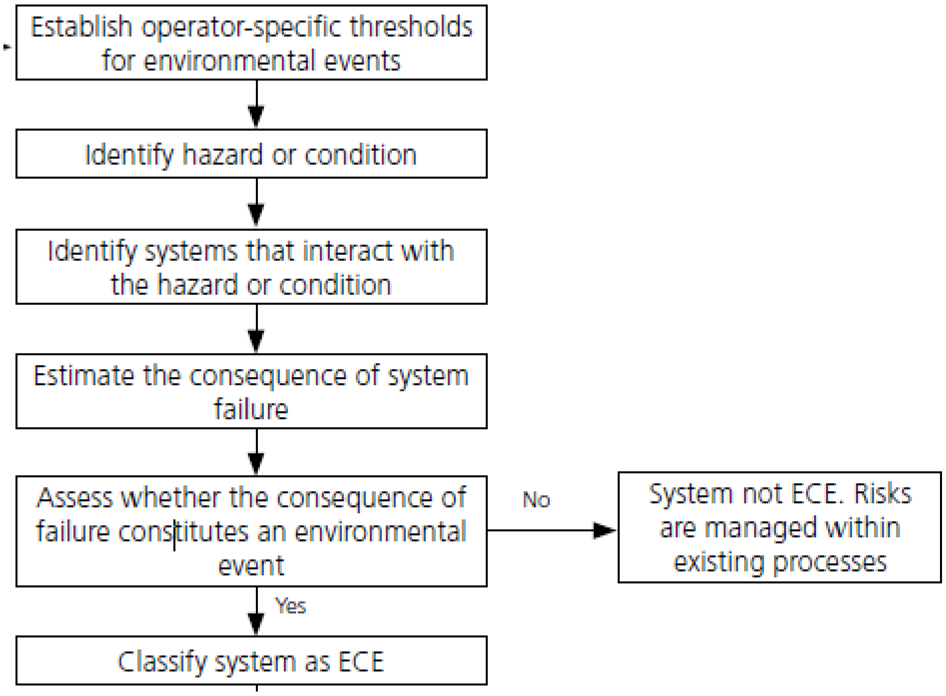


Figure 2: Identification of environment critical elements, extract from figure 1. (Energy Institute, 2012)

From figure 5 the first step is **to have a clear threshold**. The basis for the threshold should be on events that could lead to big hazard and harm to the environment. Because the threshold is based on severe events they should be prioritized in both management and maintenance. When making a threshold there are several factors that should contribute to the decision, volume, hazard and the location.

Step two**, identify hazard or condition**. There must be identified what are on the facility that could lead to hazard and discharge to sea; such as chemicals, hydrocarbons etc. if any of these elements are discharged it could lead to damage/harm to the environment.

The third step is **to find elements that are in contact with the hazard**, and learn how they interact; in case of an accident there are clear procedures on how to fix the components and the problem.
Fourth step is **to analyze the consequence is a system fail**; how much oil will go to sea if a hydraulic hose breaks etc.
Fifth step is to be **finding out if the situation will lead to environmental event or not**. This is often done by assessing the situation against the thresholds made earlier for the environmental event.

The last step is to **classify the element/system**. There should be included a report as to why the system was classified as ECE or not.
There are some other factors that must be taken into considerations; temporary equipment, turnarounds, shutdowns and other non-routine operations. (energy institute, 2012).

Performance Standards

Performance standards from figure 1 are criteria's that tell if the ECEs are performing the way it should with the required availability and reliability. To be sure that the ECEs meet the requirements there should be made a clear procedure of what actions that must be taken. The performance standards are often linked to specific equipment in the maintenance routines and checklists. There should be done inspection, replacement as a part of the maintenance plan.
Performance standards can be both quantitative and qualitative. Often if there don't already exist a standard and the risk is high, it is recommended to use quantitative methods to find the appropriate standard that will reduce risk to ALARP. The higher the risk is there should be considered using a quantitative method, if the risk is low or close to the tolerable boundary then qualitative could be considered (Energy Institute, 2012).

For Safety Critical Elements (SCE) there are requirements regarding performance standards for operators, so it is very possible that there already exist some for SCE. So when dealing with ECEs it can be useful to use the already existing standards as a basis model and follow this form and try to incorporate the new standards into the normal operations (Energy Institute, 2012).

There often are two types of ECEs, the ones that also are SCE and the once that just are ECEs. The ECE that also are SCE should be analyzed to find if the performance standard for safety is good enough to use for the environment, the standards should reflect both the SCE and ECE.

For the ECEs that are not a part of the SCE performance standard there should be made new one that only concern the ECEs, but the way to build it up can be the same way as the SCE. The main focus of the standard should concern; goal of the system, maintenance and inspection regimes, and reference to relevant procedures, permit to work, daily check list and logs. To make these performance standard there should be an experienced and knowledge person involved, to be sure that the findings and requirements are suitable and practical (Energy Institute, 2012).

Assurance activities are made so that there is a way of controlling that the ECEs meet what's required from them. Examples of what assurance activities are; activities that are required to maintain ECEs in a suitable condition, like inspection, testing and maintenance. There should be a plan for how often the activities will take place. The persons performing this should be experienced and have the right knowledge. There should be kept records of the measurement so it is possible to go back in time and check if they are functioning the way they should. (Energy Institute, 2012).

The identification of ECE is not a legal requirement, however it is highly recommended. When implementing the program it should be done the same way that already existing procedures are done. The implementation process must be a part of all the phases of the process and included in the facility management process. Often companies choose to implement the systems with the highest risk first to be sure they get the attention they need, and follow up with the system with lower risk. (Energy Institute, 2012)

3. Case description

3.1 GDF SUEZ E&P Norge AS

GDF SUEZ E&P Norge (GDF SUEZ) is a part of the GDF SUEZ group, and has been operating in Norway since 2001. GDF SUEZ plans to operate on the Norwegian Continental Shelf (NCS) and create value along the value chain by exploring, developing, producing and transporting oil and gas. They will do this in a sustainable manner and through operational excellence be respected by their stakeholders. The vision for GDF SUEZ is to be an upstream company on the NCS, among the top players, respected for their operational and HSE performance (GDF SUEZ E&P NORGE, *About Us*).

GDF SUEZ is the operator on the Gjøa field which is a fairly new field on the Norwegian sector, GDF SUEZ became operator of Gjøa in November 2010. This operator has chosen to reduce the environmental impact by being proactive and the goal for the company is to have zero acute discharge. To implement the ECEs to the system and maintenance procedures this is a way of reaching their goal of zero acute discharge to sea. As a new operator it is important to prevent accidents from happening to prove that they are a serious and professional company as they aim to get more licenses and grow as an operator on the NCS.

3.2 Gjøa field

The Gjøa field lies in blocks 35/9 and 36/7 of the North Sea and is located about 60 km west of Florø and 70 km north of the Troll field.

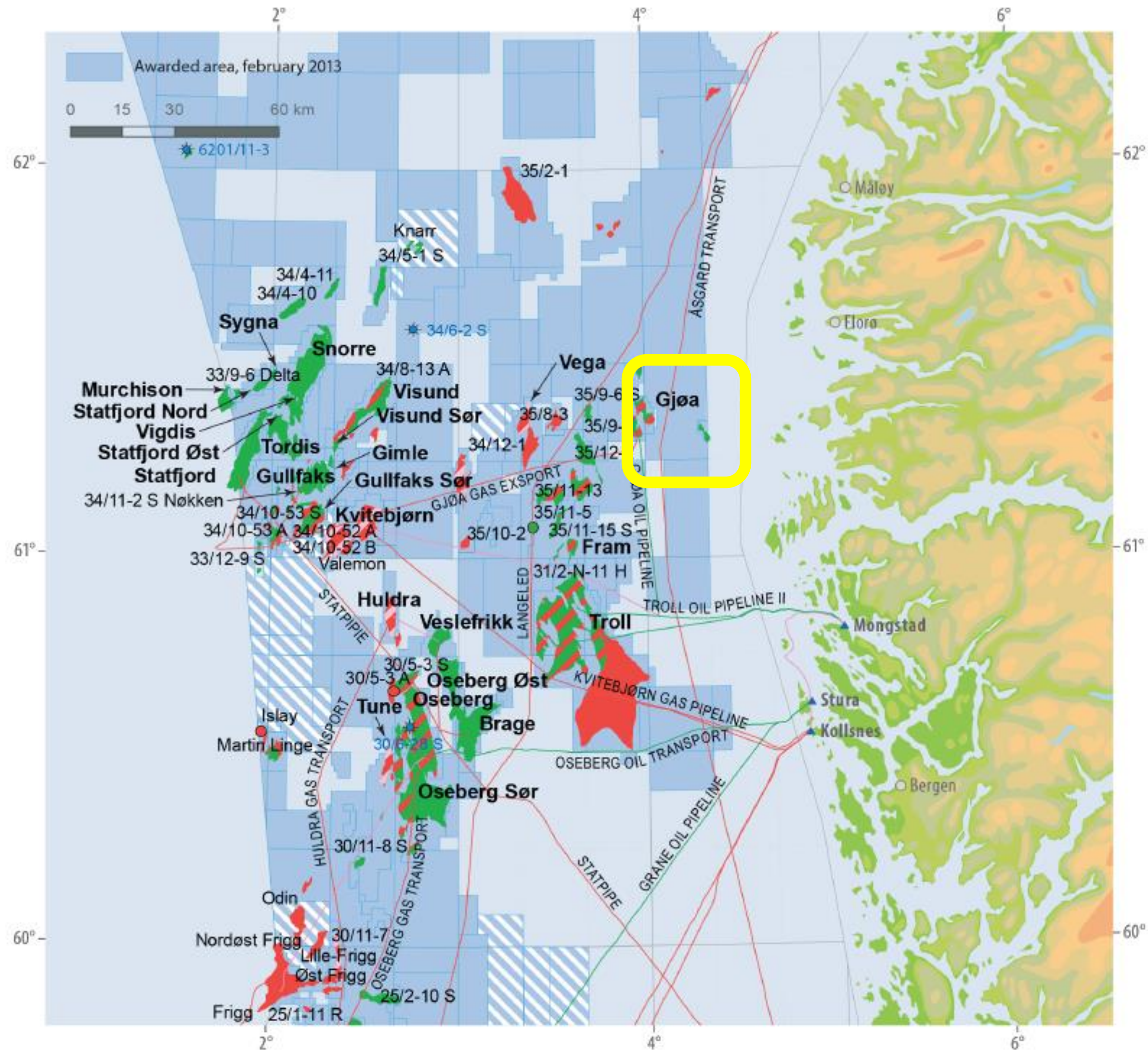


Figure 3: The location of the Gjøa field (PUD plan, internal GDF SUEZ document)

The field was found in 1989 when Norsk Hydro was operating, and it showed small amounts of oil and gas from the exploration well. The main reservoir consists of both silt, sand and shale from the Viking formation that was deposited in Jura. The reservoir quality varies from very good to poor both vertical and lateral. The zone of hydrocarbons consists of 40-50 meters thick oil column, with an overlaying gas cap (PUD plan, 2006).

The field is very complex and to be able to take advantage of this there are build many reservoir models. These models were used to find the best recovery model by simulation. The recoverable reserves in Gjøa was around 39,7 billion Sm^3 rich gas and 13,2 million Sm^3 oil (PUD plan, 2006).

The Gjøa field consists of a total of eleven wells. Four templates and one single satellite well. Vega, the third party field consist of five wells.

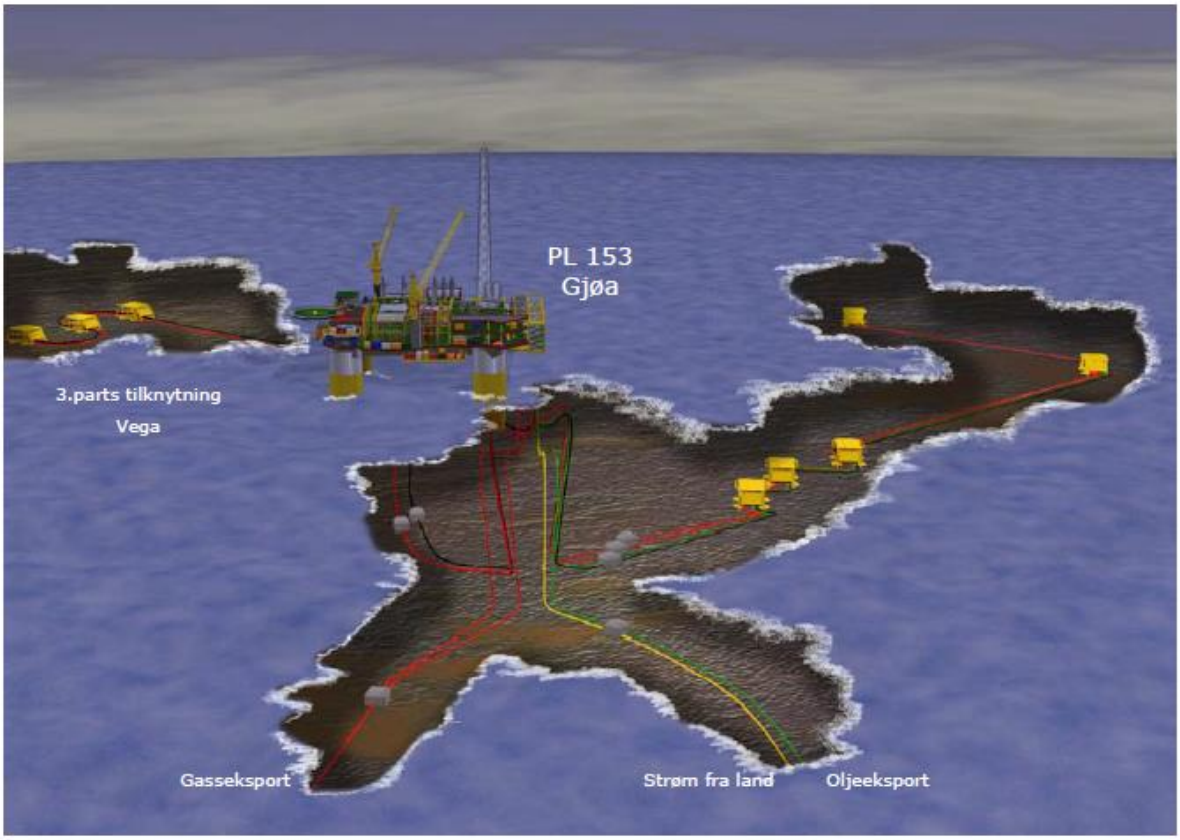


Figure 4: Simple illustration of the field and the wells of Gjøa and Vega. (PUD plan, internal GDF SUEZ document)

There were several options that was considered for the production phase, but ended up with semi-submersible platform, due to many reason; one of them being the Vega field tie-in and that a similar field in size had used this type of installation so this reduced risk (PUD plan, 2006).

Figure 5: Picture of the platform, a semi-submersible floating platform. (PUD plan, internal GDF SUEZ document)

The influence areas that are connected to discharge to sea from produced water, drainage, drilling etc. are the immediate surrounding area to the discharge points. The Gjøa field is localized near the Norwegian coastal stream, and if there are discharges this will follow this stream further north. The Norwegian stream is created due to the amount of fresh water that is added to the Baltic Sea. Excess water from the Baltic Sea drains out in to Kattegat and further to Skagerak. Because there is added so much fresh water the salt content is low, but enhances as the stream goes further north because of the encounter with the Atlantic ocean. The Norwegian coast stream is more contaminated than the open sea further west, this stream brings contamination from all over Europe that deposits in the coast areas and are taken up by various organisms. In the area where Gjøa is located there have been identified several species that are threatened; fish, seabird and marine mammals (PUD plan, 2006).

Discharges from operation are much higher than acute discharge in the petroleum industry. In general the discharge of oil has increased since the 1990's. Norway and Britain stand for most of the oil discharge, and produced water is the main source. The last years there have been a reduction in the oil discharge due to measures taken to reduce it. (PUD plan, 2006).

The Gjøa field is now in the operating phase and during this phase the discharges to sea are mainly from produced water, drainage, chemical injection and sanitary wastewater. Produced water is cleaned using EPCON technology and then discharged to sea. Today there is a tool that is used by operators to predict the environmental damage from the discharge of produced water, this tool is called "Environmental impact factor", EIF. This tool gives numerical expressions for the environmental risk, and was used to compare the cost benefit factor of different measures taken to reduce environmental risk (PUD plan, 2006).

In this field the EIF was used to decide on what technology should be used to handle produced water. As mentioned the method chosen was to clean the produced water with EPCON technology. This technology will clean the produced water for oil and other natural petroleum's components, but it will not clean the water for injected chemicals. The risk with produced water are low due to the fact that it has a quick dilution, it will not have a long enough exposed time to affect the organisms in a significant way. Many of the components from the water will precipitate or absorb to particulate matter (PUD plan, 2006).

3.3 Environmentally practices for GDF SUEZ

GDF SUEZ is committed to the enforcement of their Health, Safety and Environment Policy and the exploration and production management shall demonstrate visible HSE leadership and provide the resources to make sure that there is a high level HSE culture and competence in the company. All employees should be aware of the policy and work in a proactive way to be sure that HSE are in place at all tasks and levels. The company is committed to the application of the policy at all levels so they can reach their milestones in HSE performance, which is to be among the top E&P companies operating in Europe regarding oil and gas production (HSE, exploration & production, internal GDF SUEZ document).

The company believes that for all activities incidents are preventable, and the goal is to prevent adverse HSE impacts on employees, contractors, public, stakeholders and the environment. The management is committed to comply with local HSE regulations, integrate HSE into the management of all activities, create a safe and healthy workplace and preserve the environment, be engaged with employees and contractors to manage operations according to GDF SUEZ Exploration & Production HSE requirements, continuously monitor and improve their HSE performance, and communicate their HSE performance to all stakeholders (HSE, Exploration & Production, internal GDF SUEZ document).

4. System Analysis and Result

4.1 System description

The focus in this thesis will be on the systems that can discharge to sea; these systems include produced water and open drain and MEG regeneration. The MEG regeneration system only have a small amount that are discharged directly to sea, the main problem with this system are the leaks. The hydraulic systems do not discharge directly to sea, but there is a chance that this system can be a hazard for the environment because it contains environmentally dangerous chemicals and that is why it is included in the analysis.

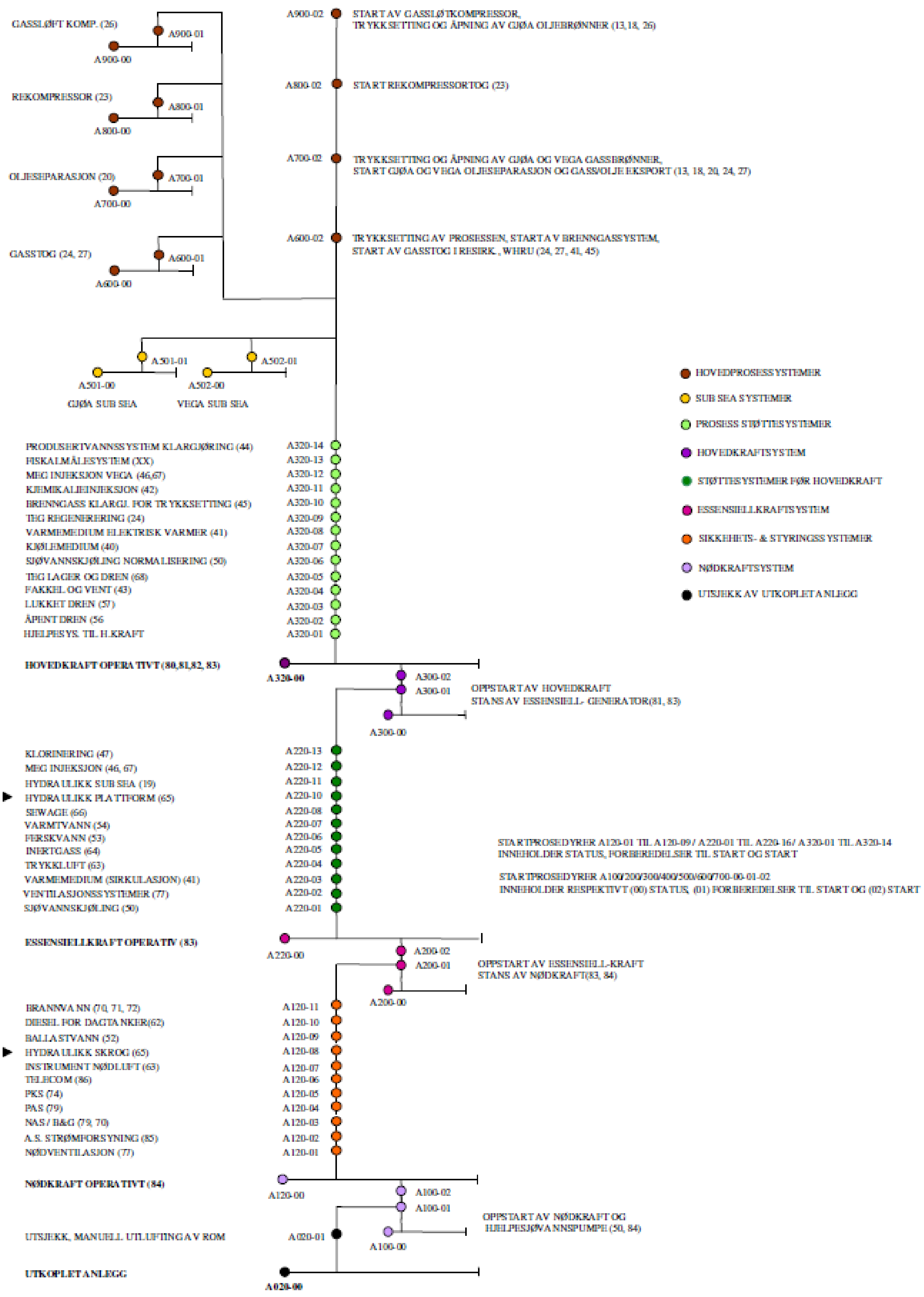


Figure 6; Illustration of how the systems on the Gjøa installation are connected. (System Book, internal GDF SUEZ document)

4.2 System 44 – Produced water

System description:

System 44, produced water contains fuel gas under pressure, fluid with high temperature and different chemicals that are harmful for both health and environment. When working on this system this must be done in a safe way (System books, 2013. Internal GDF SUEZ document).

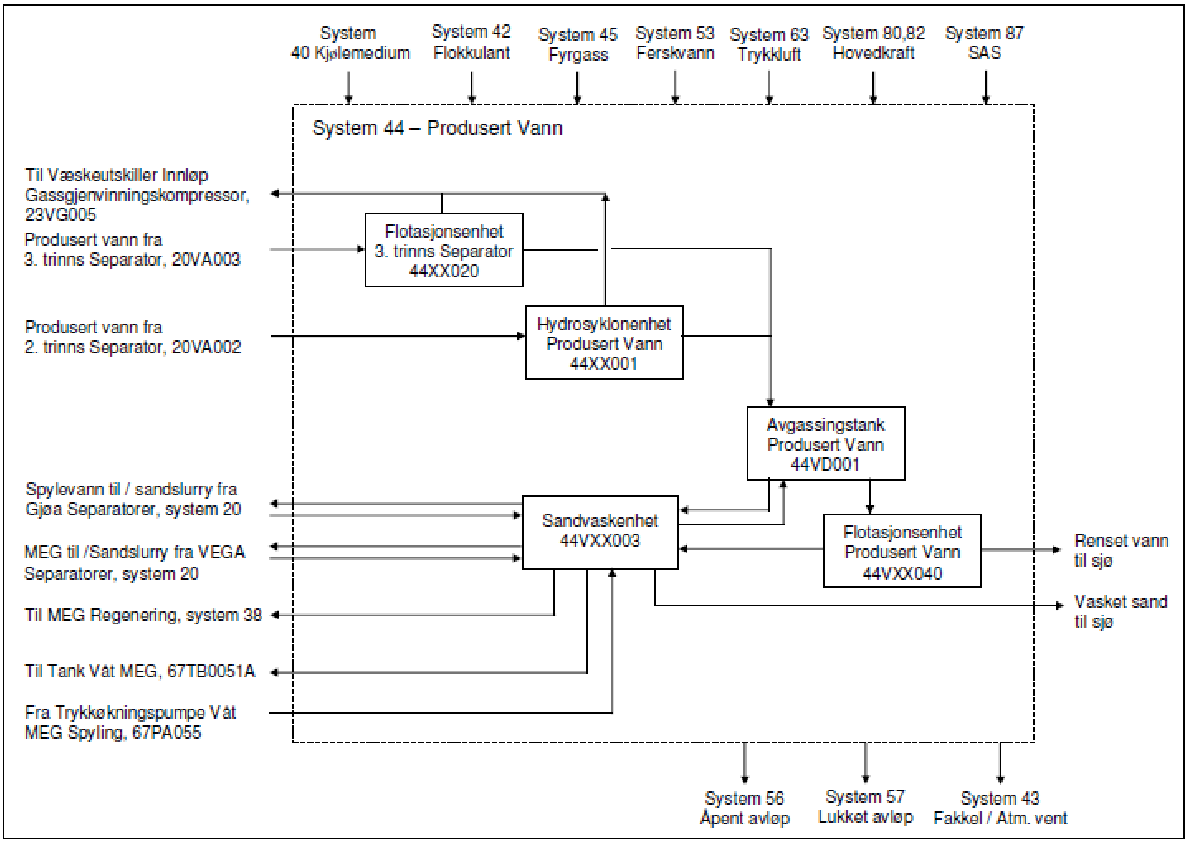


Figure 7: Block diagram of system 44. (System Book, internal GDF SUEZ document)

Process description:

The systems purpose:

The main purpose with this system is to clean the produced water that is separated out from gas and oil flow in the Gjøa plant. The water is cleaned in three stages; first there is primary treatment of the water that is produced in the 2. stage separator 20VA002. The second step is to do primary treatment of the water that is produced in the 3. stage separator 20VA003. The third and last step is to clean the entire water flow so that it can be released to sea.

The system also transports away the sand that is separated out in combination with the separation of oil and gas at the bottom of the separator and degasing tank (44XX003), the sand is then washed and discharged to sea (System books, 2013. Internal GDF SUEZ document).

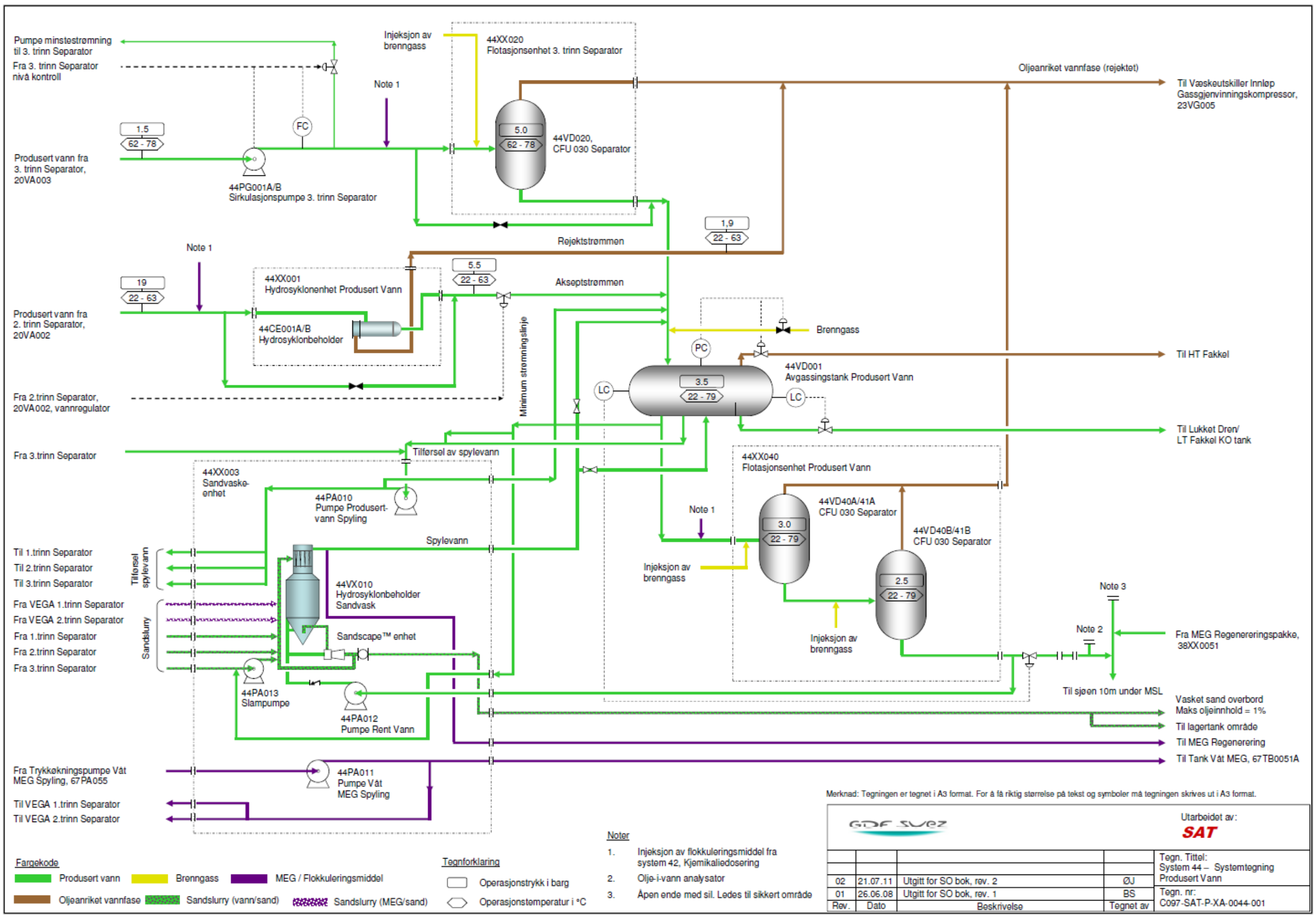


Figure 8: System drawing of system 44. (System Book, internal GDF SUEZ document)

The process in the system starts with receiving oil containing water and sand from the 2. and 3. stage separators. The main amount of produced water comes from the 2.stage separator 20VA002 and goes into the hydrocyclone unit 44XX001. The pressure in the system is high enough to transport the produced water to the hydrocyclone unit and further into the degasing tank 44VD001 without any pressure increase.

A minor amount of the produced water from 3.stage separator 20VA003 is pumped to the flotation unit 3.stage separator 44XX020 with help from a circulation pump 3stage separator 44PG001A/B.

Downstream degasing tank 44VD001 leads produced water through a 2.stage flotation unit 44XX040 that ensure that the oil in water requirements are meet before discharge to sea(System books, 2013. Internal GDF SUEZ document).

The system is designed to separate produced water from oil, gas and sand so that the requirements to cleanliness are fulfilled before discharge to sea, the maximum oil content the water can have are 30mg oil per liter of water. During the whole production time for the Gjøa plant sand will accumulate in the Gjøa separator, Vega separators and the degasing tanks. This sand must be removed by periodically cleaning the tanks. The separators are cleaned with different material, the Vega separators are cleaned with MEG while Gjøa separator and degasing tank are cleaned with produced water. The sand slurry from the washing is removed and the sand is sent to the sand washing unit 44XX003.

As mentioned there are four part of the system, primary treatment of water flow from 2.stage and 3.stage separators, end treatment of flow from degasing tank and sand cleaning (System books, 2013. Internal GDF SUEZ document).

Primary treatment of water flow from 2.stage separator 20VA002:

Oil containing process water is lead with a pressure of 19barg from Gjøas 2.stage separator 20VA002 to a hydrocyclone container 44CE001A/B that is placed in the hydrocyclone unit 44XX001. The flow is driven by the pressure difference in the hydrocyclone container. By the inlet to the hydrocyclone container there are a connection point to inject flocculent from system 42; chemical injection to the flow to make the oil drops bigger so it will be easier to separate oil from water. In the hydrocyclone container 60% of the oil gets separated from the water, the cleaned water leaves the container with a pressure of 5,5 barg and is led to the degasing tank 44VD001. The separated oil get enriched in the reject flow that leaves the container 44CE001A/B with a pressure of 1,9 barg. The reject flow is typically 2-5% of the total water flow and contains 5% oil. The separated oil is sent back to the process by the reject flow, it is sent to liquid separator inlet gas recovery compressor 23VG005.

The rate to hydrocyclone unit 44XX001 in controlled by water level regulator on 2.stage separator 20VA002 by controlling a regulating valve in the wire to degasing tank 44VD001. The rate of the reject flow and degree of separation of oil is controlled by a regulation bow that controls the relationship between reject flow and acceptance flow pressure drop over the hydrocyclone by adjusting the regulating valve in the reject wire (System books, 2013. Internal GDF SUEZ document).

Primary treatment of water flow from 3.stage separator 20VA003:

With help from circulation pump 44PG0001A/B oil containing water is pumped from 3.stage separator 20VA003 to flotation tank 44VD020 in the flotation unit 3.stage separator 44XX020. The pump is a type that is gentle towards the water so that the oil drops that are formed does not get re-emulsified. To make the oil drops larger and better to separate there is injected flocculent from system 42 to circulation pump 3.stage separator 44PG0001A/B. in addition fuel gas in injected. The gas will blend with the water flow because of the statics mixer in the downstream injection point. The injection of the gas and flocculent gives good conditions in the tank to get maximal flotation and separation.

In the flotation tank oil is separated from water with a combination of flocculation, floatation and centrifugal powers. The cleaned water I then transported from the bottom of the flotation tank to the degasing tank 44VD001.

The flotation rate is regulated by the water level regulator for 3.stage separator 20VA003 controlling the speed on the circulation pump 44PG0001A/B. with low flow to the flotation unit the regulation valve in the circulation wire opens to maintain the flow through the pump. The flow of cleaned water from the flotation unit is controlled indirect by a regulation bow that controls the pressure in the flotation unit by a regulating valve in the line to the degassing tank produced water, 44VD001. The pressure in the flotation unit is regulated to 0,5 bar over the pressure in the degassing tank that normally will be 3,5 barg. The rate of the reject flow is controlled by a regulating valve in the reject wire to the liquid separator inlet gas recovery compressor, 23VG005.

The liquid level in the flotation tank CFU 030 separator, 44VD020 is regulated automatic to the level of the insert pipe in the top of the tank. If the regulating valve in the reject wire gets blocked, the level will sink because the pressure will increase and then the regulating valve will open to the line for the degassing tank. To avoid blockage of the valve in the reject wire this is flushed regularly.

At the top of the flotation tank CFU 030 separator, 44VD020 there will accumulate oil enriched aqueous phase and gas phase. A mix of these two phases is exported by a inlet pipe in the top of the tank and led by the reject wire to the liquid separator inlet gas recovery compressor, 23VG005 (System books, 2013. Internal GDF SUEZ document).

Final treatment of the water flow from the degassing tank produced water, 44D001:

Flotation unit produced water 44XX040, consist of 2 x 50% parallel flotation lines were these again consist of two series-connected flotation tanks; flotation tank CFU030 separator, 44D040a/b and CFU 030 separator, 44VD041a/b.

The water is led with a pressure of 3,5 barg from the degassing tank produced water, 44VD001 to the inlet on the two parallel flotation lines by the pressure difference over the system through flotation unit produced water, 44XX040. To increase the size of the oil drops and easier separate oil from water flocculent is injected from system 42, chemical injection. There is also injected flotation gas that will lead to a more effective flotation process in the flotation tanks (System books, 2013. Internal GDF SUEZ document).

In the flotation tanks the oil is separated from the water phases by a combination of flocculation, flotation and centrifugal powers so that it will accumulate an oil enriched phase in the top of the flotation tank and cleaned water at the bottom. The cleaned water flow from the two flotation lines are brought together and discharged to sea. The oil level in the cleaned water are automatically controlled by oil in water analyzer; 44T1542. The oil level shout not exceed 30 ppm (System books, 2013. Internal GDF SUEZ document).

A mix of the oil enriched water phase and flotation gas flows through an inlet pipe that are mounted at the top of each of the four flotation tanks. From the inlet pipes the mix is led through the flotation tank's reject lines to a manifold then to the liquid separator inlet gas recovery compressor, 23VG005.

The rate to the flotation unit produced water, 44XX020 is controlled by the level sensor on the degasing tank produced water 44VD001 and a regulation valve placed downstream flotation unit. The rate of the reject flow is controlled by a regulating valve in each reject wire.

The liquid level in each flotation tank is regulated automatically to the level of the inlet pipe. The level can get to low if there is blockage in the regulating valve in the reject wire. The valves are flushed regularly to avoid this (System books, 2013. Internal GDF SUEZ document).

Sand washing:

The sand washing unit, 44XX003 consist of a hydrocyclone container sand wash, 44VX010 that clean the sand and pumps for the sand slurry and fluid for washing. One pump delivers cleaned water to washing and one sand-cape unit for transport and washing of excreted sand. The sand washing unit 44VX010 consist of one hydrocyclone section for cleaning of washing fluid and one section for accumulation of excreted sand.

The sand that is supplied with gas and oil flow from Gjøa and Vega is sedimented in the bottom of the separators and in the degasing tank. The sand must be removed to not disrupt the operation on the plant. To remove the sand, washing fluid is pumped in through nozzles at the bottom of the separators/degasing tanks. Sedimented sand swirls up and like sand slurry it is led out through outlet in the bottom of the separator/degasing tank. The slurry is then led to the hydrocyclone section of the hydrocyclone container sand wash, 44X010. Here the sand is separated out and accumulated at the bottom. Cleaning of the separators are done one by one, each separator is divided into parts that is cleaned periodically, the plant is operated during the sand washing.

When cleaning the Gjøa separator and degasing tank produced water are used as washing fluid. Produced water is pumped by pump 44PA010 from the degasing tank 44DV001 outlet to connector for washer nozzles on 1., 2. Or 3. Stage separator; 20VA001/002/003. From 1st and 2nd stage separator sand is led to the hydrocyclone section on the hydrocyclone container 44VX010 by the pressure difference. The operational pressure is too low on 3. Stage separator 20VA003 and degasing tank 44VD001 so sludge pump 44PA013 is used to pump the slurry to the hydrocyclone section on the hydrocyclone container 44VX010. After the sand is separated in the hydrocyclone the water returns to the degasing tank 44VD001 (System books, 2013. Internal GDF SUEZ document).

To avoid accumulation of sand in the inlet to pump 44PA010, this pump is not used when cleaning the degasing tank 44VD001. Sludge pump 44PA013 is used instead; this pumps water from the degasing tank to the hydrocyclone section on the hydrocyclone container 44VX010. From there the cleaned water is transported as washing fluid to the washing nozzles on the degasing tank (System books, 2013. Internal GDF SUEZ document).

The separators on Vega is cleaned for sand the same way as Gjøas 1. and 2. stage separators, the difference here is that they are flushed with rich MEG. Rich MEG is pumped with help from the booster pump wet MEG flushing; 67PA55, and pump wet MEG flushing, 44PA001 from tank wet MEG 67TB051A to flushing nozzles on Vega 1. stage separator; 20VA051 and Vega 2. stage separator 44VA052. From the separators sand/MEG slurry is led with help from the pressure difference on the hydrocyclone section on hydrocyclone container; 44VX010. The MEG flow returns to the degasser, 38VD001 in the MEG regeneration package; 38XX051 after the sand has been separated in the hydrocyclone (System books, 2013. Internal GDF SUEZ document).

Flushing rate is adjusted with help from a regulating valve downstream hydrocyclone section on the hydrocyclone container; 44VX010. The pressure on the flushing nozzles is adjusted with help from a regulating valve downstream pump produced water flushing; 44PA010 for produced water and pump wet MEG flushing; 44PA011 for rich MEG.
In the hydrocyclone the sand is separated from the flushing fluid because of the cyclone effect. The separated sand is collected in the washing section of the hydrocyclone container 44VX010. To avoid a mix between the produced water and the MEG as washing fluids the system is flushed with fresh water in-between the cleaning operations (System books, 2013. Internal GDF SUEZ document).

When the washing section is full of sand the oil is removed from the sand by washing it with water. The water brings the sand from the washing section on the hydrocyclone container 44VX010 through a sand cape unit to the hydrocyclone section were the sand is separated and falls back to the washing section. In the sand cape unit the sand is flushed with clean water, the water and the separated oil is then transported to degassing tank 44VD001 (System books, 2013. Internal GDF SUEZ document).

The sand from the washing section is discharged to sea after it has been cleaned to oil level that is acceptable; if the oil level is higher than what is accepted the sand has to be transported to land. When discharge to sea the pump 44PA012 is used, this will lead the sand from the washing section and in in the flow of cleaned water (System books, 2013. Internal GDF SUEZ document).

Hydro cyclone

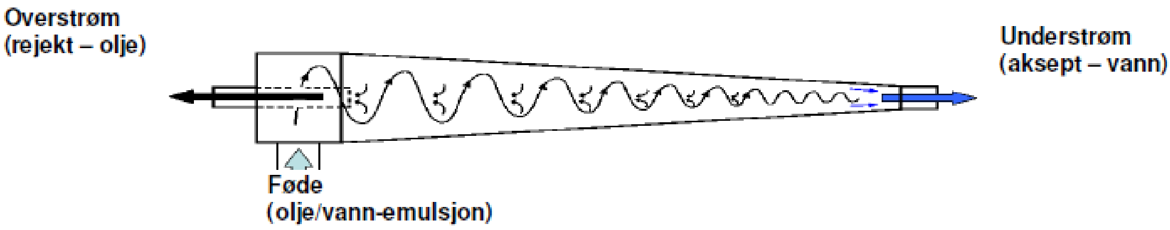


Figure 9: Illustration of a HydroCyclone. (System Book, internal GDF SUEZ document)

In a hydrocyclone an emulsion gets separated into two liquid phases with different densities or liquid slurry separated in solid and a liquid phase (System books, 2013. Internal GDF SUEZ document).

Liquid/liquid hydro cyclones:

Liquid/liquid hydrocyclones are used to separate to liquid phases with different densities; oil from water flow. Hydrocyclone is shaped like a cylindrical conical container that tappers conically from inlet to outlet.

Liquid emulsion that shall be separated is tangential led into the widest part of the hydrocyclone. The liquid then starts to rotate, and this will generate a radial power that gets the heaviest water phase to enrich by the cylinder wall and then will flow out through the smallest outlet of the cylinder (underflow). The lightest phase will be enriched in the middle part of the cylinder and flow out through a centrum pipe in the widest part of the cylinder (overflow) (System books, 2013. Internal GDF SUEZ document).

The effect of the hydrocyclone increases with decreasing radius, that why the hydrocyclones are designed with small radius and several tubes are in parallel in one hydrocyclone module to get the wanted capacity. The separation effect in a hydrocyclone module depends on cone shape also available pressure drop, liquid viscosity, density difference and size of the oil drops. The effect gets better with low liquid viscosity and high density difference; these parameters are decided by the liquids that are to be separated (System books, 2013. Internal GDF SUEZ document).

When the oil drops gets bigger the separation power gets better, therefore there can be added flocculation to the hydrocyclone upstream. Adding flocculent makes the small oil drops bind together.

The separation effect in managed by controlling the relationship between pressure drop over the hydrocyclone for up and down stream (System books, 2013. Internal GDF SUEZ document).

Liquid/solid hydro cyclones:

Liquid/solid hydrocyclones are used to separate liquid phases from solid, sand from a water flow, they work the same way as liquid/liquid hydrocyclones.

Flotation:

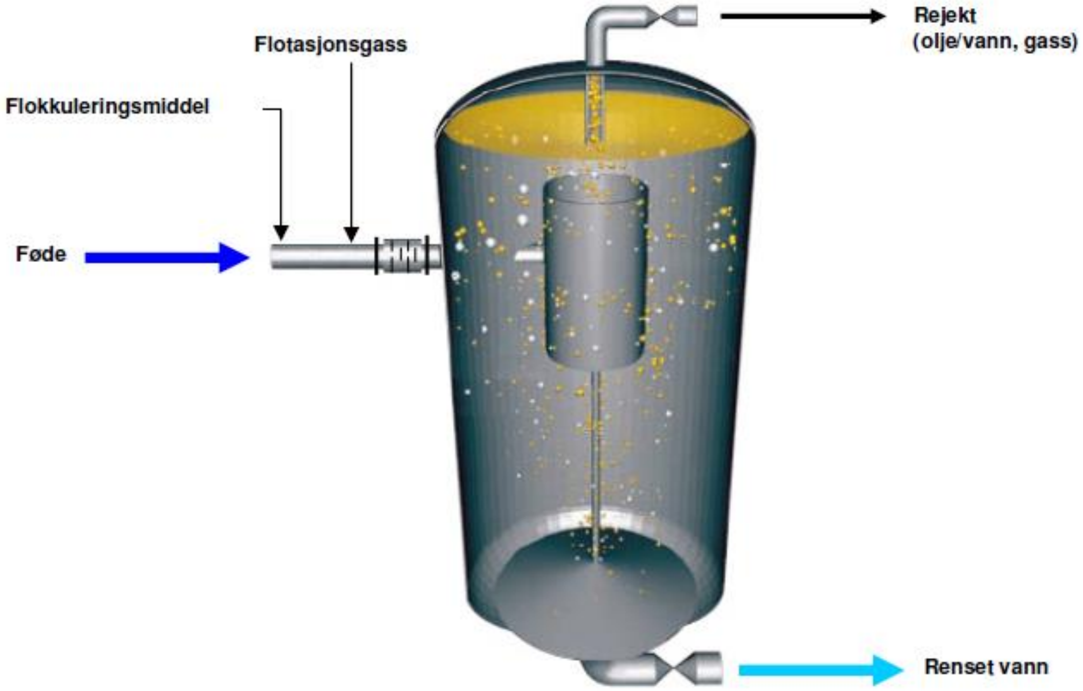


Figure 10: Illustration of flotation process. (System Book, internal GDF SUEZ document)

When flotation the different phases are separated in a liquid emulsion with help from gas bobbles that flow through the liquid. The flotation is carried out in a vertical container that continually is fed with the liquid emulsion that will be separated. In the inlet to the container flotation gas is injected to the emulsion flow. The emulsion is led tangential in to the inner tube in the container and then there becomes a radial power that magnifies the separation. When the emulsion flow comes in to the container the gas will rise to the liquid surface that will bobble. During the transportation through the liquid the oil will bind to the bobbles and gather on the liquid surface at the same time the water at the bottom will be cleaned for oil (System books, 2013. Internal GDF SUEZ document).

Environmentally Critical Elements in system 44; produced water

In system 44, produced water, there are several components that can fail and lead to discharge to sea and be critical to the environment. The components that are analyzed in this system are:

2. stage Separator, 20VA002

This is the component that serves the system with the main amount of produced water and sand and goes further into the hydrocyclone containers for primary treatment. If the separator has poor conditions this could lead to bad separation and the amount of oil discharged to sea could end up being not acceptable and be reported as an acute spill or breach of the discharge permit. The Separator also has five sections with shut off valves that open and closes for produced water for the respective components, if these five sections of valves are not controlled in a way they should the amount of produced water that goes to the hydrocyclone container could be too high or too low and the separation in the container will not be optimal.

Hydrocyclone container, 44CE001A/B

This is an important cleaning phase, and it depends on the pressure for the best separation effect. By the inlet to the hydrocyclone container there is a connection point to inject flocculants to increase the size of the oil drops to better the separation. In this component there are separated more than 60% of the oil from the water. If this is not functioning optimal with the right pressure it will not separate enough and the discharge will contain more oil than what is acceptable.

The hydrocyclone container has liners inside that will keep the separation under the best condition, but as it has shown these liners can break and the separation will be very poor and the water and oil will not be separated.

Valve below the hydrocyclone container, 20HV1230:

If this valve that is placed below the hydrocyclone container as a bypass valve is not controlled properly there is an opportunity that the produced water can go through this valve without going through the hydrocyclone container before it goes further through the system to the degassing tank 44VD001, if this happens there will be a high amount of oil that will be discharged to sea because the produced water was not treated in the hydrocyclone container before it went further into the system and discharged to sea.

CFU 030 separator, 44VD40A/41A, 44VD40B/41B:

These separators are a part of the flotation unit 44XX040. This is the last stage of separation, and the water is separated in two parallel flotation lines. If they are not functioning properly and not separating as they should, oil can be discharged to sea.

There are a switch to prevent that there will be formed eddy current in the separators. Each separator has a level sensor and a pressure sensor that can be read in the control room, there is also a local indicator, if these sensors are broken the separation effect could be less than it should and as this is the last separation stage it is important that all sensors are functioning properly.

Last barrier valve: 44LV1505;

This valve is a regulating valve, and is a part of the regulating bow. Valves that are the last barrier before discharge should be checked if they are functioning optimal and if they are remote controlled, they should be visually checked to be sure that they are not sending wrong signals to computer systems. They could send a signal that they are closed, but because of some failure they might still be open and then oil could be sent to the sea, when it should be sent through the separation system once more.

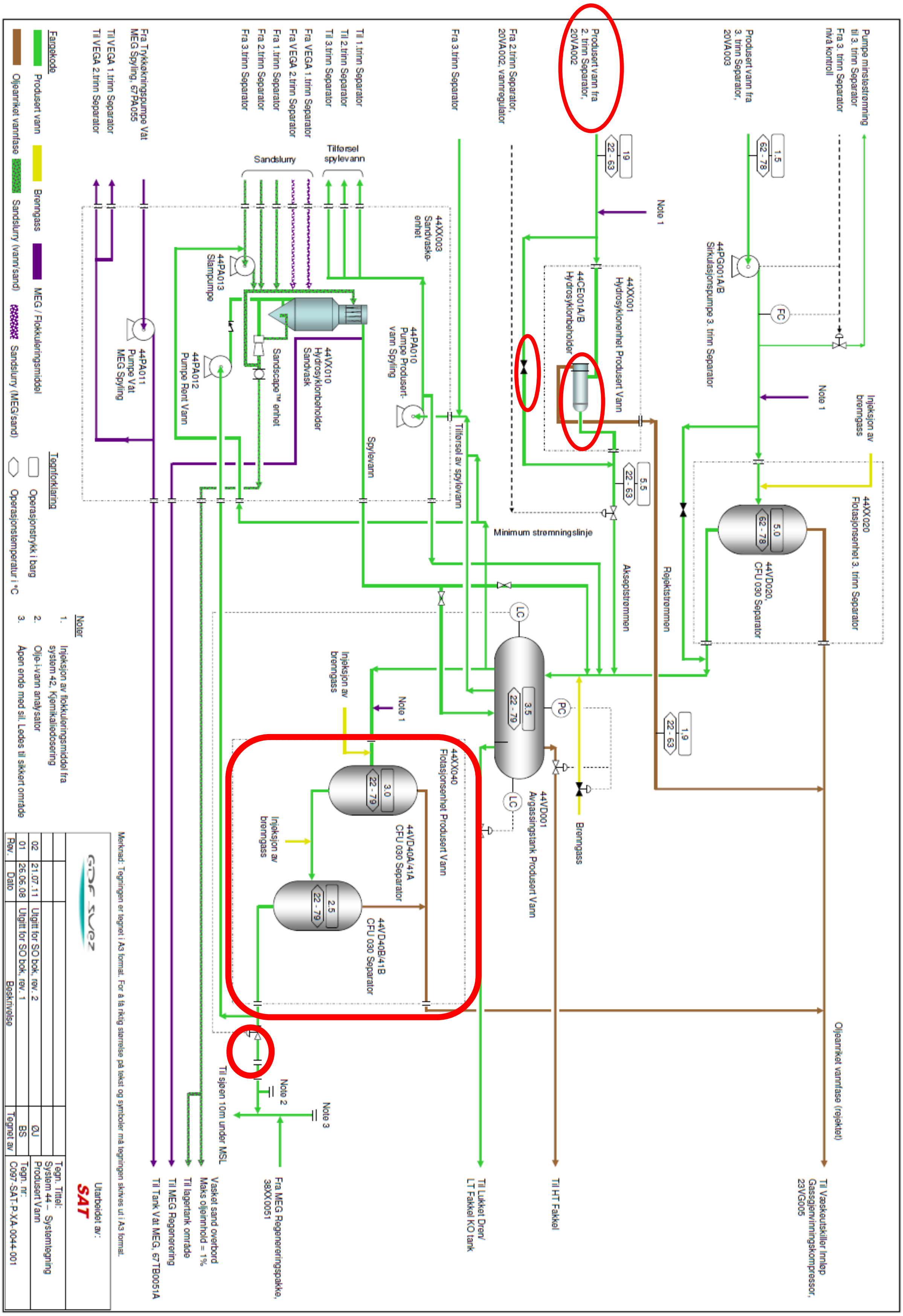


Figure 11: System drawing of system 44, with the ECE's for the system (System Book, internal GDF SUEZ document).

Checklist; System 44 Produced Water

This checklist represents the criticality of the tags that I found was ECEs. To find the existing criticality of the equipment I used COMOS, COMOS is a management and maintenance system at GDF SUEZ. I compared the already classified criticality of production and HSE (safety) to my assessment of the criticality for the environment.

The first column represents the tag number of the ECEs equipment. The second column represents a description of the equipment. The third column; criticality production represent the criticality the equipment have regarding the production itself. I have included this column to the checklist too see the connection between the criticality of production, HSE (safety) and the environment. The fourth column represents the criticality of the equipment associated with HSE, with the main focus on safety and not environment. The fifth column represents my findings and the new criticality is based on the environment according to my analysis of the tags.

Tag number	Description	Criticality production	Criticality HSE, main focus on safety	Criticality focus on Environment
20VA002	2.stage separator	High	Low	High
44CE001A/B	Hydrocyclone container	Low	High	High
20HV1230	Valve	Low	Medium	High
44VD40A/41A	CFU 030 Separator	Low	High	High
44VD40B/41B	CFU 030 Separator	Low	High	High
44LV1505	Last barrier valve	Low	High	High

4.3 System 56 – Open drain

System description:

The purpose of system 56, open drain is to collect and lead rain water, fire water and waste water from the process, help systems and riser module to the sump tank for cleaning before discharged to sea. This is done to minimalize discharge that can contaminate the environment. In addition there are a lens system for water that comes in to the hull itself (System books, 2013. Internal GDF SUEZ document).

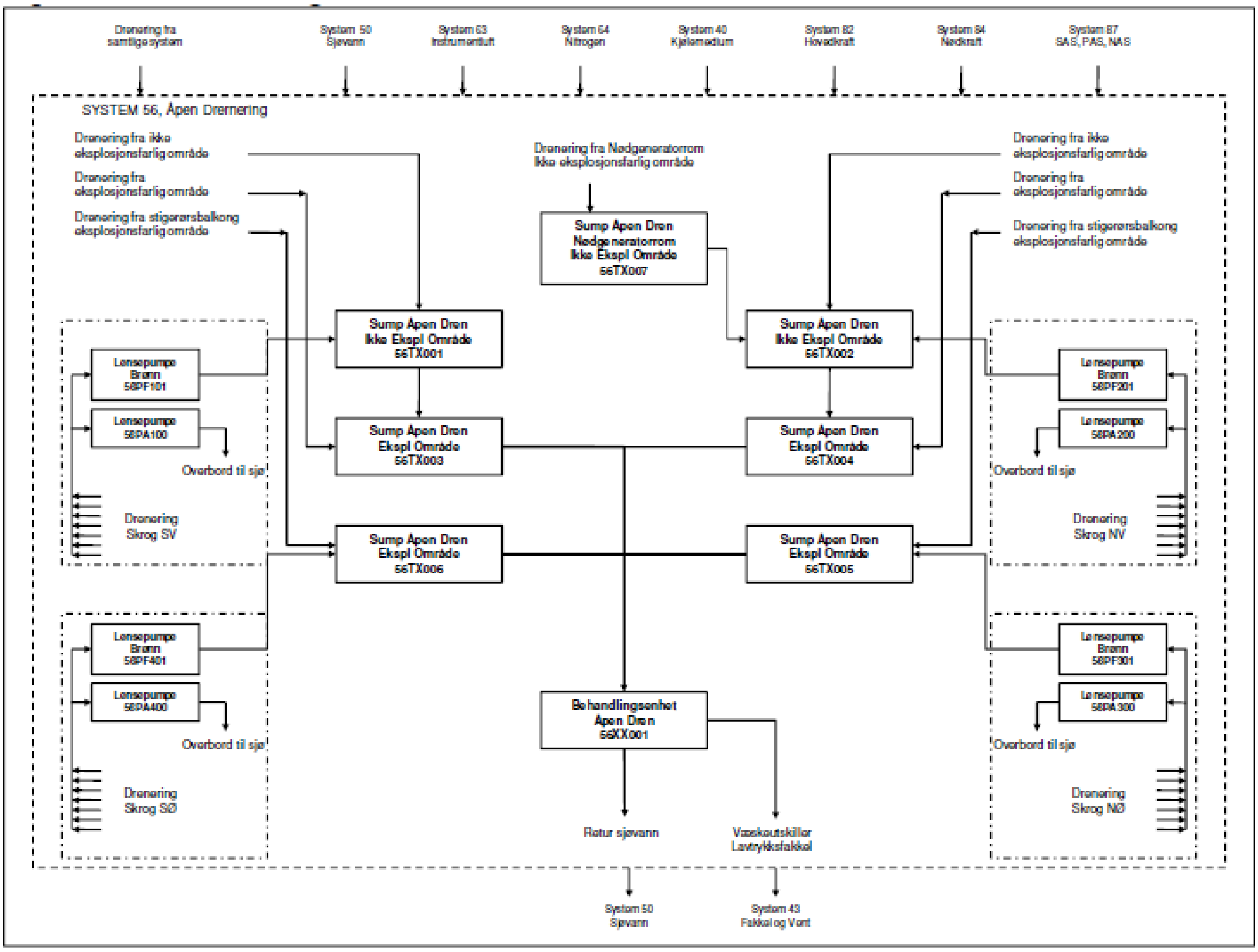


Figure 12: Block diagram of system 56 (System Book, internal GDF SUEZ document).

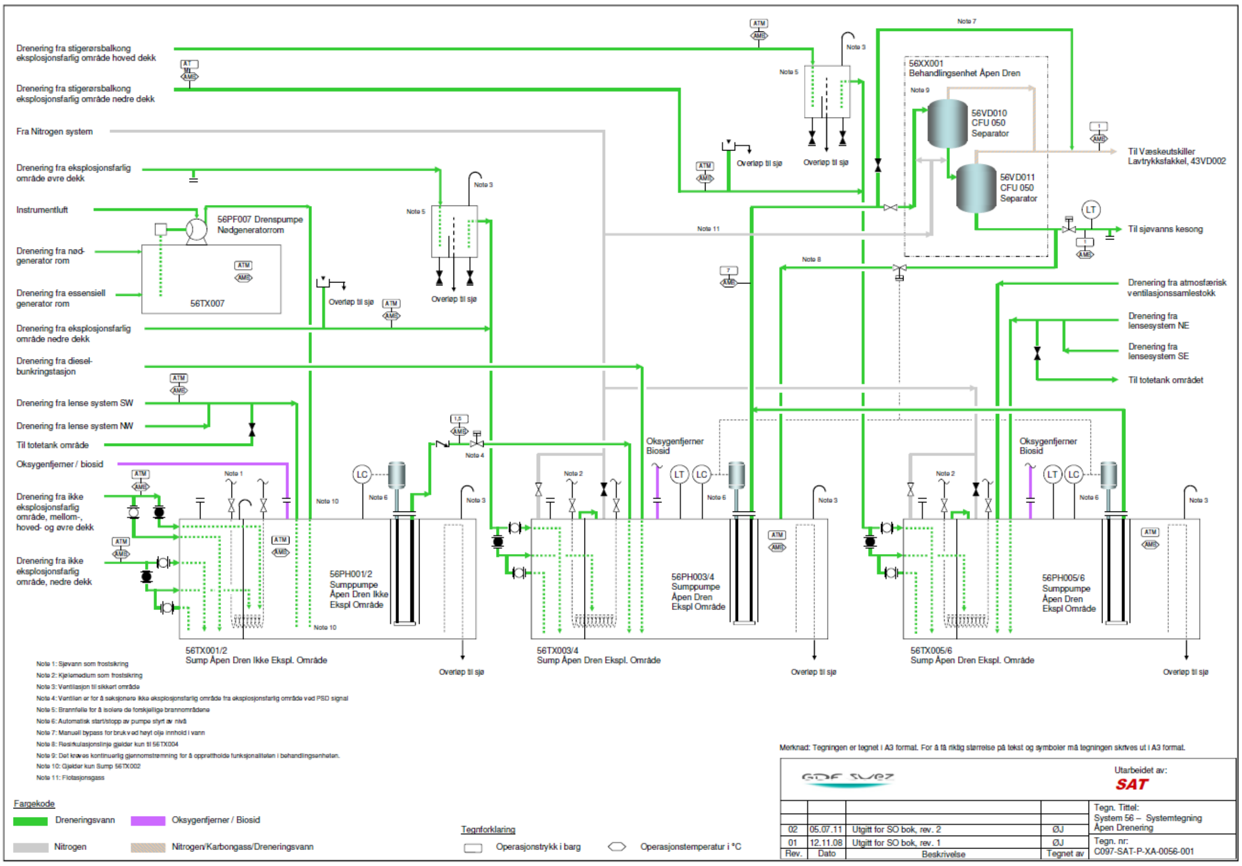


Figure 13: system drawing, system 56 (System Book, internal GDF SUEZ document).

Process description:

The systems purpose:

System 56, open drain consist of one drainage system for hazardous areas and one system for non hazardous areas. These two system are separated to limit the possibility of transferring hydrocarbons to the safe area through the drainage system. The system are divided into five main components; drain in no hazardous area, drain in hazardous area; process module, drain in hazardous area; riser balcony, cleaning of drainage fluid (System books, 2013. Internal GDF SUEZ document).

Drainage from non-hazardous area:

Drainage from a non-hazardous area covers the help system module and includes equipment, drip, drainage containers on deck that are placed in this module. Drainage from single sources is gathered in manifolds and are led to sump open drain non-hazardous area; 56TX001/002, one for the south area and one for the north area. Drainage lines is dimensioned with fall of 1:35 in to the sump tanks and will generally not have low points. The sump tanks are linked by horizontal lines so there are always fall towards one of them independent of the roll angel to the hull (System books, 2013. Internal GDF SUEZ document).

Every sump tank is divided into inlet chamber and main chamber. All drainage is sent to the inlet chamber except water from lens system to the hull because it is clean and can be sent directly to the main chamber. In the inlet chamber sand and larger particles are separated and sinks to the bottom, but water and any oil goes in overflow to the main chamber. Inlet to the inlet chamber is submerged in the liquid phase and ended 40mm above the tank bottom and created a gas barrier that prevents gas from spreading to upstream equipment and area. A 2" welded bow with sea water flow that covers inlet and main chamber frost protects the sump tank. There are permanent connection for injection of biocide that prevents growth of algae and microorganism. The amount and interval between every injection should be based on the operation of the plant (System books, 2013. Internal GDF SUEZ document).

Sump pump open drain non-hazardous area; 56PH001/002 pumps drainage fluid from respective sump tanks to sump open drain hazardous area; 56TX003/004. The sump pumps are submerged to a own pump well to avoid that gas from the tank escapes when there are maintenance on the pumps. When the pump is not used for operation there is an actuated valve in the pump outlet for close of to avoid reflux of gas (System books, 2013. Internal GDF SUEZ document).

Drainage from the emergency and essential generator goes to a separate sump; sump open drain emergency generator room non-hazardous area; 56TX007. This is done to prevent the emergency generator room get filled up with drainage water from other areas and part of the plant if the plant should be subjected to a roll rate near the maximum value; 17 degrees. Drainage from sump tank in the emergency generator room is pumped to 56TX002 with air operated sump pump 56PF007. Outlet pipe in the pump is installed so that water will not flow back to the emergency generator room and fill this when maximum roll rate on the plant (System books, 2013. Internal GDF SUEZ document).

Drainage from hazardous area in the process module:

Drainage from hazardous area in the process module includes drainage from equipment, drip and drainage container on deck. The process module consist of several fire areas, the drainage from the different areas are separated with fire seal pots to prevent spreading of fire and smoke from one fire area to another. Drainage from the single sources are gathered in a manifold and led to sump open drain hazard area; 56TX003/004. Drainage lines are dimensioned with fall of 1:35 in to the sump tanks and will generally not have low points. The sump tanks are linked by horizontal lines so there are always fall towards one of them independent of the roll angel to the hull (System books, 2013. Internal GDF SUEZ document).

Every sump tank is divided into inlet chamber and main chamber. All drainage is sent to the inlet chamber except water from drainage fluid from sump tank open drainage non-hazardous area; 56TX001/002, this goes directly to the main chamber; 56TX003/004. In the inlet chamber sand and larger particles are separated and sinks to the bottom, but water and any oil goes in overflow to the main chamber. Inlet to the inlet chamber is submerged in the liquid phase and ended 40mm above the tank bottom and created a gas barrier that prevents gas from spreading to upstream equipment and area. A 2" welded bow with sea water flow that covers inlet and main chamber frost protects the sump tank. There are permanent connection for injection of biocide that prevents growth of algae and microorganism. The amount and interval between every injection should be based on the operation of the plant (System books, 2013. Internal GDF SUEZ document).

Sump pump open drain hazard area 56PH003/004 pumps drainage fluid from respective sump tank to treatment unit open drain; 56VD010 and 56VD011 for cleaning. The sump pumps are submerged to a own pump well to avoid that gas from the tank escapes when there are maintenance on the pumps. Sump tanks, 56TX003/004 continually gets flushed with nitrogen and ventilated in a safe area outside the process module to be sure there are clean atmosphere in the tanks (System books, 2013. Internal GDF SUEZ document).

Drainage from hazardous area, riser module:

Drainage from hazardous area in the process module includes drainage from equipment, drip and drainage container on deck. The process module consist of several fire areas, the drainage from the different areas are separated with fire seal pots to prevent spreading of fire and smoke from one fire area to another. Drainage from the single sources are gathered in a manifold and led to sump open drain hazard area; 56TX005/006. Drainage lines are dimensioned with fall of 1:35 in to the sump tanks and will generally not have low points. The sump tanks are linked by horizontal lines so there are always fall towards one of them independent of the roll angel to the hull (System books, 2013. Internal GDF SUEZ document).

Every sump tank is divided into inlet chamber and main chamber. All drainage is sent to the inlet chamber except drainage fluid from atmospheric vent manifold, this is clean and is sent directly to the main chamber in the sump tank; 56TX005. In the inlet chamber sand and larger particles are separated and sinks to the bottom, but water and any oil goes in overflow to the main chamber. Inlet to the inlet chamber is submerged in the liquid phase and ended 40mm above the tank bottom and created a gas barrier that prevents gas from spreading to upstream equipment and area. A 2" welded bow with sea water flow that covers inlet and main chamber frost protects the sump tank. There are permanent connection for injection of biocide that prevents growth of algae and microorganism. The amount and interval between every injection should be based on the operation of the plant (System books, 2013. Internal GDF SUEZ document).

Sump pump open drain hazard area 56PH005/006 pumps drainage fluid from respective sump tank to treatment unit open drain; 56VD010 and 56VD011 for cleaning. The sump pumps are submerged to an own pump well to avoid that gas from the tank escapes when there are maintenance on the pumps. Sump tanks, 56TX003/004 continually gets flushed with nitrogen and ventilated in a safe area outside the process module to be sure there are clean atmosphere in the tanks (System books, 2013. Internal GDF SUEZ document).

Cleaning of drainage fluid:

Drainage fluid from the four sump tanks for the hazardous area; 56TX003/004/005/006, are gathered in a manifold and are then sent to treatment unit open drain, 56XX001. The treatment unit consists of two CFU separators, 56D010/011, which are connected in series. The reason they are connected is to achieve higher cleaning effect (System books, 2013. Internal GDF SUEZ document).

A CFU separator (compact flotation unit) is a vertical two phase separator that uses centrifugal power and flotation gas to separate oil and water. Nitrogen from system 64 is used as flotation gas and is injected in the inlet to each CFU050 separator. The gas is mixed into the water flow with help from a static mixer downstream in each injection point. The injection of flotation gas keeps maintains an effective flotation process (System books, 2013. Internal GDF SUEZ document).

In CFU 050 separators oil is separated from the water phase because of the accumulation of oil enriched phase at the top and a cleaned water phase at the bottom of the tanks. The water phase from the CFU separators; 56VD010 is sent to CFU separator; 56VD011 for further treatment. The cleaned water flow from 56VD011 is discharged to sea, while the oil enriched water phase from 56VD010 and rejected water phase from 56VD011 is gathered and sent to liquid separator low pressure torque; 43VD002. Control of the reject valves; 56FV4088 and 56FV4094 are set so that 0,1-1% of incoming liquid flow together with the gas from flotation process is evacuated to liquid separator low pressure torque; 43VD002 (System books, 2013. Internal GDF SUEZ document).

CFU separator:

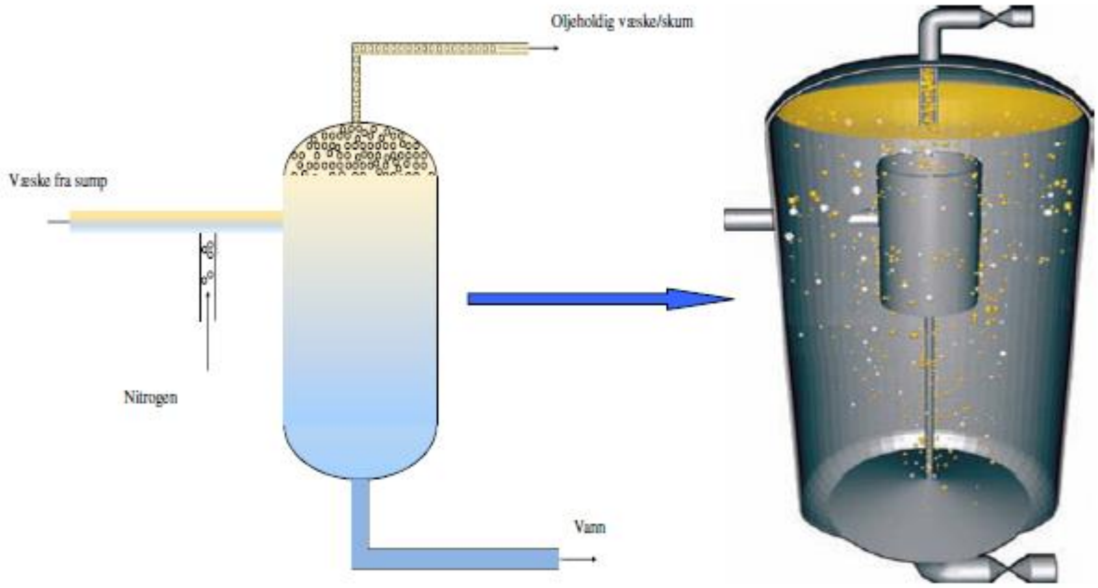


Figure 14: Illustration of a CFU separator shows where flotation gas (nitrogen) is injected (System Book, internal GDF SUEZ document).

Separation of oil from water in a CFU separator happens with help from flotation gas. Flotation gas in this case is nitrogen that is added to the fluid by the inlet to the separator. By the inlet to the container flotation gas is injected to the emulsion flow. The flow is led tangential in to the inner tube in the container, and here radial force is created that enhance the separation. When the flow enters the tank the gas rises to the liquid surface as bobbles. During transportation through the liquid oil binds to the bobbles and is accumulated at the liquid surface at the same time the water at the bottom is cleaned for oil (System books, 2013. Internal GDF SUEZ document).

Lens system in the hull:

The lens system is placed in the hull and consist of four small pneumatic lens pumps, lens pump well; 56PF101/201/301/401 and four big electric lens pumps; 56PA100/200/300/400, the big lens pumps have associated lens startup pumps; 56PF102/202/302/402. The lens pumps are placed in each corner of the corners to the hull (System books, 2013. Internal GDF SUEZ document).

The lens system in the hull operates fourteen ventilated rooms and seventy-four dry tanks called voids in pontoons and pillars. Waste water from equipment and flushing is led to the drainage containers that are connected to lens wells in the ballast pump room or directly to the lens wells. Each pump room has two lens wells with separate output to the lens pumps. During assembly of the hull and deck all the tanks are filled with water to lower the hull sufficient so that the main deck can be skidded over the pillars. All the tanks are equipped with 8” pipe to connect the voids to the ballast system. These 8” pipes are normally blinded but will routinely be inspected for leak. The pipes are located in the voids to make inspection and access easier. Leak from these areas is sent to the lens wells for respective pump rooms. All the voids has manually operated valves that normally are closed, in addition there are installed reject valves in series (System books, 2013. Internal GDF SUEZ document).

Normally lens pump well; 56PF101/201/301/401 is used to remove water that comes from minor leaks and low draining rates into the hull. Drainage fluid from pump 56PF101 and 56PF201 is sent to respectively sump open drain non-hazardous area; 56TX001/002 while pumps; 56PF301 and 56PF401 sends the fluid to respectively sump open drain hazardous area; 56TX005 and 56TX006 for further treatment. Drainage of the lower chain lockers are directly associated with lens pump 56PF101/201/301/401. Chain lockers get purged with air to prevent corrosion. A constant overpressure is held to prevent intrusion of hydrocarbons through chain glands (System books, 2013. Internal GDF SUEZ document).

With bigger leaks or high drainage rates, lens pump 56PA100/200/300/400 is used. These discharge water directly to sea. The lens systems are also connected to the ballast water system for drainage of ballast water tanks in case they are emptied completely due to maintenance. The pump room has actuated valves that can open/close from the control room, while the voids has manually valves that are placed as close as possible to the tanks due to access. Suction points from dry rooms are equipped with filters to avoid blockage of valves, wires or pumps. The tanks in the pillars are drained through a sump at the bottom, while the suction pipes in rooms and tanks in the pontoon are placed 30mm above ground (System books, 2013. Internal GDF SUEZ document).

Environmentally Critical Elements in system 56; open drain

In system 56, open drain, there are components that can fail and lead to discharge to sea and be critical to the environment. The components that are analyzed in this system are:

CFU 050 separators; 56VD010/56VD011

These two separators are a part of the treatment unit, 56XX001 and are the two most important components in these systems because these are the components that separate out what should be discharged to sea. These Separators are connected in series to get a better separation effect. If not functioning or a failure within these will result in discharge to sea that should not have happened.

In the treatment unit 56XX001 there are injected chemicals to keep the separation high, if there are problems with the injection the separation could be much lower than expected and the discharge could be higher than allowed.

Sieve, 56SX4062:

This is a sieve that was placed after production had started because of trouble with blockage of the separators due to different material clogging the pipes and preventing the separators to separate. This sieve must be a part of the maintenance program and periodically checked to be sure that it is functioning optimally.

Valve 56HV4080:

This valve is placed by the inlet to the treatment unit open drain, 56XX001. This valve is controlled by a pressure difference and will close if the pressure is too low to prevent injection of nitrogen to the separators. If this valve is not controlled properly it could let in too much flow and the separators could get overloaded and again not separate good enough.

Last barrier valve, 56PV4095:

This valve is one of the last barriers before discharge to sea, it also contains the pressure in the treatment unit. For this system as for system 44, valves that are the last barrier before discharge should be checked if they are functioning optimal and if they are remote controlled, they should be visually checked to be sure that they are not sending wrong signals to computer systems. They could send a signal that they are closed, but because of some failure they might still be open.

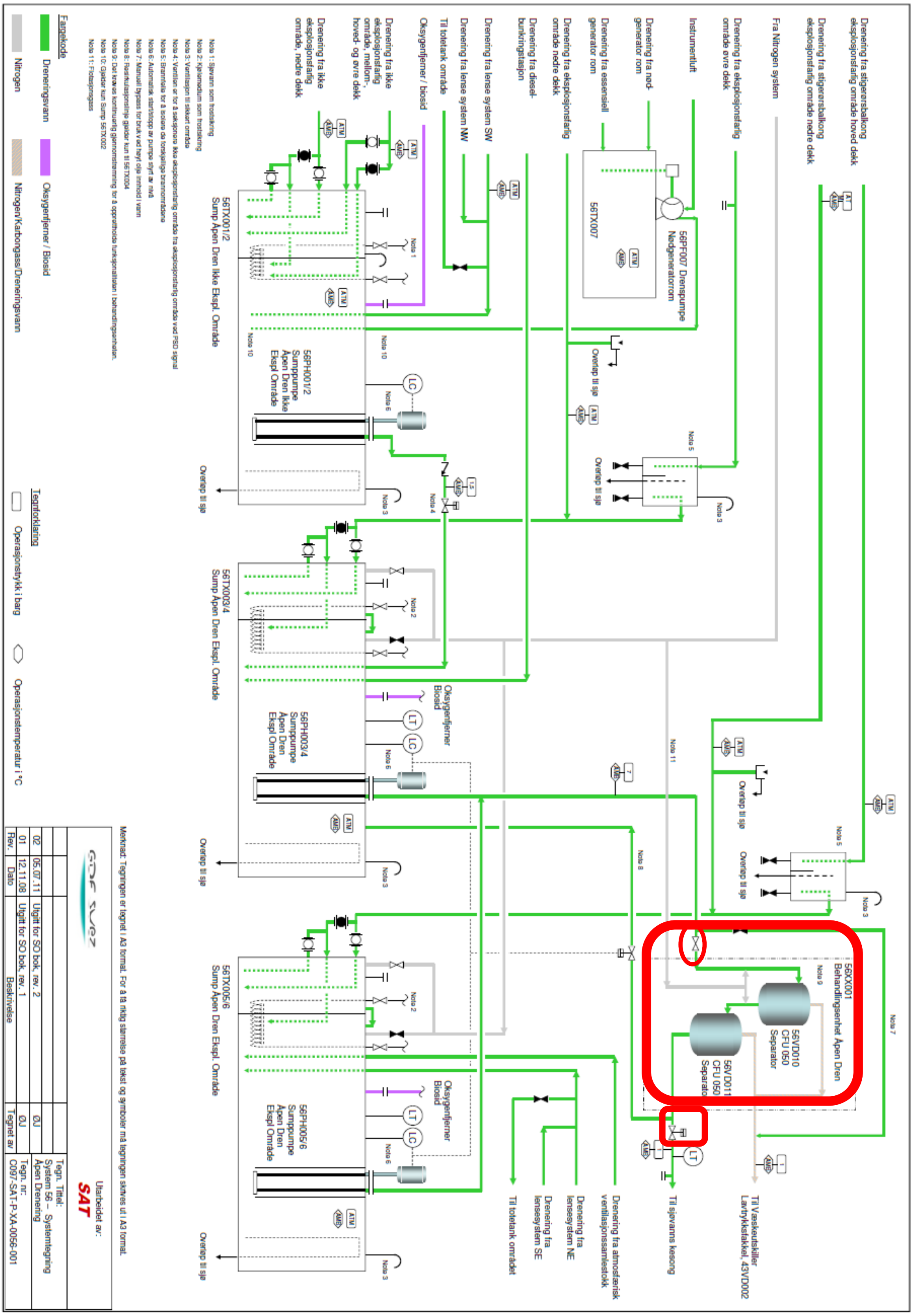


Figure 15: System drawing of system 56, with the ECE's for the system (System Book, internal GDF SUEZ document).

Checklist; System 56 Open Drain

This checklist represents the criticality of the tags that I found was ECEs. To find the existing criticality of the equipment I used COMOS, COMOS is a management and maintenance system at GDF SUEZ. I compared the already classified criticality of production and HSE (safety) to my assessment of the criticality for the environment.

The first column represents the tag number of the ECEs equipment. The second column represents a description of the equipment. The third column; criticality production represent the criticality the equipment have regarding the production itself. I have included this column to the checklist too see the connection between the criticality of production, HSE (safety) and the environment. The fourth column represents the criticality of the equipment associated with HSE, with the main focus on safety and not environment. The fifth column represents my findings and the new criticality is based on the environment according to my analysis of the tags.

Tag number	Description	Criticality production	Criticality HSE, main focus on safety	Criticality focus on Environment
56VD010/011	CFU 050 Separator	Low	High	High
56SX4062	Sieve	Low	Medium	High
56HV4080	Valve	Not evaluated	Not evaluated	High
56PV4095	Last barrier valve	Low	High	High

4.4 System 38 – MEG regeneration

System description:

The purpose of system 38; MEG regeneration is to regenerate the MEG (mono ethylene glycol) that is separated from gas-/condensate flow from the Vega field so it can be used again.

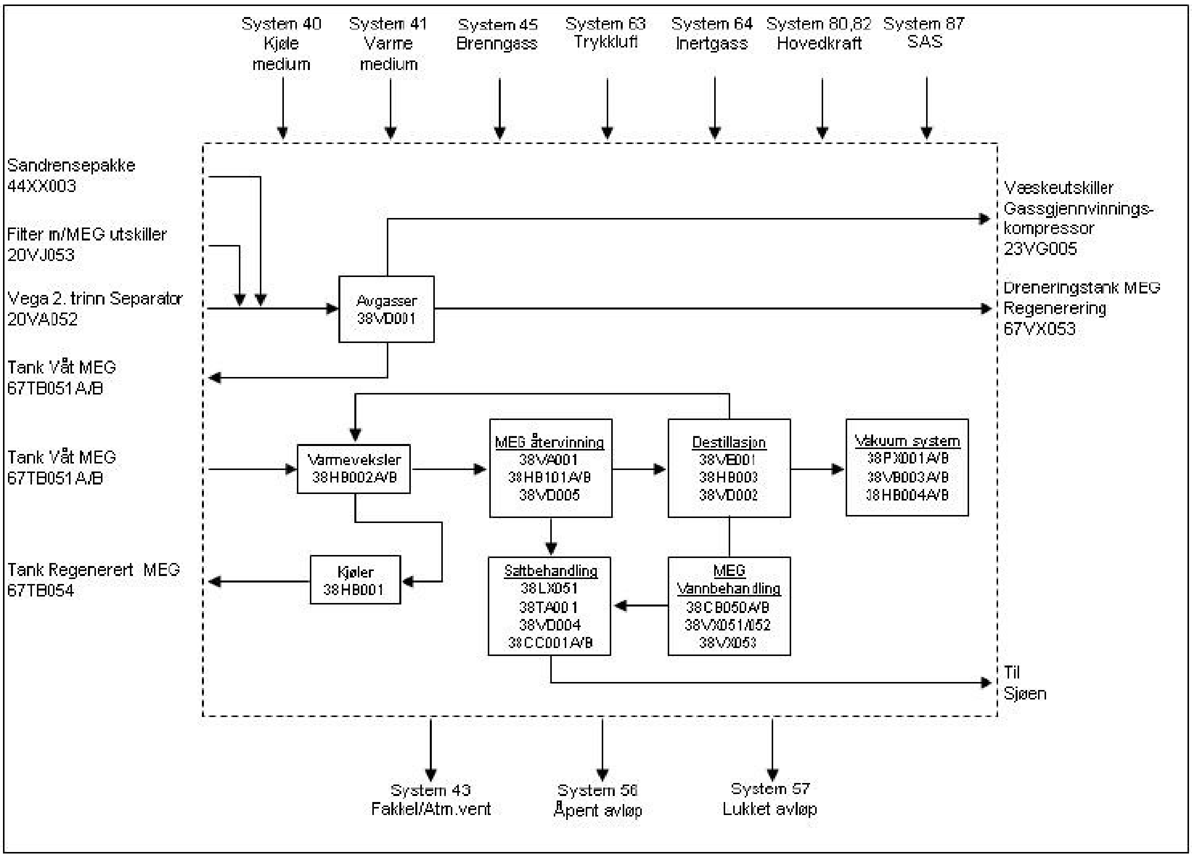


Figure 16: Block diagram system 38 (System Book, internal GDF SUEZ document).

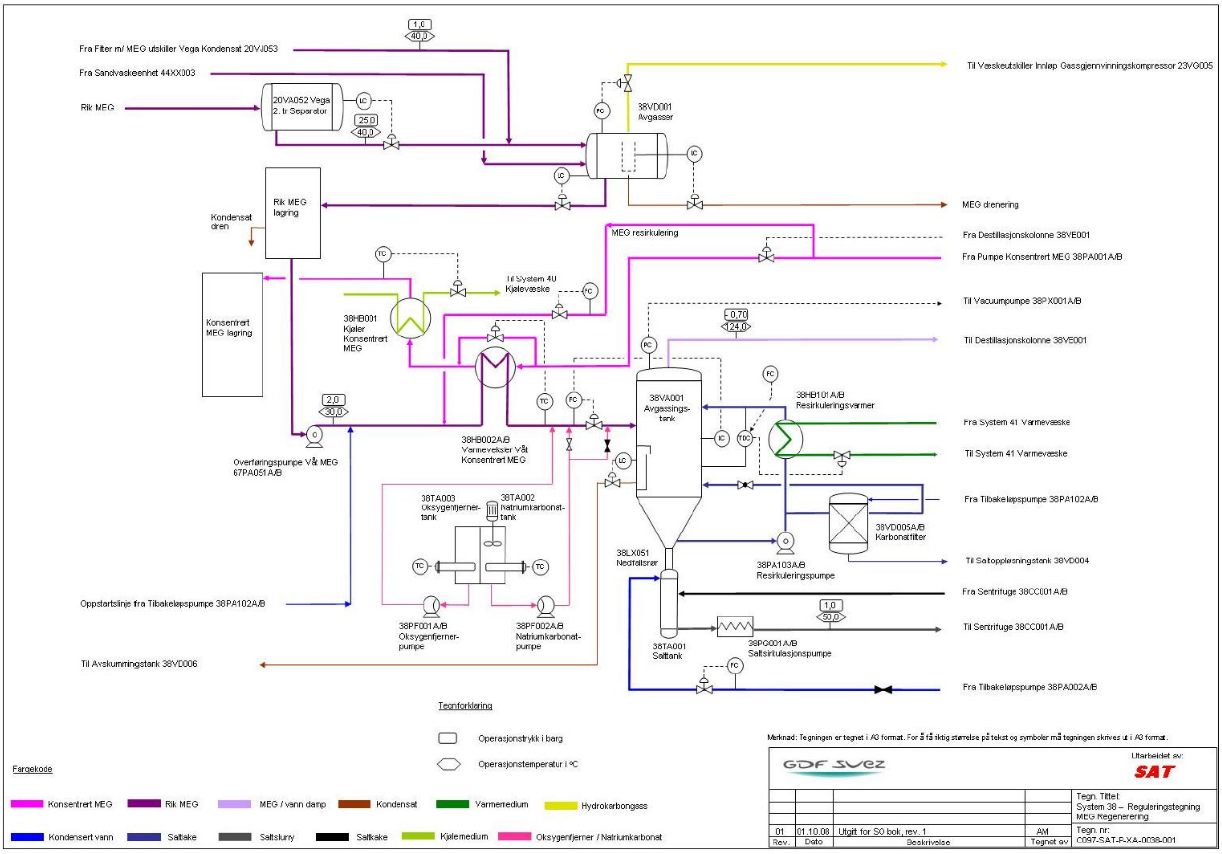


Figure 17: System drawing, system 38 (System Book, internal GDF SUEZ document).

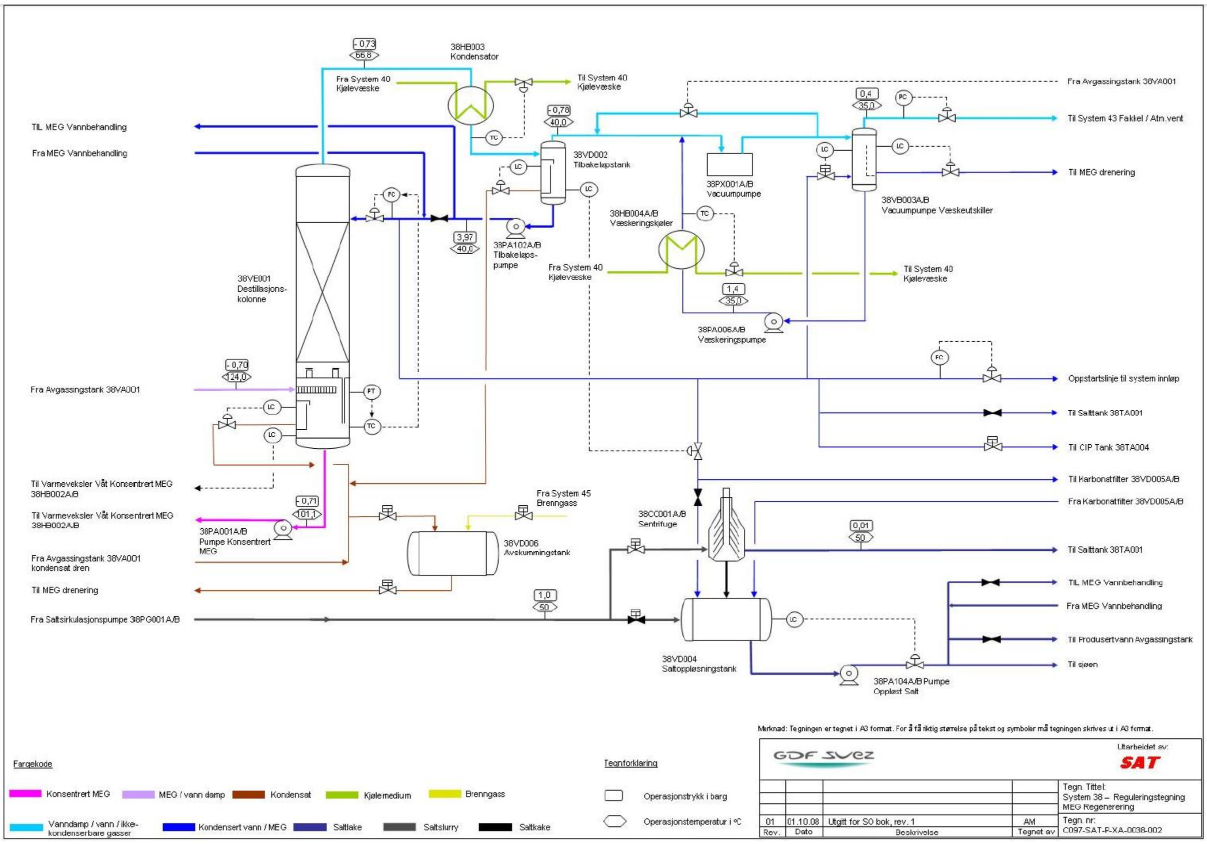


Figure 18: System drawing, system 38.

Process description:

The systems function:

To avoid hydrate formation MEG is regularly injected to the Vega field. The injected MEG is returned with the gas-/condensate flow that goes from Vega field to Vega 1.stage separator; 20VA052 located on the Gjøa platform. Here the gas is separated from a liquid phase that consist of MEG, water and condensate. The liquid phase is transported to Vega 2.stage separator; 20VA052 where it is separated to a MEG/water phase and a hydrocarbon phase. The MEG/water phase is led to system 38, MEG regeneration. In addition to MEG and water the separated MEG/water phase contains salts and residues of hydrocarbons, sand and other particles. To use the MEG over again, water, salts, particles and hydrocarbons must be removed from the MEG/water phase. This is done in system 38, MEG regeneration and after the regeneration it is led to tank regenerated MEG 67TB054 for reuse (System books, 2013. Internal GDF SUEZ document).

System 38, MEG regenerating consist of: degasser; 38VD001, MEG regenerating package; 38XX051, MEG water treatment and salt treatment package; 38XX052. In these units the MEG/water phase goes through degassing, pretreatment, MEG recycling, distillation and salt treatment. In addition there is a CIP system for cleaning of the equipment in the MEG regeneration unit (System books, 2013. Internal GDF SUEZ document).

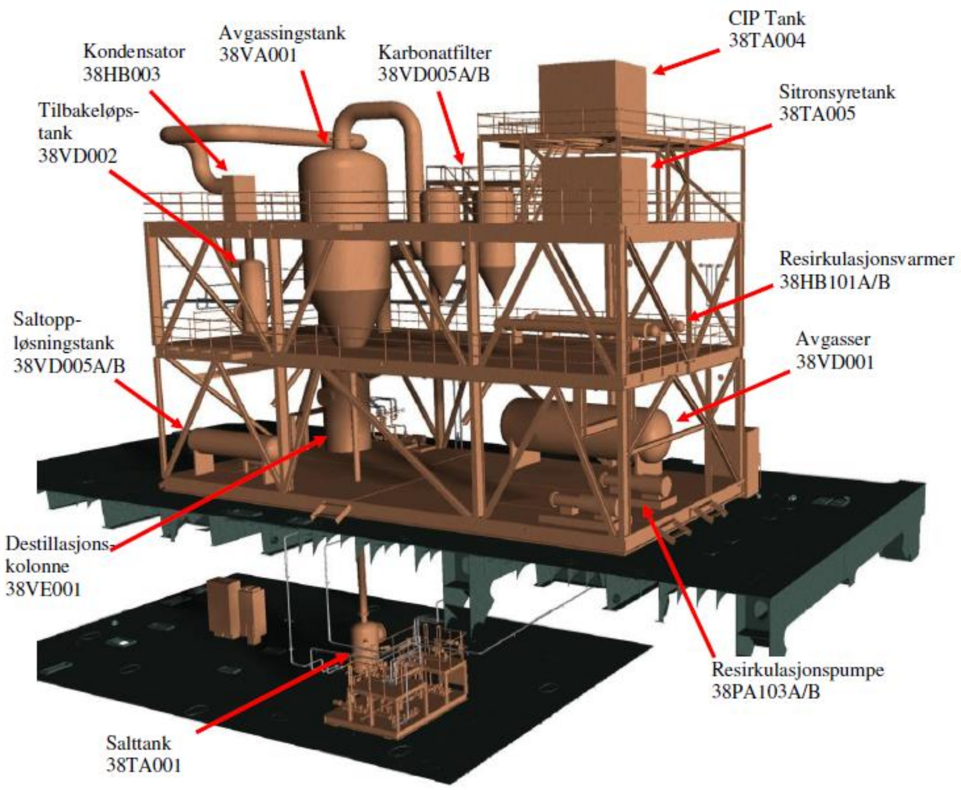


Figure 19: Picture of main components in the MEG system (System Book, internal GDF SUEZ document).

Degassing of wet MEG:

Separated wet MEG from Vega 2.stage separator; 20VA052 and from filter MEG separator Vega condensate 20VJ053 is led with help from the differential pressure through level regulator valves 20LV2205 and 20LV2311 to degasser 38VD001. The temperature on both flows is 40 degrees Celsius.

When sand cleaning of Vega 1./2. Stage separators 20VA051/052 there is led a flow of wet MEG from sand package 44XX003 to degasser; 38VD001. Degasser 38VD001 operates with a much lower pressure than Vega 2.stage separator 20VA052 and therefore the hydrocarbons that have been absorbed is separated from wet MEG flow here.

Hydrocarbons in gas state is led from the top outlet of the degasser; 38VD001 to the liquid separator inlet gas recycle compressor; 23VG005 in the gas recompression system. The flow is controlled by a pressure regulating valve; 24PV4000A, upstream pressure regulating valve is 38XV4268 and downstream is a flow measure 38FT4145.
The pressure in the degasser is controlled by a pressure regulating valve; 38PV4000A in combination with pressure regulating valve; 38PV4000B, in the line for burn gas from system 45.
The hydrocarbons that are separated in the liquid phase is separated from wet MEG phase by flowing over overflow to an outlet chamber for hydrocarbons. From this outlet chamber the separated hydrocarbon phase is led through a level regulating valve; 38LV4005 to a drainage tank MEG regeneration; 67VX053. In the outlet line for hydrocarbons there are valve 38XV4149 and flow meter 38FT4146, also there are connected a sampling point; 38AP4298 in this line (System books, 2013. Internal GDF SUEZ document).

Degassed wet MEG is led with help from the pressure difference from the bottom outlet on the degasser; 38VD001 under the level regulating tank 67TB051A7B. The normal flow rate for wet MEG is 11,2m^3 /t. To be able to handle the increase in flow rate when pigging operations the degasser is dimensioned to a flow rate up to 36m^3/t with a residence time in the tank of 20 minutes. To get the best precision on level regulating from high to low flow rate there are two parallel level regulating valves; 38LV4003A/B in the wire to the storage tank. These operate in shared force of the regulator; 38LIC4003.
Degasser 38VD001 is depressurized to system 43, through safety valve 38PSV4001A or B. a mechanical interlock; 38SK4002 makes sure that one of the safety valves always are operating (System books, 2013. Internal GDF SUEZ document).

Pretreatment:

MEG regenerating package; 38XX051 is fed with degassed wet MEG from tank wet MEG 67TB051A/B, with help from transfer pump wet MEG; 67PA051A/B. Before wet MEG flow is led to the degassing tank 38VA001 it is treated, partly by adjustment of concentration and partly by heating and injection of chemicals.

Normal feed rate to the package is 11,2m^3/t. To be able to catch up a day of production stop in five days the package is dimensioned with 20% extra capacity. This is why the MEG regeneration package is designed to have a fed rate of 13,44m^3/t or 14367kg/t, the rate to the package are controlled by a regulating valve; 38FV4012.
Wet MEG flow is heated up to fifty-seven degrees Celsius in a heat exchanger wet concentrated MEG; 38HB002A/B by heat exchanger against concentrated MEG flow from the distillation column; 38VE001. The temperature of the wet MEG flow is controlled with the help of bypass valve; 38TV4011 that lets concentrated MEG through the heat exchanger. This is done to prevent formation of coating on the surface of the heat exchanger with high temperatures.
Heat exchanger wet MEG; 38HB002A/B is secured for overpressure on wet MEG and concentrated MEG side to system 43; torque and ventilation through the safety valves; 38PSV4009/4017 and 38PSV4008/4016 (System books, 2013. Internal GDF SUEZ document).

MEG regeneration package; 38XX051 is designed to process wet MEG that has a concentration of 50-60% weight. To control that the concentration is at this level there are upstream heat exchanger wet MEG distillation meter; 38AT4164, a temperature sensor; 38TE4007 and pipework for supply of concentrated MEG or condensed water to wet MEG flow. Pipework for concentrated MEG are connected to the pressure side on pump concentrated MEG; 38PA001A/B, in the bottom inlet line from distillation column; 38VE001. Pipework for condensed water are connected through MEG water treatment system to pressure side on reflux pump; 38PA102A/B, in the outlet line from reflux tank; 38VC002.
Using measurement for density and temperature the concentration in the wet MEG flow is calculated. Based on the current concentration the supply of concentrated MEG or condensate is controlled automatically. If the concentration is lower than 50% the supply of concentrated MEG is raised through regulating valve; 38FV4065. If the concentration is higher than 60% it is diluted with condensed water using regulating valve; 38FV4246.
Downstream heat exchanger wet concentrated MEG; 38HB002A/B there are pipework for injection of the chemicals; sodium and oxygen remover to the wet MEG flow before it

is led into the degassing tank; 38VA001 (System books, 2013. Internal GDF SUEZ document).

Sodium carbonate (Na_2CO_3) is injected to make sure that there will not occur free calcium chloride ($CaCl_2$) in the feed flow to the degasser tank. Calcium chloride does not precipitate like crystals, but they can form a viscous fluid that accumulates in the bottom of the degassing tank. When adding sodium carbonate the potential calcium chloride convert to calcium carbonate ($CaCO_3$), and this will be precipitated as particles in the fluid, at the same time sodium carbonate converts to sodium chloride (NaCl):

$CaCl_2 \rightarrow CaCO_3 + 2NaCl$

Both of these will crystalize as solid in the degassing tank.

Sodium carbonate is saved as a 20% water solution in sodium carbonate tank; 38TA002, that are equipped with mixer sodium carbonate tank; 38CJ001 and heater sodium carbonate tank; 38FE001. The tank is ventilated to the atmosphere. Sodium carbonate is injected from the tank to MEG flow using a dosage pump; 38PF002A/B.
Outlet from sodium carbonate pump; 38PF002A/B depressurizes back to the tank through safety valve; 38PSV4142/4139.
Oxygen remover is injected to make sure that there not occurs free oxygen in the feed rate to the degassing tank. Potential oxygen will lead to quicker corrosion on the equipment in the MEG regeneration package and the MEG will also disintegrate quicker.
The oxygen remover consists of a mixture between sodium bisulfite and a catalyst. The oxygen remover makes the sodium bisulfite use the potential oxygen in the fluid when it oxidizes to sodium sulfate.

$2\ NaHSO_3 + \frac{1}{2}\ O_2 \rightarrow Na_2SO_4 + SO_2 + H_2O$

The function of the catalyst is to ease the oxidation reaction between oxygen and sodium bisulfite. Sodium sulfate precipitates as crystals in the degassing tank; 38VA001 and is removed there together with salts.

The oxygen remover is only injected to remove small parts of oxygen, bigger part there are different procedures. Oxygen remover is preserved as a water solution in oxygen remover tank; 38TA003, that is equipped with heater oxygen remover tank; 38FE004.
Outlet from the oxygen remover pump; 38PF001A/B depressurizes through a safety valve; 38PSV4135/4136. To mix the chemicals in wet MEG flow most effective there is a static mixer 38SX4001 in the pipework to the degassing tank; 38VA001 (System books, 2013. Internal GDF SUEZ document).

MEG – recycling:

The pretreated wet MEG flow is led to the degassing tank; 38VA001, here the MEG is recycled by most of the MEG and water evaporates and is led through the tanks top outlet. MEG and water that not evaporates accumulates as salty MEG fluid in the degassers bottom section.
Wet MEG flow is led through a tangential inlet in the upper part of the degassing tank; 38VA001. Her it quickly evaporates because it is mixed with a heated recirculation flow with salty MEG fluid that is led through the tanks bottom section through a recirculation bow. Evaporated MEG and water is led as a vapor flow through a mist eliminator out through the tanks top outlet and goes from there to the distillation column; 38VE001. The mist eliminator is flushed regularly with concentrated MEG from the MEG regenerating tank; 67TB054 to remove salt deposits (System books, 2013. Internal GDF SUEZ document).

Non-evaporated fluid and solid flows in a spiral down the tank wall to the bottom section and accumulates there as a salty fluid volume. Since MEG has a larger boiling point that water, the MEG concentration in this fluid is normally higher than 95% weight. Since most MEG and the water content has evaporated, the salt is precipitated as crystals. These are sedimented together with other solid down through the salty MEG fluid and led through tumbledown pipe; 38LX051 to a salt treatment package; 38XX052 for further treatment.
Evaporation temperature for MEG/water mix is kept down because the degassing tank; 38VA001 is operated with a pressure of -0,7 barg. The temperature is normally 110 to 130 degrees Celsius and depends on the pressure in the degassing tank and MEG

concentration in the fed flow of wet MEG to the tank. See figure 20 (System books, 2013. Internal GDF SUEZ document).

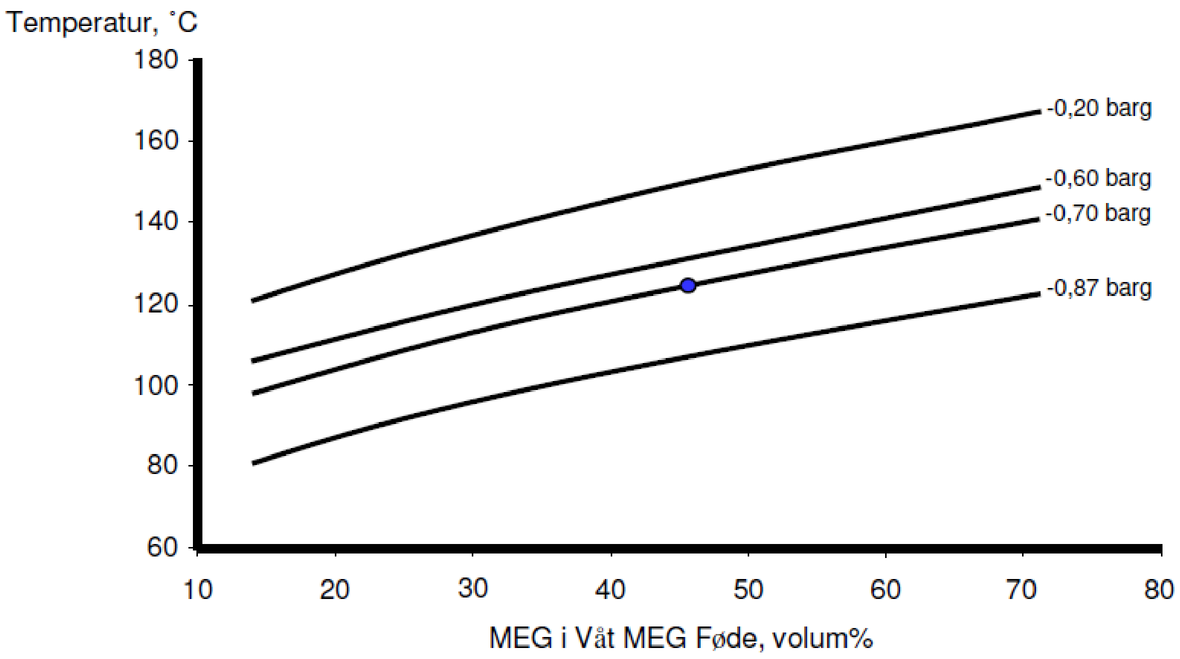


Figure 20: Temperature in degassing tank, 38VA001 as a function of MEG concentration in the birth rate of wet MEG and the pressure in the tank (System Book, internal GDF SUEZ document).

The vacuum in the degassing tank is contained because it floats on the pressure in distillation column; 38VE001, that are connected to vacuum pump; 38PX001A/B. The low pressure implies that there is not risk of creating explosive vapor mixture if oxygen enters. With such low pressure there are not enough oxygen molecules near the hydrocarbon molecules that combustion could occur. Because of this there is no need for supply of inert gas to the degassing tank during normal operation (System books, 2013. Internal GDF SUEZ document).

Degassing tank; 38VA001 are designed to separate out particles to minimize amount of solid that can cause erosion and contamination in the recycling bow. The tanks has baffles that lead salt and other particles down to the fallout pipe; 38LX001 in the bottom of the tank, at the same time salty MEG fluid with low particle content accumulate in the upper part of the liquid volume of can flow to the recycle bow.

Salty MEG fluid from the upper part of the liquid volume in the bottom section on the degassing tank; 38VA001 is pumped using a recycling pump 38PA103A/B through recycling heather 38HB101A/B and is transported like a recycling flow tangential to the upper part of the tank and is then mixed with birth rate of wet MEG. The pipeline is reduced to 6" and the speed is very high because of this (8,1m/s) by the inlet to the tank. Even if the degassing tank 38VA001 is designed to minimize the amount of particles in the upper part of the bottom section of the liquid volume the recycling flow will contain salt crystals and other solid. To prevent these particles from precipitate in the pipeline or the recycling heater 38HB101A/B the recycling pump 38PA103A/B is designed to maintain high flow rate through recycling bow. Flow rate is normally 544m^3/t.

In the recycling heater 38HB101A/B the recycling flow is heated with 15°C using heat exchanger with heat medium. The heater is designed to add a heating effect of 7150kW to the recycling flow. This is enough for all the MEG and water in the birth rate of wet MEG to condensate when it is mixed with the recycling flow.

The recycling heater 38HB101A/B is a spiral heat exchanger where the recycling flow is led through the cold side. To prevent precipitation of salt particles on the heat exchanger surface the flow rate through the spiral cold side are high. This prevents heat transfer through heat exchanger surface is reduced because of salt coating. The high flow rate causes high heat transfer numbers and that the MEG is only in contact with worm metal surfaces in a short period of time. The last contributes to reducing the thermal decomposition of the MEG.

Recycling heater 38HB101A/B is depressurized on the outlet side for the recycling flow and on the outlet side for the heat medium to system 43 (torque and ventilation) through the rupture disk 38PSE4033/4045 and the safety valves 38PSV4039/4051.

The calcium and iron carbonate crystals that precipitates to the degassing tank 38VA001 are smaller than the sodium chloride crystals that precipitate. Small crystals sediments slower than bigger crystals so there will be an accumulation of iron carbonate and calcium in the liquid volume of salt MEG in the tanks bottom section. To make sure that the amount of iron carbonate and calcium does not increase a partial flow of the recirculation flow is led through a carbonate filter 38VD005A/B where the small crystals are captured. From the filter the partial flow is led back to the degassing tank.

When the carbonate filter is filled it gets automatically drained for MEG and flushed with condensed water from the reflux pump 38PA102A/B. flushing water and salt crystals are led to the salt resolution tank 38VD004.

Degassing tank 38VD005A/B has an outlet chamber for separation of hydrocarbons and similar fluid that floats on the surface of the salty MEG fluid in the bottom section. If these are not removed they will accumulate on the liquid surface and form a foam layer that can interfere with the operation of the degassing tank. The hydrocarbons are separated when flowing through an overflow to the outlet chamber. Bottom outlet to the outlet chamber goes through a pipeline that is connected to a skimming tank 38VD006.

The level at the bottom section is normally controlled during the overflow to the outlet chamber. The operator can periodically remove the hydrocarbons by using a automatic skimming sequence. This will raise the level so the hydrocarbons flow through the overflow to the outlet chamber. When a level sensor in the outlet chamber detects hydrocarbons flowing in a valve in the pipeline to the skimming tank 38VD006 will open. When the outlet chamber is drained the valve is closed and the level is back to normal.

Skimming tank 38VD006 is also used to drain hydrocarbons from the distillation column 38VE001 and reflux tank 38VD002. When the skimming tank is full it is drained using collected fluid is pushed through valve 38HV4176 to the drainage tank MEG regeneration 38HV4178. To the outlet pipe from the skimming tank to the drainage tank there is a sample point 38AP4303.

Skimming tank 38VD006 is vented to the distillation column 38VE001 through valve 38HV4177 (System books, 2013. Internal GDF SUEZ document).

Distillation:

The flow of MEG vapor and water vapor from degassing tank 38VA001 is led into the lower part of the distillation column 38VE001 with a temperature of 124°C and a pressure of -0,7barg. In this the vapor flow is separated in a base product of concentrated MEG, and a top product of water. To minimize the MEG loss the column is operated with as low as possible concentration of MEG in the top product and in the base product the concentration of MEG should be 90% weight.

Distillation column 38VE001 consist of an amplifier column, this is enough to achieve the desired purity in top and base products. In the column there is a pack where the separation between MEG and water takes place. Since the birth rate to the distillation column already are in vapor phase there is no need for a boiler to generate the vapor flow through the column.

In the distillation column the birth rate of MEG and water vapor rises through the pack. At the same time a reflux of the liquid water flows through the pack. When there are contact between vapor and liquid flow in the pack the MEG transfers from vapor to liquid phase at the same time as water goes the opposite direction, from liquid to vapor phase. When the vapor rises through the pack, MEG is partly removed from the gas flow when it meets a water flow with cleaner water. In the same way water is removed from the liquid flow when it goes through packer and meets a vapor flow with rising concentration of MEG.

The vapor flow from the distillation column is led to condenser 38HB003. This is a plate heat exchanger where all vapor condenses to liquid with heat exchange against cooling medium from system 40. The temperature of the condensate is controlled to be 40°C using a temperature regulating valve 38TV4079 in the outlet pipe for cooling medium from the condenser. Condensate that consists mainly of water is collected as condensed water in the reflux tank 38VD002. Reflux tank 38VD002 is depressurized to system 43 (toque and ventilation) through safety valves 38PSV4078A/B. a mechanical interlock 38SK4038 secures that they are always operating.

From the reflux tank 38VD002 the condensed water is pumped using reflux pump 38PA102A/B through MEG heat treatment system where hydrocarbon residues and particles are removed. Separated hydrocarbons are led to 3.stage separator 20VA003.

From the MEG heat treatment system a partial flow of condensate water is led the top of the distillation column through a regulating valve 38FV4068. Residues of the liquid is pumped to various consumers or dumped.

Excess of condensed water is discharged to sea through carbon filter 38VD005A/B that is a backup and the salt dissolving tank 38VD004. The flow rate is controlled by the level in the reflux tank 38VD002 using a regulating valve 38LV4074.

To maintain a minimum flow through reflux pump 38PA102A/B there are a reflux pipe that leads from the pump outlet back to the reflux tank.

Distillation column, condenser and the reflux tank is operated under vacuum using vacuum system that is connected to the top of the reflux tank. Since degassing tank 38VA001 are connected to the distillation column through vapor pipes the vacuum are contained because of the vacuum system.

The liquid that flows from the column packer has a MEG concentration of minimum 90% weight and collected as concentrated MEG in the bottom section on the distillation column. The concentration is controlled indirectly using a temperature regulating bow that controls reflux of water to the top of the distillation column.

From the bottom section concentrated MEG is pumped using pump concentrated MEG 38PA001A/B through a regulating valve 38LV4057 and a heat exchanger 38HB002A/B and cooler concentrated MEG 38HB001 to the tank regenerated MEG 67TB054.

To maintain a minimum flow through pump concentrated MEG38PA001A/B there is a reflux pipe that leads from the pump outlet back to the distillation column.

With low MEG concentration in the birth rate to the degassing tank 38VA001 concentrated MEG can also be pumped through regulating valve 38FVO4063/4064 into the birth rates heat exchanger wet concentrated MEG 38HB002A/B.

In the heat exchanger wet concentrated MEG 38HB002A/B that are a spiral heat exchanger, the flow is cooled down using concentrated MEG by the heat exchanger against the birth rate of wet MEG from tank wet MEG 67TB051A/B.

Cooler concentrated MEG 38HB001 is a plate heat exchanger, in this concentrated MEG is cooled down to 35°C. The temperature is controlled using regulating valve 38TV4013 in the outlet pipe for the cooling medium from the cooler.

Cooler concentrated MEG 38HB001 is depressurized on the outlet side of concentrated MEG to system 43 through safety valves 38PSV4244A/B. a mechanical interlock 38SK4015 secures that the valves are operating.

The bottom section in the distillation column 38VE001 and reflux tank 38VD002 there are a outlet chamber for separation of liquid hydrocarbons and similar fluids that floats on the liquid surface of the concentrated MEG phase or the condensed water phase. If these fluids not are removed they accumulate on the surface and form a foam layer that can interrupt the operation of the equipment. The hydrocarbons are separated by going through a overflow to the outlet chamber. The bottom outlet for each outlet chamber goes through a pipeline that is connected to the degassing tank.

The level at the bottom section is normally controlled during the overflow to the outlet chamber. The operator can periodically remove the hydrocarbons by using a automatic skimming sequence. This will raise the level so the hydrocarbons flow through the overflow to the outlet chamber. When a level sensor in the outlet chamber detects hydrocarbons flowing in a valve 38LV4195/38LV4199 in the pipeline to the skimming tank 38VD006 will open. When the outlet chamber is drained the valve is closed and the level is back to normal.

The vacuum system consists of vacuum pump 38PX001A/B, vacuum pump liquid separator 38HB003A/B, liquid ring pump 38PA006A/B and liquid ring cooler

38HB004A/B. The vacuum pump extracts non-condensable gas from the process equipment and leads the gasses through liquid separator and the ventilation pipe to the atmosphere. Liquid separator is operated with a pressure of 0, 4 barg. The pressure is controlled by e regulating valve 38PV4214/4215 in the ventilation pipe. To the ventilation pipe there are connected an oxygen analyzer 38AT4216 that gives an alarm if the oxygen level in the gas is too high.

The vacuum systems capacity is controlled by a pressure regulating bow that controls the pressure in the degassing tank 38VA001. The capacity is controlled by adjusting the opening of the regulating valve in the recycling pipe around the vacuum pump. The pressure in the degassing tank is -0, 7 barg and this causes the pressure at the top of distillation column and the reflux tank are -0, 73 barg and -0, 78 barg (System books, 2013, Internal GDF SUEZ document).

Salt treatment:

Salt crystals and other solids that are separated in the degassing tank 38VA001 is treated in salt treatment package 38XX052 before they are discharged to sea as saltwater dissolvent.

To minimize the loss of MEG the salt crystals are cleaned for MEG in a displacement system with saltwater. This consists of vertical tumbledown pipe 38LX051 that are connected on the degassing tank 38VA001 together with the inlet on the salt tank 38TA001. The upper part of the tumbledown pipe has a cooling housing and through this the cooling medium from system 40 circulates.

The tumbledown pipe and salt tanks are filled with saturated brine with high density. Because the brine is saturated with salt the MEG has low solubility, because of this and because the brine has higher density than the MEG there will form boundary layers between upper MEG phase and lower brine phase by the inlet to the tumble down pipe. This prevents the MEG from flowing down through the pipe. The salt crystals have a higher density than the brine and the MEG will sediment down through the tumble down pipe into the salt tank.

Salt and other solids that fall down the salt tank form together with the brine sludge that contain around the same amount salt and water. The sludge contains a residue of 5 grams MEG per kilo salt. For the slurry in the salt tank will be mixed and ready to be pumped the content in the tank is circulated continually using salt circulation pump

38PG001A/B. This pumps slurry from the lower part of the salt tank through a recycling pipe from the pumps outlet, back to the upper part of the salt tank through a valve 38HV4121.
Salt circulation pump are a screw pump that depressurizes from the outlet back to the salt tank through safety valves 38PSV4107/4109.
Eventually as the salt crystals fall down and accumulate in the salt tank the slurry's solid containment will gradually increase as will the density. To monitor the amount of solid in the salt tank there are density monitors 38AT4104 and 38AT4112 that measures the density in the salt tank and the recycling pipe. When the density monitors indicates that the salt tank starts to fill up with solid the slurry is pumped to a centrifugation 38CC001A/B that are located above the salt dissolving tank 38VD004.
The pumping of slurry from the salt tank to the centrifugation 38CC001A/B happens using a automatic sequence that are programed in the process control system. The pumping starts when the slurry density is above 1265 kg/m^3 and is stopped after a given time or when the centrifugation is full.
In the centrifuge brine and MEG are separated from the salt crystals using the centrifugal power. Separated brine and MEG is transported back to the salt tank while the salt crystals released through a vertical pipe down to the salt dissolving tank.
To prevent oxygen from entering the process equipment the centrifuge is flushed with nitrogen, and the pipe for crystals leads in under the liquid surface in the salt dissolving tank. The nitrogen is ventilated from the centrifugal system to system 43 through valve 38HV4260/4329.
Centrifuge 38CC001A/B is depressurized to system 56, open drain through safety valve 38PSV4262/4331.
The salt dissolving tank 38VD004 is used to dissolve separated salt in water so they can be discharged to sea.
It is also possible to pump slurry directly from the salt tank 38TA001 to the salt dissolving tank.
In the tank the salts are dissolved by mixing it with condensed water that are added from the reflux tank 38VD002. The mix happen using pump dissolved water 38PA104A/B that pumps the salty water from the bottom outlet and back into the tank through special nozzles. The level in the tank is controlled using control valve 38LV4116 in the outlet pipe (System books, 2013. Internal GDF SUEZ document).

CIP system:

CIP system is used to clean different equipment in system 38, MEG regeneration. Normally the equipment is cleaned with water, but sometimes there has to be used citric acid solution to get it clean.

Because the cleaning water has to be oxygen free there are used condensed water from the reflux tank 38VD002. The water is stored in the CIP tank 38TA004 that is kept filled up using level control that controls valve 38XV4228 in the pipeline from the reflux pump 38PA102A/B.

The concentrated citric acid is stored in citric acid tank 38TA005 that is filled up from a transportation tank in system 42, chemical injection. The concentrated citric acid is diluted with water before used for cleaning. CIP pump 38PA005 is used to pump concentrated citric acid from the citric acid tank to CIP tank 38TA004 that are filled with water. The concentration of citric acid in the water is controlled by observing the level increase in CIP tank 38TA004. To mix the citric acid with the water the CIP pump can be used to circulate the containment in the CIP tank.

CIP tank 38TA004 and citric acid tank 38TA005 each has a electrical heater; heater CIP tank 38FE002 and heater citric acid tank 38FE003. These are temperature controlled to a temperature that secures that the liquid does not freeze. To contain a oxygen free environment the tanks are flushed continually with burn gas from system 45, that are ventilated from the tanks to system 43.

The cleaning fluid is pumped using CIP pump 38PA005 from CIP tank 38TA004 to the equipment being cleaned through a CIP manifold. From relevant equipment the cleaning fluid is circulated back to the CIP tank through CIP return manifold. In the return pipe for cleaning fluid from the return manifold to CIP tank 38TA004 there are a pH analyzer 38AT227 and a sampling point 38PA376 (System books, 2013, Internal GDF SUEZ document).

Environmentally Critical Elements in system 38; MEG Regeneration

In system 38, MEG regeneration, there are components that can fail and lead to discharge to sea and be critical to the environment. The components that are analyzed in this system are:

Inlet filter, 38CB050A/B

This is a filter were particles in the water are separated out. The filter is a vertical cylindrical tank. There must be maintenance on this filter before discharge to sea, so that it will filter out what is not going to sea, so that too much MEG is not discharged to sea.

Well fluid

In the start phase of new wells the well fluid can give high salt and hydrocarbon load to the MEG system, this can lead to unstable conditions and increased oil discharge. So it is important to monitor the load and be sure that it is the right properties.

Rich MEG Storage tank valve, 67XV1512:

This is a valve that controls the rich MEG volume and how much that is let into the system, if this valve fails for various reasons there will be too much MEG in the system.

Salt tank, 38TA001:

This tank is filled with slurry, when it is filled it is pumped to the centrifuge. The tank is a part of a salt treatment package and it is here salt crystals and other solvents are removed and sent to the degassing tank. On one side of the tank there is a density sensor, these sensor measure the density of the slurry, as the tank gets filled with crystals the density increases. These sensors must be operating or else the tank can get over filled and leak into the system.

Salt circulation pump, 38PG001A/B:

This pump is circulating the slurry of salt crystals from the bottom of the salt tank through a wire and back to the top of the tank so that the slurry is mixed and ready to be pumped. The pump is a part of a salt treatment package and it is here salt crystals and other solvents are removed and sent to the degassing tank. If this pump is out of order the slurry will not be sent back to the tank, instead it will go through the system, and the system will discharge an amount of MEG that is to large.

Valve 38HV4111:

This valve is located right before the salt dissolving tank and are connected with the circulation pump. The salt normally are pumped through valve 38HV4110 to the centrifuge, but it can also be pumped directly to salt dissolvent tank through valve

38HV4111. If the valve is not operated the way it should it could lead to much MEG to the salt dissolving tank and further through the system.

Valve 38HV4110:

This valve is located right before the centrifuge 38CC001A/B and are a part of the circulation pump. This valve pumps the slurry to the centrifuge. If the valve is not operated the way it should it could lead to much MEG to the centrifuge and further through the system.

Salt dissolving tank, 38VD004:

The salt dissolving tanks function is to dissolve precipitated salt and discharge them to sea. This component receives water and salt crystal. The excess condensed water is discharged into sea through a filter and through the salt dissolving tank. The flow rate is controlled by a regulating valve 38LV4074. If the valve and filter are out of order the discharge to sea will be of a higher concentration MEG than indented.

Dissolved salt pump, 38PA104A/B:

This pump pumps salt dissolvent from the salt dissolving tank to the sea. There are installed pipes that can transport the salt back to the system or to the degassing tank in system 44. This pump is a part of a salt treatment package that removed salt crystals that are separated from the degassing tank from the MEG before they are discharged to sea as a salt dissolvent. The pumps flow rate are controlled by a sensor that gives a signal if there are too low or too high pressure. If the sensor is broken it will be difficult to monitor the flow rate and amount of MEG that is discharged.

Last barrier valve, 38LV4116:

This control valve controls the level in the dissolving tank. Valves that are the last barrier before discharge should be checked if they are functioning optimal and if they are remote controlled, they should be visually checked to be sure that they are not sending wrong signals to computer systems. They could send a signal that they are closed, but because of some failure they might still be open and then MEG could be sent to the sea, when it should be sent through the system once more.

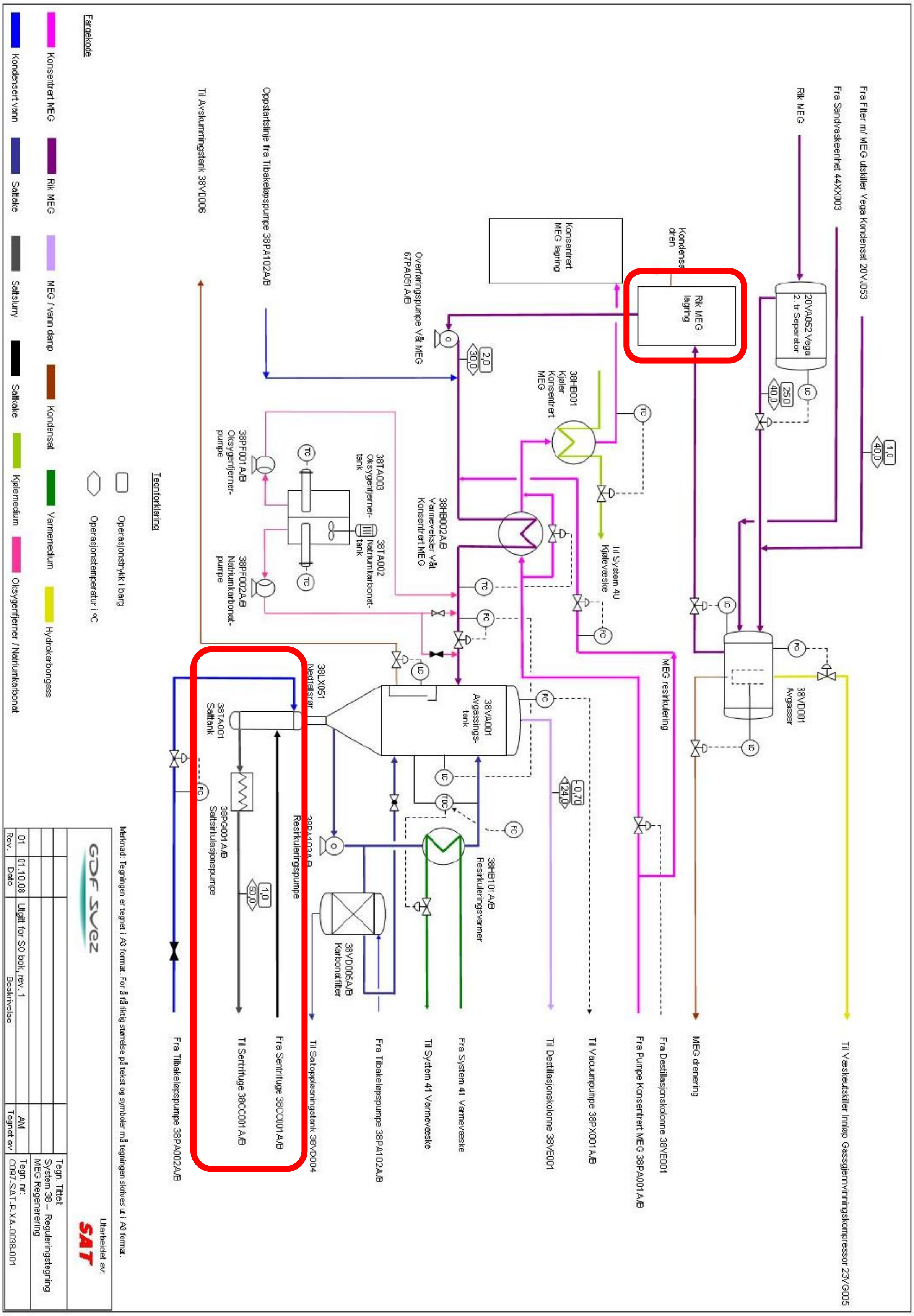


Figure 21: System drawing of system 38, with the ECE's for the system (System Book, internal GDF SUEZ document).

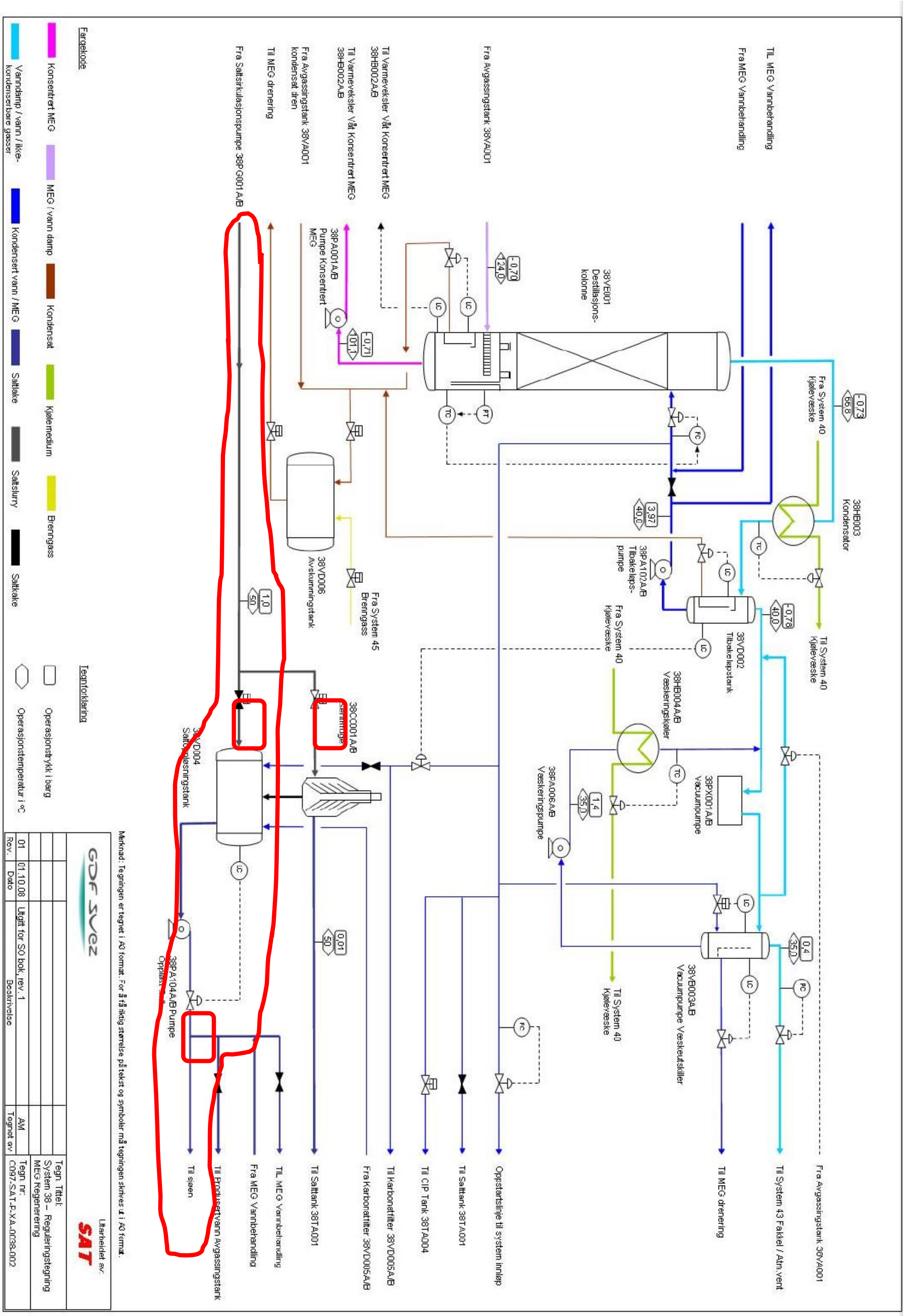


Figure 22: System drawing of system 38, with the ECE's for the system (System Book, internal GDF SUEZ document).

Checklist; System 38 MEG Regeneration

This checklist represents the criticality of the tags that I found was ECEs. To find the existing criticality of the equipment I used COMOS, COMOS is a management and maintenance system at GDF SUEZ. I compared the already classified criticality of production and HSE (safety) to my assessment of the criticality for the environment.

The first column represents the tag number of the ECEs equipment. The second column represents a description of the equipment. The third column; criticality production represent the criticality the equipment have regarding the production itself. I have included this column to the checklist too see the connection between the criticality of production, HSE (safety) and the environment. The fourth column represents the criticality of the equipment associated with HSE, with the main focus on safety and not environment. The fifth column represents my findings and the new criticality is based on the environment according to my analysis of the tags.

Tag number	Description	Criticality production	Criticality HSE, main focus on safety	Criticality focus on Environment
38CB050	Inlet filter	High	Low	High
67XV1512	Rich MEG Storage tank valve	Low	Medium	High
38TA001	Salt tank	High	Low	Medium
38PG001	Salt circulation pump	High	Low	Medium
38HV4111	Valve	High	Low	High
38HV4110	valve	High	Low	High
38VD004	Salt dissolving tank	High	Low	High
38PA104	Dissolved salt pump	High	Low	Medium
38LV4116	Last barrier valve	High	Low	High

4.5 System 65 – Hydraulic

System description:

The purpose of system 65, hydraulic is to provide hydraulic oil with a specific pressure and cleanliness to the consumer on the Gjøa installation. The consumers on the platform are hydraulic operated valves (ESV, XV and HV) to the platforms process and help system and also to louvers. In figure 23 the whole process of system 65 is shown.

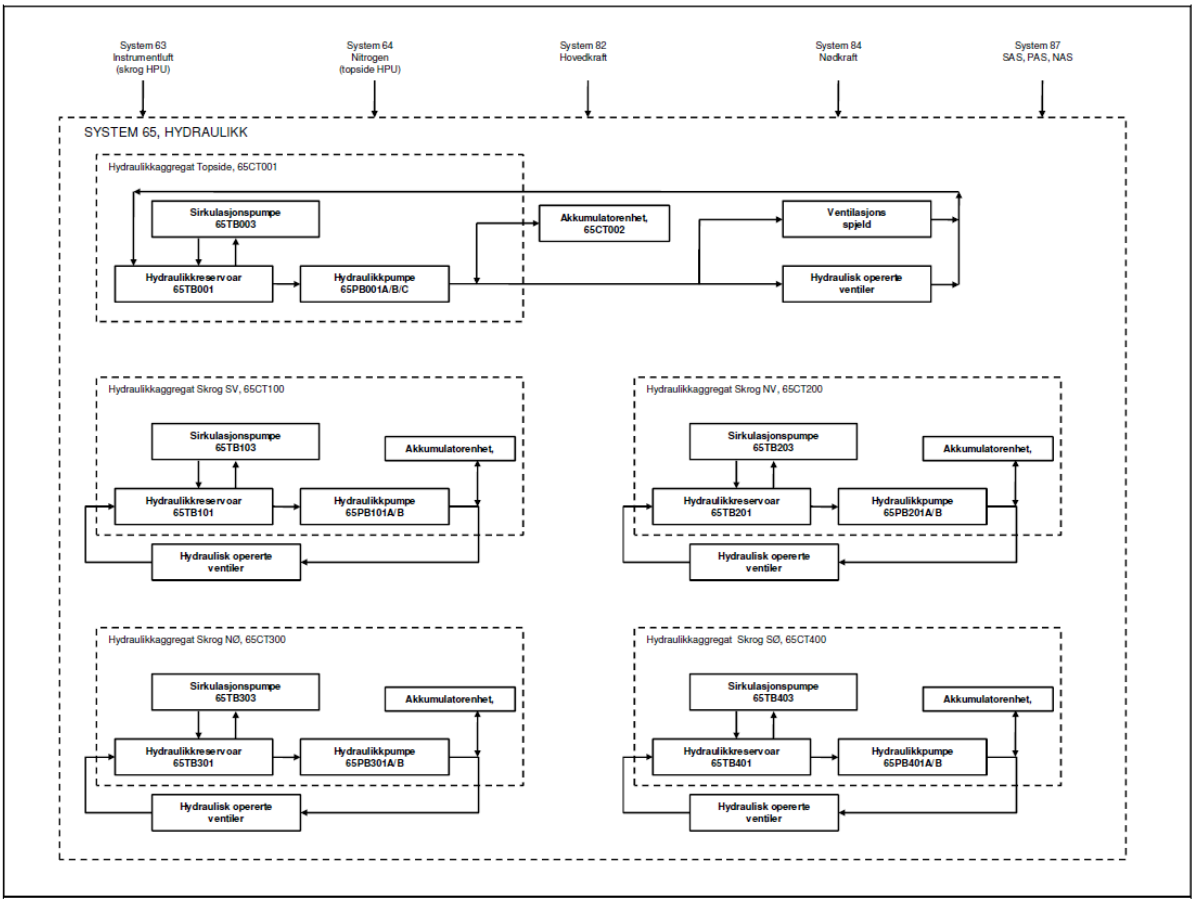


Figure 23: Block diagram, system 65 (System Book, internal GDF SUEZ document).

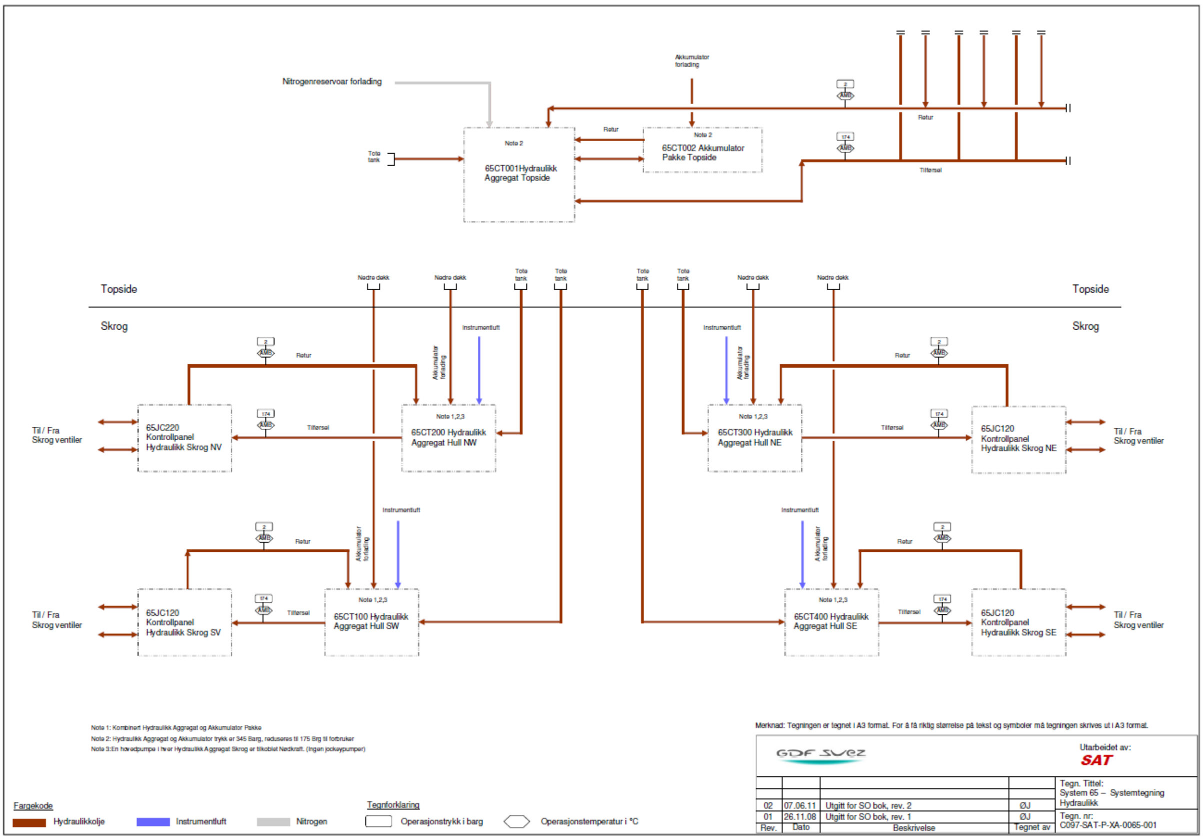


Figure 24: System drawing, system 65 (System Book, internal GDF SUEZ document).

Process description:

The systems function:

System 65 consists of the following components:

Hydraulic unit topside; 65CT001 that again consist of hydraulic reservoir, hydraulic circulation pump, three 50% hydraulic pumps, filters and water separators (System books, 2013. Internal GDF SUEZ document).

Accumulator unit topside; 65CT002 that again consist of six accumulator banks that contain three accumulators with nitrogen tanks (System books, 2013. Internal GDF SUEZ document).

Hydraulic generator hull SV; 65CT100 that consist of hydraulic reservoir, hydraulic circulation pump, two 100% hydraulic pumps, filter and water separator and also integrated accumulator unit (System books, 2013. Internal GDF SUEZ document).

Hydraulic generator hull NV; 65CT200 that consist of hydraulic reservoir, hydraulic circulation pump, two 100% hydraulic pumps, filter and water separator and also integrated accumulator unit (System books, 2013. Internal GDF SUEZ document).

Hydraulic generator hull NØ; 65CT300 that consist of hydraulic reservoir, hydraulic circulation pump, two 100% hydraulic pumps, filter and water separator and also integrated accumulator unit (System books, 2013. Internal GDF SUEZ document).

Hydraulic generator hull SØ; 65CT400 that consist of hydraulic reservoir, hydraulic circulation pump, two 100% hydraulic pumps, filter and water separator and also integrated accumulator unit.

All five hydraulic units are build up the same way, so for this purpose there will just be a explanation for the hydraulic unit topside; 65CT001 (System books, 2013. Internal GDF SUEZ document).

Hydraulic unit top side; 65CT001:

The hydraulic unit top side; 65CT001 is placed on the lower deck, area R152. This unit consist of three 50% hydraulic pumps; 65PB001A/B/C. The number of pumps in operations depends on the pressure in the system. Hydraulic pump 65PB001A/B/C gives a pressure of 180 barg that also are the operating pressure of the accumulator unit topside, 65CT 002. This is done to reduce the number of accumulators at the same time to avoid jockey pump.

The hydraulic reservoir topside, 65TB001 supplies the hydraulic pump 65PB001A/B/C with hydraulic oil from each its own separate outlet from the hydraulic reservoir topside, 65TB001. The hydraulic reservoir is separated into two chambers, one supply chamber and one return chamber. The supply chamber can contain 4215 liters and the return chamber can contain 2715 liters. The hydraulic reservoir topside, 65TB001 is pressurized with nitrogen from system 64, nitrogen.

Hydraulic reservoir topside; 65TB001 is equipped with hydraulic circulation pump 65PB003. The hydraulic oil circulates through a 2x100% 3μ circulation filter, 65CB003A/B and a 2x100% water removal filter 65CB004A/B. Both have one in operation and one in emergency for removal of particles and the moist from the oil. Hydraulic circulation pump, 65PB003 is continuous working and pumping normally from return to supply chamber, it can also be reversed so that the oil is pumped from the supply chamber to the return chamber. Hydraulic circulation pump, 65PB003 is also used for filling and emptying of the hydraulic reservoir topside, 65TB001.

In the downstream hydraulic pump, 65PB001A/B/C there are a 5μ supply filter, 65CB001A/B, where one filter is in operation and one for emergency.

Downstream sampling point, 65AT0002 there are 25μ return filter, 65CB002A/B, where one filter is in operation and one for emergency (System books, 2013. Internal GDF SUEZ document).

Accumulation unit, 65CT002:

Hydraulic generator topside, 65CT001 have associated accumulator unit, 65CT002 that is placed on lower deck, R153. The accumulator unit consist of six sets that contain three accumulators that can contain 54 liters, for each of the three accumulators there are also three nitrogen bottles that contains 52 liters. The nitrogen is used to keep the pressure stable in the accumulators. The accumulators is pressurized by the hydraulic pumps 65PB001A/B/C. This is done to have a backup if the hydraulic pumps fail (System books, 2013. Internal GDF SUEZ document).

Distribution:

Distribution for topside has two ring wires, one for the supply and one for the return. A ring wire means that the supply separates and goes into a bow, this means that it is possible to close parts of the bow without the equipment that are connected losses its pressure when there has to be done maintenance or reconstruction. The return filter on the topside HPU has a circulation line with spring loaded return valve that opens with a pressure of 4 barg. this secures that the return line is not over pressures in a emergency situation, by opening when the return amount is larger than the capacity of the filter (System books, 2013. Internal GDF SUEZ document).

Hydraulic generator hull; 65CT100/65CT200/65CT300/65CT400:

The hydraulic generator hull ; 65CT100/65CT200/65CT300/65CT400, in constructed the same way as the hydraulic unit topside, 65CT001 except the size and dimensions. The important differences are:

Hydraulic reservoir hull, 65TB101/65TB201/65TB301/65TB401 has each a supply chamber that can contain 760 liters and a return chamber that can contain 420 liters.

Hydraulic reservoir hull, 65TB100/65TB200/65TB300/65TB400 is pressurized with air from system 63, pressurized air, instead of nitrogen like topside.

Hydraulic reservoir hull, 65CT100/65CT200/65CT300/65CT400 each has two 100% hydraulic pumps; 65PB101A/B, 65PB201A/B, 65PB301A/B, 65PB401A/B.

Hydraulic pump, 65PB101A/B, 65PB201A/B, 65PB301A/B, 65PB401A/B. Hydraulic generator hull, 65CT100/200/300/400 has a common outlet from the hydraulic reservoir that branches out upstream from the hydraulic pumps.

Hydraulic generator hull 65CT100/200/300/400 has integrated accumulators , that is placed together with the hydraulic generator in each own hulls. Each of these has two accumulator banks, and each accumulator bank consist of two accumulators that contains 40 liters that is supplied with nitrogen pressure from two nitrogen bottles that contains 52 liters (System books, 2013. Internal GDF SUEZ document).

Hydraulic equipment is very vulnerable for particles and moisture in the system. It is therefore very important to filter the oil for both particles and moisture. This happens with the use of different types of filter with mask from 150µ down to 3µ and a water separator. Particles destroy the equipment by getting in between movable parts and damaging the packages, bearings and sliding surfaces. Water damages the equipment by creating corrosion that again leads to particles that damage the equipment (System books, 2013. Internal GDF SUEZ document).
In system 65, the accumulators are used to store hydraulic oil under high pressure that shall supply hydraulic valves if the hydraulic pumps should fail. Accumulators are also used to stabilize the pressure of the hydraulic pumps during start and stop.

Environmentally Critical Elements in system 65; Hydraulic

Hydraulic Power unit topside, 65CT001:

This component is located on lower deck and consists of three hydraulic pumps; the amount of pumps that are in operation depends on the pressure in the system. This is the component in the system with the highest volume of hydraulic fluid; this component has a flow rate of 34, 4 l/min. This is a component that could cause much damage to the environment if the valves and supply lines to respective component are not functioning optimally.

Hydraulic reservoir topside, 65TB001:

This component is a part of the Hydraulic Power unit, 65CT001. The component has a supply chamber of 4215 liters and a return camber of 2715 liters. This component delivers hydraulic fluid to the hydraulic pumps with separate outlets. If the outlet valves are not operating the way they should there could be delivered too much fluid and it could go out of the system and damage the environment if not stopped fast enough. There are level sensors in the system that gives an alarm if there are too much or too little fluid in the system, and these sensors will stop the pumps if the alarm goes off. If the sensors are out of order the pumps will not shut down and the system will be fed with more fluid that it can handle.

Valves associated with hydraulic reservoir:

65BL4147: normally closed

65BL4148: normally closed

65BL4152: normally closed

65BL4153: open/close

65BL4154: open/close

65BL4158: open/close

The main issue with these ball valves is that they are right up to the hydraulic reservoir and if they start to leak or are opened/closed when they should not be there is no closing opportunity. The valves that are normally closed can be opened manually, and if a unexperienced person by accident opened these there can leak a great amount of hydraulic oil.

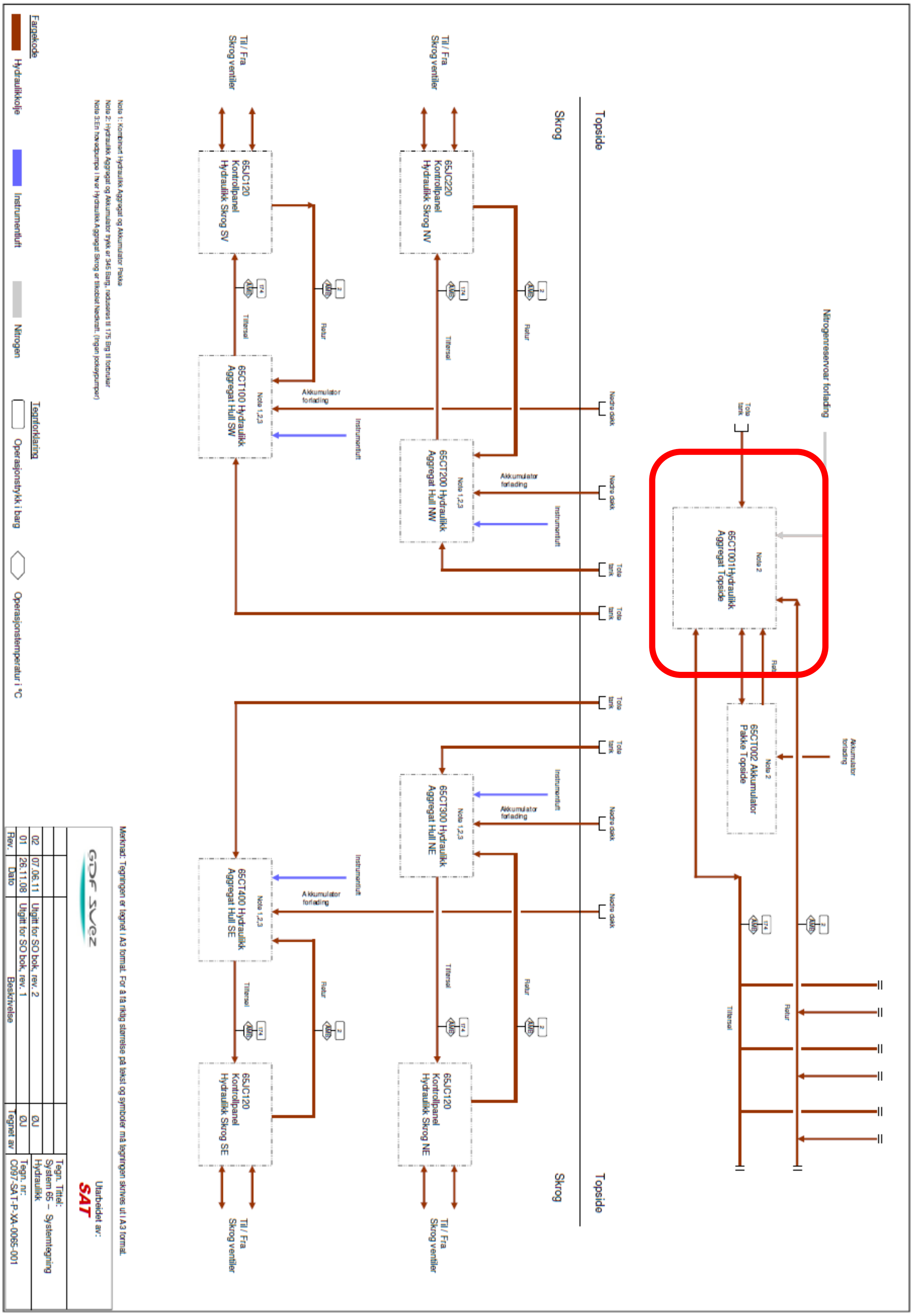


Figure 25: System drawing of system 65, with the ECE's for the system (System Book, internal GDF SUEZ document).

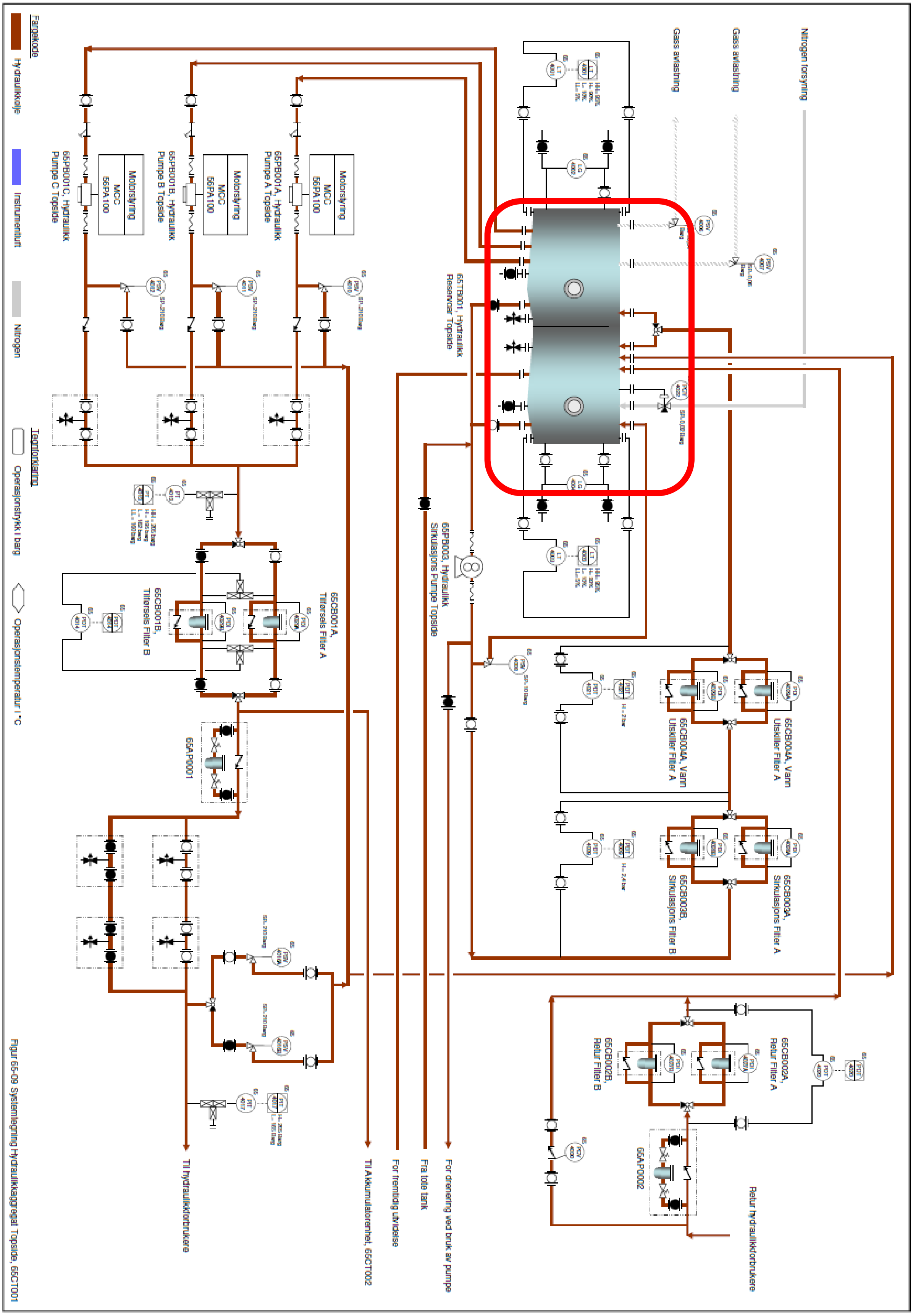


Figure 26: Zoom figure 25, of system drawing of system 65, with the ECE's for the system (System Book, internal GDF SUEZ document)

Checklist; System 65 Hydraulic

This checklist represents the criticality of the tags that I found was ECEs. To find the existing criticality of the equipment I used COMOS, COMOS is a management and maintenance system at GDF SUEZ. I compared the already classified criticality of production and HSE (safety) to my assessment of the criticality for the environment.

The first column represents the tag number of the ECEs equipment. The second column represents a description of the equipment. The third column; criticality production represent the criticality the equipment have regarding the production itself. I have included this column to the checklist too see the connection between the criticality of production, HSE (safety) and the environment. The fourth column represents the criticality of the equipment associated with HSE, with the main focus on safety and not environment. The fifth column represents my findings and the new criticality is based on the environment according to my analysis of the tags.

Tag number	Description	Criticality production	Criticality HSE, main focus on safety	Criticality focus on Environment
65CT001	Hydraulic power unit topside	High	Low	Medium
65TB001	Hydraulic reservoir topside	High	Low	Medium
65BL4147	Ball valve	Medium	Low	High
65BL4148	Ball valve	Medium	Low	High
65BL4152	Ball valve	Medium	Low	High
65BL4153	Ball valve	Medium	Low	High
65BL4154	Ball valve	Medium	Low	High
65BL4158	Ball valve	Medium	Low	High

5. Recommendation

In this thesis I have analyzed four different systems, produced water, open drain, MEG regeneration and hydraulic system.

For all system it is important that both offshore and onshore personal have information and knowledge about the systems. Companies must use resources to teach the different personnel about the different system so that it is understandable for both onshore and offshore personnel. Communication among the staff is key to better understanding and learning, and this is something that must be worked on in many industries.

System 44 – Produced water

In this system I identified six tags that were ECEs. In COMOS the management and maintenance system at GDF SUEZ where equipment is classified with their criticality I found that two of the six tags had the wrong criticality according to my analysis when I compared the environment criticality to the HSE (safety).

Tag 20VA002, 2. Stage separator is classified as high criticality for production and low criticality associated with safety, I assessed this with a high criticality regarding the environment because this separator serves the system with produced water and if it is not separating the way it should the amount of oil that will go through the system and at the end be discharged to sea will to be an unacceptable amount. Also the five sections with shut off valves that are connected to this component could lead to hazard for the environment if not operated properly. So this equipment is not just critical for the production, but also a critical component for the environment. As we can see from the former assessment of HSE criticality this is classified as low, but the environment is possibly not taken into consideration when deciding the criticality.

Tag 44CE001A/B hydrocyclone container is classified as low criticality regarding production, but classified as high according to HSE. Former problems with this component, such as liners breaking have increased the criticality of the component. My recommendation for this equipment is to keep the criticality as it is, because it is already classified as high. In addition I would recommend keeping a close eye on this equipment as it is the most important separator in the system; here 60% of the oil gets separated out. If the hydrocyclone container is not separating under the conditions it should there can be large effect on the separation and also lead to a large amount of oil discharged to sea.

Tag 20HV1230, bypass valve. This tag is classified as low criticality for production, medium for HSE (safety). For the environment this tag could be very critical, so my assessment is to give this valve the criticality high. The reason this is given high criticality is because the valve is placed below the hydrocyclone container as a bypass valve, if not operated properly the produced water can go directly to a degassing tank without going through the hydrocyclone container, and because this separated most of the oil out, the produced water that is discharged without going through the hydrocyclone container first will contain too much oil.

Tag 44VD40A/41A, 44VD40B/41B, CFU 030 separator. These separators are classified as low for production and high for HSE (safety), my assessment is that these should have the criticality high for the environment. The reason for my assessment is that the separators are the last phase of separation before it is discharged to sea, so it is important that they function and are able to remove the amount of oil that are over the allowed amount to discharge. This component have level sensor to control if the separation is at the right level, the sensors can be read both in a control room and manually. The sensors can send out the wrong message if they are broken, so to check them manually from time to time would be my recommendation.

Tag 44LV1505, last barrier valve. This regulating valve is classified as low criticality for production and high criticality for HSE (safety). My assessment for the environment criticality is high. The valve is the last barrier and critical equipment. The valve is remote operated, and there have been cases where valves send out signals that it is closed/open when it is not, because of a failure in the system. There can be some small part broken and the valve is not able to open/close fully. If the case is that the valve should be closed and it send out a signal that it is closed, but a piece is broken so the valve was not able to close fully the produced water is discharged to sea, when it was not supposed to.

System 56 – Open drain

In this system I identified four tags that were ECEs. For this system there were two tags that according to my analysis had the wrong criticality when I compared the environment criticality to the HSE (safety).

Tag 56VD010/56VD011, CFU 050 separators. These separators is classified as low for production and high for HSE (safety). My assessment for the environment is that the criticality should be high. The reason for my assessment is that these separators are a part of the treatment unit and the two most important separators in the system. In this system there are injected chemicals to the flow to give a better separation, if the injection point are damaged or fails the separation will not be as good and the discharge could contain solids and other fluids that should not be discharged to sea. Because these are the two largest separators in the system they are very critical for the environment, and the criticality must be high.

Tag 56SX4062, sieve. This sieve is classified as low criticality for production and medium for HSE (safety). For the environment I have classified this as high criticality. The reason this is high criticality is because if it is not functioning the separators can get blocked and not functioning the way they should and the discharge to sea would not be the amount that is allowed by the authorities. There have been problems with blockage of pipes and the separators before this sieve was placed, so to prevent the blockage from happening and keep the separation up this sieve is very important.

Tag 56HV4080, valve. This valve has not been evaluated in COMOS. My evaluation of this valve is that it is high criticality for the environment. The valve is placed by the inlet to the treatment unit, and is controlled by a pressure difference. If the pressure is too low the valve will close to prevent injection of nitrogen to the separators. If the valve is not functioning there could be let in too much nitrogen and the separation effect could get reduced and the discharge to sea will contain particles that should not been discharged.

Tag 56PV4095, last barrier valve. This valve is classified with low criticality for production and high criticality for HSE (safety). My assessment of the valve for the environment is that the valve should have high criticality. This valve is one of the last barriers before discharge to sea, so it is very important that it is functioning properly and is monitored. The valve also contains the pressure in the treatment unit, so if the valve is out of order it could let out the pressure in the treatment unit and the separation effect gets reduced. Because this is one of the last barriers before discharge to sea the valve should have visual inspection, not just trust that the signal it sends to the computer system is the right message.

System 38 – MEG regeneration

In this system I identified eight tags that were ECEs. In this system all the eight tags was classified with the wrong criticality according to my analysis of the tags when I compared the environment criticality to the HSE (safety).

Tag CB050A/B, inlet filter. This filter is classified as high criticality for production, low criticality for HSE (safety), for the environment the criticality should be high according to my assessment. This filter is a vertical cylindrical tank that separates out particles in the water. To maintain the filter at a good level there must be done maintenance on the filter, so that the amount of MEG that is discharged to sea is at the level the authorities have allowed.

Well fluid. This component are not a part of the criticality system, but it is important to be aware that when starting with a new well fluid or new wells there could be high salt and hydrocarbon load in the MEG system. This can lead to unstable conditions and increase the oil and MEG discharge, so my recommendation is too be aware of this and monitor the load and properties to be sure they are the right once.

Tag 67XV1512, rich MEG storage tank valve. This valve is classified as low criticality for production and medium criticality for HSE (safety). For the environment the criticality should be high because this is the valve that controls the MEG volume and how much is let into the system. If this valve fails there could be let in too much MEG into the system, and this could again lead to too much MEG in the water that is discharged.

Tag 38TA001, salt tank. The salt tank is classified with high criticality for production and with low criticality for HSE (safety). For the environment the criticality should be classified as medium criticality. In the salt tank that is filled with slurry are where most of the salt crystals and other solvent are removed and sent to the degassing tank. There is a density sensor on one side of the tank, this sensor measures the density of the slurry, as the tank gets fillet the density increases. If the sensors are damaged the tank can get over fillet and go further into the system.

Tag 38PG001A/B, salt circulation pump. The salt circulation pump is classified with high criticality for production and low criticality for HSE (safety). For the environment the criticality has been assessed to medium criticality. The pump is circulating the slurry of salt crystal from the bottom of the salt tank through a wire and back to the top of the tank. If this pump is out of order the slurry will not be sent back to the tank, and instead go through the system and the amount of MEG that is discharged will be too high.

Tag 38HV4111, valve. This valve is classified with high criticality for production and with low criticality for HSE (safety). For the environment the classification is high criticality. The valve is placed right below the salt dissolving tank. the problem with this valve is that if it is not operated correctly the salt can be sent directly to the salt dissolvent tank without going through the centrifuge and there can be too much MEG in the salt dissolving tank that can go further into the system.

Tag 38HV4110, valve. This valve is classified with high criticality for production and with low criticality for HSE (safety). For the environment the criticality should be high. The valve is located right before the centrifuge and is used to send the flow further to the centrifuge. If the valve is not operated by personnel that are familiar with the function the valve can let too much slurry flow into the centrifuge and it will not separate out the solid and salt that it is meant to.

Tag 38VD004, salt dissolving tank. The salt dissolving tank is classified with high criticality for production and with low criticality for HSE (safety). For the environment the criticality according to my assessment the criticality should be high. The function of the tank is to dissolve precipitated salt and discharge them to sea. The tank consist of a filter and a valve that must be functioning so that the discharge is the correct amount. The recommendation is that experienced personnel check that the valve and filter are operating as it should on a regular basis.

Tag 38PA104A/B, dissolved salt pump. The dissolved salt pump is classified with high criticality for production and with low criticality for HSE (safety). For the environment the criticality should be medium. This pump pumps dissolved salt from the salt dissolving tank into sea. If the pump is out of order it can pump too much or too little into sea. Even if the MEG is classified as a green chemical there are regulations too how much the companies are allowed to discharge each year, so if the pump if not operating as it should there could be consequences for the companies.

Tag 38LV4116, last barrier valve. This valve is classified with high criticality for production and low criticality for HSE (safety). For the environment the criticality should be high. This is a last barrier valve that controls the level in the dissolving tank.

This valve is remote controlled and for that reason it is important to routinely check that it is not broken. The valve can send signals to computer system that it is closed when it can actually be open, because of various failures, a broken handle or other parts on the valve.

System 65 – Hydraulic

In this system I identified eight tags that were ECEs. All the eight tags had the wrong criticality according to my analysis of the tags when I compared the environment criticality to the HSE (safety).

Tag 65CT001, hydraulic power unit topside. This component is classified with high criticality for production and with low criticality for HSE (safety). For the environment the criticality should be classified as medium criticality. This is the component in the system that has one of the largest volumes of hydraulic fluids. If some valves or supply lines for this component rupture or gets damaged the hydraulic fluid could go further into the system and end up on the platform, or worse into the sea. Hydraulic fluids are often environmentally unfriendly chemicals, and can cause a lot of damage on the environment and ecosystems.

Tag 65TB001, hydraulic reservoir topside. This component is classified with high criticality for production and with low criticality for the HSE (safety). For the environment the criticality should be medium. This component delivers hydraulic fluid to hydraulic pumps. It is very important that the valves are in order so that there is not sent too much fluid into the system. The sensors that tell if there is too much or too little fluid in the system are very important components that must be checked regularly by experienced personnel, if the sensors are out of order the equipment and the environment can get damaged.

Tag 65BL4147,48,52,53,54,58, ball valves associated with the hydraulic reservoir. All these six valves are classified with medium criticality for production and with low criticality for HSE (safety). For the environment the ball valves should be classified with high criticality. The problems with these valves are that they are placed so close to the reservoir that there is no closing opportunity if they should start to leak. These valves are normally closed, but they can be opened manually, so if an unexperienced person is given an assignment to open a valve and are not familiar with the system they could easily open the wrong valve and then a large amount of hydraulic fluid that should not have been there will go into the system. So for these valves there should be good marking and signs that states that it must not been opened.

6. Discussion

The scope of the thesis was to identify Environmentally Critical Elements (ECE). I started by learning about the different systems and made a decision that the four systems I was going to analyze was produced water, open drain, MEG regeneration and hydraulic. These four systems were the systems I felt were the ones that could be the most critical to the environment as they discharge directly to sea, and I chose the hydraulic system because of the hazard the hydraulic fluid is to the environment.

After deciding on the systems I started learning more in detail how the systems worked and I used P&IDs to identify the tag/equipment I meant were ECE. After identifying the ECEs I made a checklist were I compared the classified criticality of production and HSE (safety) to the environment and made a new criticality from an environmentally point of view. From my assessment it became clear that the HSE criticality was not including the environment, but was based on the safety aspect.

My recommendation in order to take the findings forward is that the checklist gets implemented into the COMOS system, and that the ECEs are kept as a separated part, so that there is an opportunity to check that the environment is a part of the analysis when classifying equipment according to criticality.

Overall in the four systems I found twenty-eight ECEs, since all the tags are critical to the environment and can cause hazard if not monitored and maintained in a proper way, I would recommend that experienced offshore personnel routinely check the equipment for damage and failure. They should actively use the checklist as a part of the day to day operation.

Because this thesis only covers four systems I would recommend that GDF SUEZ use experienced personnel to analyze the other systems in detail and identify the ECEs of these systems. They should also include personnel that don't normally work in the HSEQ department so they can get more familiar with the process and gain more knowledge. After the systems are analyzed and the tags are identified all the relevant personnel should get a report or course so that not just the once that have worked on it have the knowledge, but all relevant personnel know the importance of defining ECEs.

There were different challenges during the thesis, first the lack of experience on my part, I was totally unfamiliar with the process, and had no background knowledge and had to learn everything from scratch. I did not have experience with the Gjøa installation and had to learn how the systems worked, and I had to learn how to read P&ID drawings. After I had gotten some knowledge on the systems and on the P&IDs I had to get familiar with the term ECE and gather information on how the process worked so I could start the work on identifying ECEs in the chosen systems on the Gjøa installation.

The other challenge was that this is a method that is not very evolved, there have been methods for finding safety critical elements, but this is a different approach than the one for finding ECE. Because this is a new approach that not many in the oil and gas industry have implemented there was very little information to find, so a challenge was to gather enough information to get a clear picture on Environmentally Critical Elements.

During the work with the thesis I have had a steep learning curve, and gained a lot of knowledge. I have learned about different systems on the Gjøa installation, learned about GDF SUEZ as a company. I have learned how to read P&IDs and what information you can find from reading these. I have also learned a lot about ECEs, what they are and how important they are to the oil and gas industry. When working on the thesis I have experienced how important communication and team work are for companies in general, especially for oil and gas companies since they often have employees both onshore and offshore. It is very important that both offshore and onshore employees have the information they need to make informed and good decisions. All in all I have had a great amount of learnings during the thesis work.

7. Conclusion

The main objective in this thesis was to look at the Gjøa installation and analyze if there were environmentally critical elements and make a check list to help reduce the discharge to sea. The four systems that were analyzed was produced water, open drain, MEG regeneration and hydraulic. The systems were analyzed by system books and P&IDs to identify the ECEs.

The main issue in the thesis was the lack of references and experience. This is a very new process and there has been done very little research on the process of finding ECE.

The findings in the study lead to the following conclusion about identifying ECE in the four systems:

System 44, Produced Water

- Six ECE was identified
- The comparison with HSE (safety) and environment showed that the environment have been left out when classifying the criticality of the different equipment.

System 56, Open Drain

- Four ECE was identified
- The comparison with HSE (safety) and environment showed that the environment have been left out when classifying the criticality of the different equipment.

System 38, MEG Regeneration

- Ten ECEs was identified
- The comparison with HSE (safety) and environment showed that the environment have been left out when classifying the criticality of the different equipment.

System 65, Hydraulic

- Eight ECE was identified
- The comparison with HSE (safety) and environment showed that the environment have been left out when classifying the criticality of the different equipment.

For further study a more detailed analysis of all the system on the Gjøa installation would perhaps give a better idea and understanding of ECEs. In this thesis only four of the system have been analyzed and there was found 28 ECEs in only these four systems.

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Appendix

Appendix A

Glossary

Term	Meaning
ALARP	As low as reasonable practical
$CaCl_2$	Calcium chloride
$CaCO_3$	Calcium carbonate
CFU	Compact flotation unit
COMOS	Management and maintenance system at GDF SUEZ
DECC	Department of energy and climate change
ECE	Environmentally critical element
Environmental aspect	Element of the company's activities, products or services that can interact with the environment
ISO 14001:2004	European and British standard for environmental management system
MEG	Mono ethylene glycol
Na_2CO_3	Sodium carbonate
NaCl	Sodium chloride
$NaHSO_3$	Sodium bisulfite
NCS	Norwegian Continental Shelf
Operator	The company responsible for the exploration or production of hydrocarbons under a license issued by DECC
P&ID	Piping and instrument diagram
Performance standard	A statement of the performance required of a system or item of equipment in order

	for it to satisfactory fulfil its purpose
PSA	Petroleum Safety Authority Norway
PUD plan	Plan for development of the facility and Operation
Safety critical elements	A part of the installation whose failure would cause or contribute to a major accident
SCE	Safety critical elements
System	A system of hardware designed to fulfil a particular function e.g produced water system, drain system, meg regeneration system, chemical injection system

Appendix B

ECE implementation flow diagram

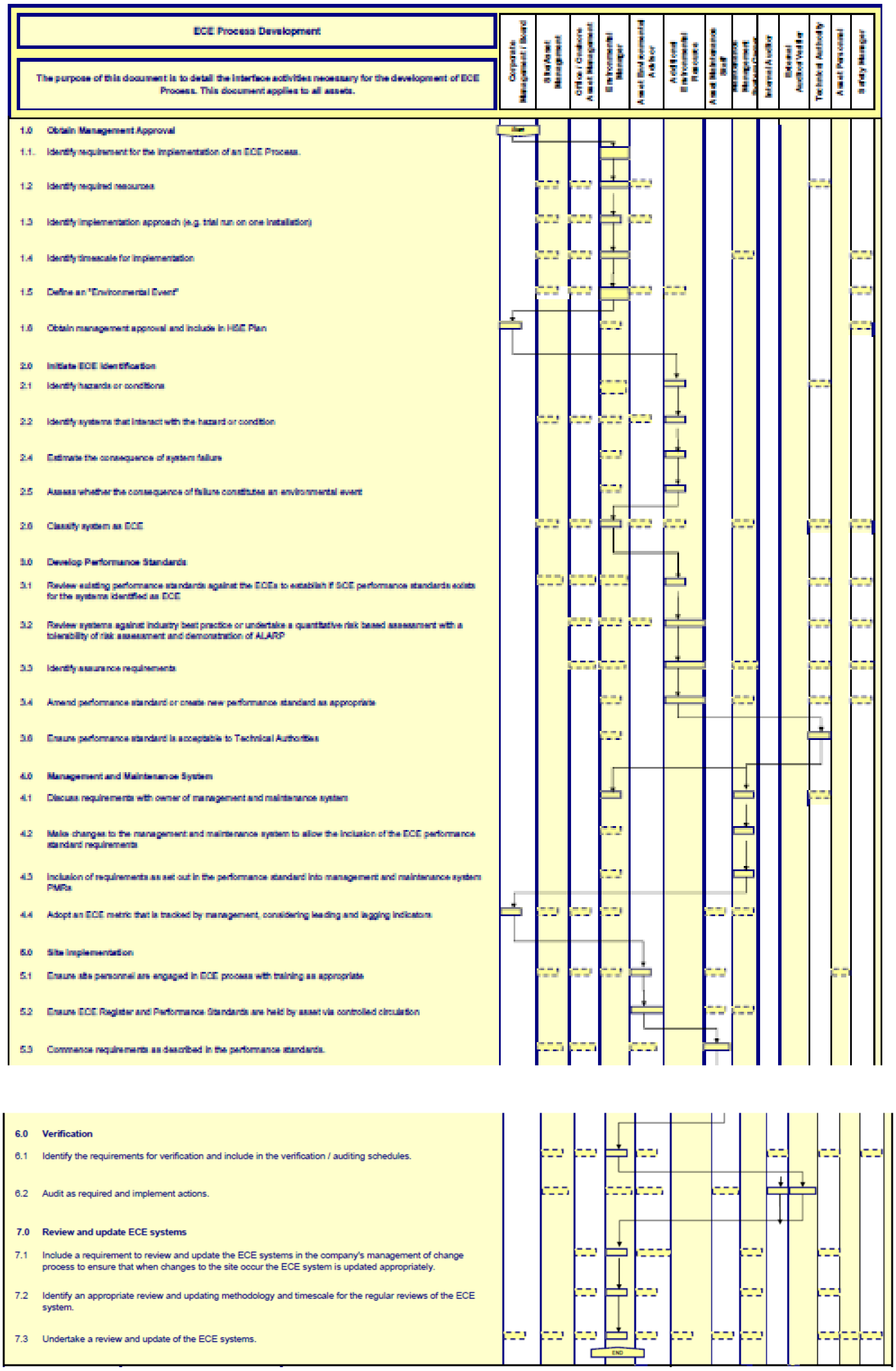

Figure 27: (energy institute, 2012)