# **EXPERTS IN TEAM GULLFAKS VILLAGE 2011**

# - Technical report part B -

# Group 3



# Norwegian University of Science and Technology

**Faculty of Engineering Science and Technology** Experts in Teamwork Gullfaks Village 2011

### **REPORT FROM PROJECT IN SUBJECT TPG 4851 SPRING 2011**

Subject: TPG 4851 Experts in Teamwork Gullfaks Village 2011

Title: Improved Oil Recovery from Gullfaks Sør Statfjord

#### **Project group:** # 3

# Group participants:

Wynda Astutik Lars Myrvang Gaute Dag Løset Jan Cornet Henrik Sehested Næsgaard Bruck Haile Woldeselassie

# Main coordinator: Knut Müller, Jan Ivar Jensen and Jon Kleppe

Project partner: Statoil ASA-Gullfaks lisensen

#### **Summary:**

This report is the result of Group 3's project work in the Experts in Team - Gullfaks Village. The project is a cooperation between NTNU and Statoil ASA about increasing oil recovery from Gullfaks South Statfjord. The challenge given was issues related to running wireline (WL) below the rig (Challenge 3b). The project was completed with the help of Knut Müller, the group's advisor and drilling supervisor on the Gullfaks field.

The main part of the project was to propose solutions that could be applied to fully secure the WL operations area from the drilling area located above. Running WL and drilling operations simultaneously on the same shaft on Gullfaks requires full safety. The issues are presented in the risk assessment matrix given by Statoil and include falling objects, transport from one shaft to another; access limitation, etc. The group has listed all the components of a WL rig up to get an overview. It is economically favorable to rig up below the rig due to reduced downtime.

The project group came up with 15 ideas using plates and nets preventing falling objects from hitting the WL deck. Ideas such as the Slope Catch Net and the Metal Plate are solutions which with some changes and more engineering the group think can be feasible. The ideas were results of brainstorming and then further discussed in the team. Statoil ASA will hopefully find some of the ideas worthwhile and be able to develop them more in detail. The project group did not discuss details due to lack of overview of dimensions and structure arrangements.

# PREFACE

This project report is based on a challenge given in the subject Experts in Team (EIT) TPG 4851 Gullfaks village at NTNU in Trondheim. The project is based on teamwork and the report is written by six students with various engineering backgrounds.

For a good understanding of the content in the report, some knowledge about wireline (WL) and offshore operations is recommended.

The project group would especially like to thank Statoil ASA advisor Knut Müller, project advisor Jan Ivar Jensen and village leader Jon Kleppe for guidance through the project.

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Wynda Astutik

Lars Myrvang

Gaute Dag Løset

Jan Cornet

Henrik Sehested Næsgaard

Bruck Haile Woldeselassie

# NOMENCLATURE LIST

BHA	-	Bottom Hole Assembly
BOP	-	Blowout Preventer
D&W	-	Drilling & Well
EiT	-	Experts in Team
FO	-	Falling Object(s)
HSE	-	Health, Safety and Environment
MHDF	-	Movable Hatch Deck Foundation
MHS	-	Movable Hook System
NTNU	-	Norges Teknisk-Naturvitenskaplige Universitet / Norwegian University of Science and Technology
WL	-	Wireline
XMT	-	Christmas Tree / X-mas Tree

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# **1 INTRODUCTION**

This project is a result of the cooperation between NTNU and Statoil ASA (further referred to as Statoil) in the subject Experts in Team (EiT). The main goal is to improve the oil recovery at the Gullfaks field. The project challenge given was issues on running wireline (WL) below the rig (Challenge 3b). Statoil has installed the Gullfaks database at NTNU and the project village has visited Statoil's offices in Bergen. During the visit in Bergen, the project group had an informative meeting with Knut Müller, the group's advisor and drilling supervisor at the Gullfaks field. The meeting helped the project group set goals for the project. The group set these goals:

- Explain a standard wireline (WL) rig up
- Use risk assessment analysis to define main issues with WL below the rig
- Come up with new ideas for solution to the issues
- Define financial benefits by doing WL below the rig

The project group had to come up with new ideas on how to do WL operations below the rig safely. These ideas are based on the issues presented in a risk assessment analysis given by Statoil. The ideas were the result of a brainstorming and further development in teamwork. Statoil will hopefully find some of the ideas worthwhile and can develop them more in detail. The ideas have not been developed in detail due to the lack of overview of dimensions and structure arrangements.

In the following chapters the group presents and explains a WL rig-up, main issues with WL below the rig, new ideas for solutions, financial benefits and a conclusion.

# **2 WIRELINE RIG UP BELOW THE RIG**

Wireline (WL) is used to do intervention operations as maintenance, logging and fishing in wells. It is beneficial to have the WL rig up below the rig due to space savings, and the possibility of simultaneously doing drilling and WL operations on the same shaft. Rigging up beneath the rig brings up several challenges, especially safety issues due to falling objects (FO), WL rig up height etc. Picture 1 shows a WL rig up below the rig from Gullfaks.



Picture 1 Wireline rig up below the rig on Gullfaks.

To get a better understanding of what a WL rig up is, the project group has gone through some of the standard components. Figure 1 shows a principle sketch of a WL rig up with main components. Each component has a numbering and the components are discussed further in this chapter.



Figure 1 Principle sketch of a WL rig up.

#### Wireline #1

The WL is usually between 0,066 to 0,108 inches thick and 10000 to 25000 ft long. It is made of high tensile steel to minimize the wire diameter and its working limit is 50% of the maximum breaking strength. It has a major importance since it is carrying all the tools at its end. [1]

Length measuring device #2



The length measuring tool is measuring the length of the wire. Knowing the length of the wire tells the operator when to slow down when pulling out of hole in order not to hit the stuffing box etc.[1]

Picture 2 Length measuring device for the WL operation [A] Weight indicators #3



The wire is supporting all of the weight, so it is of capital importance to always know the load applied on the wire, to prevent wire break and catastrophic scenarios. [1][2]

Picture 3 Weight indicator for WL operation[B]

# Reel system#4



The reel system is basically the tool that is winding and delivering the desired length of wire. Reels are necessary to transport the line from one well site to another without damage. The weight of the line and tools is sufficient to unwind the line from the reel. In case of heavy pulling during swabbing and fishing the second drum can be used.[1][3]

Figure 2 Reel system [3]

## Floor blocks and pulley #5



*Picture 4 Floor blocks and pulley [1]* 

Floor blocks or pulleys with sheaves are used to reduce stress and bending in the wire when a change of direction has to be done. They are attached to weight indicators and for more accurate measurements the wire should be deviated 90° by the pulley. The diameter of the pulley is chosen to provide minimum bending stress. Picture 4 shows floor blocks and pulley.[1]



WL stuffing boxes are used when working under pressure. It is used to seal and lubricate the wire with sealing grease. In most cases the stuffing box provides a swivel bracket and sheave which guides the measuring line down. Heavier stuffing boxes can be equipped with an additional BOP. Picture 5 shows standard stuffing box. Picture 6 shows an example of a stuffing box positioned behind the sheave in order to save height which is particularly useful for WL below deck.[1][4]

# Picture 6 Stuffing box [C], Picture 5 Stuffing box saving height Lubricators and quick unions #7 and #8



The lubricator is assembled on the rig using tubular pipe (see picture 7) and quick unions as connections. It is used to lubricate the bottom hole assembly (BHA) and line before and during run in hole. It has to be at least the size of the BHA and it has a higher working pressure than the tools lowered into the well.[1]

*Picture 7 Lubricator[D]* 

Stuffing box #6

# Blowout preventer for wireline #9

The BOP is one of the barriers of the well so it has an important safety role (another barrier is the down hole safety valve). The BOP can isolate the pressure in the well in two ways, it can close by annular or shear rams. Some grease is often injected in the BOP to reduce the possibility of gas escaping through the armor. Picture 8 and 9 illustrate BOP's. [3]





Picture 8 Bop[D]

Picture 9 Cross section of a BOP[3]

# Gin pole and mast #10



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A mast has to be used to allow a convenient displacement of the lubricator on and from the wellhead. Gin pole and mast are not used offshore; they are usually replaced by the platform crane. Picture 10 shows an example of such a crane. [1]

Picture 10 Example of a platform crane in used offshore. [E]

## Bleeder valve #11



The bleeder valve is used to relieve or equalize the pressure in the lubricator. Picture 11 illustrates how a bleeder valve can be assembled. [3]

Picture 11 Bleeder (needle) valve attached to lubricator. [F] Christmas tree #12



The x-mas tree is an assembly of valves, spools, and fittings which primary function is to control the flow in or out of the well. Look at picture 12 for a figure of a x-mas tree. [3]

Picture 12 Illustration of a x-mas tree. [G]

# Lifting clamp #13

The lifting clamp is used to support the lubricator and provide stability to the rig up. [1]

# Wellhead adapter flange #14

Wellhead adapter enables WL and other well service operations to be performed through the wellhead and into the well bore. It provides a direct connection between surface pressure equipment and the wellhead. [2]

# Line wipers (situated at well head, not visible on the drawing) #15

The line wipers clean the line at or near the wellhead, thus avoiding safety and maintenance issues. [1]

## Tool catcher #16

The tool catcher "catches" the cable head to prevent possible loss of tool string. [4]

# **3 MAIN ISSUES FOR RUNNING WIRELINE BELOW RIG**

The project group received a risk tolerance matrix made by Statoil. The assessment lists up several issues of running WL below the rig. Actions carried out and possible solutions to the problems are also a part of the analysis. Each problem has its own risk degree in each of these three categories: Well Objective, Drilling & Well (D&W) cost and Health, Safety and Environment (HSE).

The risk assessment was divided into several sub-categories. The following is a summary of the problems and actions in the different sub-categories:

# Regular route, spotting and placement of equipment

This includes transport problems and injuries due to bad maneuverability of crane. The main solutions include having a movable red-zone (keeping people away from danger areas) and the use of larvafeet/minicrane.

# Physical obstacles for placement of equipment

This includes access limitation to slots, cranes and decks due to cables, tubes and other components. This category also includes safety risks of hoisting operations.

The main solutions include securing the pipes/cables and bend them away from the desired slot, or rebuilding the whole kill/choke system of drilling. Other solutions include anti-collision measures, strategic placement of equipment and use of minicrane.

# Falling objects from drilling deck / level above

This includes falling equipment from drilling tower, pipe handling system, BHA and from pipedeck.

The main solutions are to close as many holes as possible, not to conduct two simultaneous operations on the same shaft and use of nets and Kevlar to catch small FO.

# Wireline Mast

This includes falling objects and collision dangers of WL mast. The solutions include practical placement of mast and good safety procedures.

# Hydrocarbon leakage from the bore

This includes lack of seals and barriers to prevent leakage.

To solve this problem, one suggests more equipment checks and the addition of  $H_2S$ -sensors.

# Exposure to chemicals from drilling

This includes danger of exposure to chemicals from flowline, when plugged. The only proposed solution is to keep an eye on the flowline during pumping.

# Evacuating / alertness

This includes the lack of escape routes, firewater, fire detection systems and communication between drilling and borehole/well. The solutions proposed are to better the emergency procedures. The solution is to not do operations when the danger is too high.

# Cooperation with drilling

This includes limited access to WL operations during drilling operations (limited space and safety). The lack of communication between WL operator and drilling is also mentioned. To avoid these issues the operators need several radios, and the area must be closed while pulling BOP/XMT.

## Reservoir challenges

This includes procedures for drilling on live wells while doing WL and guidelines for emergency situations.

The solution is to not have any dependencies between drilling and WL operations (both equipment and personnel).

In the risk assessment matrix, each issue is given a code to display its degree of impact and probability. Based on these degrees, a severity level is given by the colors green, yellow and red within each category (see figure 3). The three categories are:

# Well objectives

Well objective is focused on the results of the drilling and well activities. For production, this includes among others production profile, future need of well intervention and that an injector is not giving the wanted effect. For exploration, it is typically related to information collected during the operation.

## D&W Cost

D&W cost is focused on the execution of the drilling and well operation itself. It is typically related to the cost of delays (downtime, equipment failure, sidetracks and re-completion).

# HSE

HSE includes health, safety, environment and reputation issues. These are typically related to barrier integrity, injuries and strain to personnel, strain/leaks to sea/air and environmental consequences.

Risk tolerance criteria - Drilling and well process									
Show HSE details		Well objective	Well objective D&W Cost H		Increasing probability (pr project)				
		(profit/flow or (cost, information) resou	(cost, time & resources)	t, time & Environment & Reputation	< 1 %	1 - 5 %	5 - 25 %	25 - 50%	> 50%
Sho	w Description	(post DG4) (CAPEX)	(CAPEA)		P1	P2	P3	P4	P5
	15	>250 MNOK Lost/reduced/ delayed production, future well interv.	>250 MNOK Lost well, sidetrack, recompletion	Major injury/fatality/spill, loss of both well barriers					
act	I4	50-250 MNOK Lost/reduced/ delayed production, futrure well interv.	50-250 MNOK Sidetrack, recompletion, delays	Moderate injury/strain/spill, loss of one well barrier					
easing imr	13	5-50 MNOK Lost/reduced/ delayed production	5-50 MNOK Delays, reduced ROP, equipment failure.	Minor injurg/strain/spill, uncertain well barrier condition					
Incr	12	<5 MNOK	<5 MNOK	Neglible injurg/strain/spill					
	I1	No impact	No impact	No impact					

Figure 3 Risk tolerance criteria from the risk assessment analysis.

The risk assessment includes only five issues with severity level red, signifying a huge risk impact. The issues are mainly related to falling objects and HSE, except one related to transport and costs. The group made an overview of these points, see figure 4.

Risk elements				Initial risk				
RID	Risk	Description		Impact				
		Description	FIOD	HSE	OBJ	TC		
	Regular route. Spotting and placement of equipment							
R 1-3	Transport problem	Not possible to transport WL equipment from one BOP deck to the other with BOP crane.	P3	11	14	13		
	Falling objects from drilling deck / the level above							
R 4-2	Injury FG	Falling objects / equipment from pipe handling equipment in drilling. For example, it has been declining pipeline from Eagle on GFC	P1	15	11	11		
R 4-3	Injury FG	Depending on the slot that drilling is on, the opening between the rig and the pipedeck is big. This increases the risk of exposure FO.	P1	15	11	11		
R 4-4	Injury FG	Falling objects from the derrick, working in the tower	P1	15	11	11		
R 4-6	Injury FG	FO from pipedeck to the BOP deck	P1	15	11	11		

Figure 4 Overview of the red-indicated issues from the risk assessment analysis.

From the risk assessment the group learned that the main issues of running WL below the rig were related to falling objects from all the areas above, and from the WL rig-up itself. There is a transport problem, since the Wireline BOP cannot be lifted from one shaft to the other with the BOP crane. The main crane needs to be used for this purpose and that limits other operations. Access is also a problem. While doing WL below the rig, there are a lot of piping, tubes and other equipment that needs to be secured and moved. There is a lack in emergency procedures for chemical exposure, hydrocarbon leakage and running WL while drilling in the same shaft.

The project group has limited knowledge of the rig structure, and little overview of where the equipment is located or needs to be moved. Therefore, the group has chosen to focus on coming up with ideas to prevent FO, since this is the most critical safety category (with reference to the matrix). Focusing on FO also has the benefit of letting every member of the group contribute on a more equal level, since it demands only for a limited technical knowledge.

The different ideas are presented in the upcoming chapters.

# **4** IDEAS WITH PLATES AS COVER

The ideas are in their first stage, are explained in principle and do not contain details. Each idea has a pros and cons section at the end of each chapter. The ideas in this chapter are most of all based on using plates as cover. Material thought to be used are carbon steel or strong composite.

# 4.1 Plate as cover

The idea is simply developed from using one big plate with hatches (or manholes) to cover the space above the shaft. On the plate there is one hatch for each slot as shown in figure 5. In this way there is an opening for drilling operations and long/high WL equipment.



Figure 5 Principle sketch of a plate cover with hatches

With the plate above the shaft, it will be safe to work on BOP-deck (slot deck) with regard to falling objects. Drilling and WL operations can be done simultaneously on the same shaft by opening the hatches on the plate as shown in figure 6.



Figure 6 Illustration of the plate idea

The plate can easily be lifted in and out of place. Chain in each corner (ends) can be connected to a crane hook (similar to a container) as shown in figure 7.



Figure 7 Illustration of how the crane moves the cover

The plate is easy to assemble and disassemble with bolts and pins (or similar arrangement) in the anchor point of the fundament.

# 4.1.1 Multiple plates (puzzle)

Assuming that one big plate is impossible due to storage and space, it is suggested that the plate is divided into a "puzzle". The "puzzle" consists of many pieces that can be assembled to one big plate. Each piece will be lifted by a crane in a predetermined procedure. Figure 8 shows examples of a plate with 4 and 6 pieces, but the amount of pieces can be as big as necessary.



Figure 8 Plate cover divided into 4 and 6 pieces

The plate pieces are designed to be stacked upon each other (similar to some containers in the industry). In this way they will take a minimal space and be securely stored when not in use. Figure 9 shows a principal sketch of the plate-piece and the stacking arrangement.



Figure 9 Illustration of how the pieces can be stacked

# 4.1.2 Multiple plates with beams underneath

If there is a need for support beams and there are no available beams installed or there cannot be installed because of crane operations, it is suggested to install moveable beams. The moveable beams can be similar to the beams on an overhead crane in a workshop. Look at figure 10 for a principal sketch



Figure 10 Principle sketch of movable beams

Pros

One plate:

+Simple

Multiple plates:

+Easy storage

+Flexible

Plates with beams:

+High strength

- +Flexible
- +Safe

Cons

One plate:

-Difficult regarding space and storage

Multiple plates:

-Difficult to realize without beams

Plates with beams:

- Expensive
- Complex

# 4.2 Moveable hatch deck foundation (MHDF)

The idea is to install a new movable deck above the BOP-deck where we want to have the WL operations. The deck has many hatches for openings for drilling and high WL rig up. The deck can move independently from the drilling tower and thus get out of the way when "full opening" to BOP-deck is needed. The disadvantage with this idea is that the MHDF always will be above one of the shafts. Figure 11 and 12 give simple principal sketches of the idea.



Figure 11 Principle sketch of the MHDF



Figure 12 MHDF seen from above

## Pros

- +One whole floor protecting from FO
- +Fast movement of the protection cover

## Cons

-expensive and difficult technically-MHDF must always be above one of the shafts-Must remove drill string and WL before moving MHDF

# 4.3 Roof above WL assembly

The idea is a protection roof with regards to falling objects above the WL equipment and workers. This roof will need to be easy to assemble and disassemble typically like scaffolding, and made of a material which can withstand high impact forces. On the edges of this safety roof, there needs to be a safety tagging which prevents workers from moving outside the safe zone and into the dangerous zone. Figure 13 gives a simple principal sketch of the idea.



Figure 13 Sketch of roof over WL

Pros

Cons

+Flexible

+Fast assembly and disassembly

-Strong material is needed to withstand impacts and large forces.

# 4.4 Folding Plates with Nets

This idea is a combination of plates and nets to cover the opening in the deck. The main objective is to have an automatic mechanism in the process, so we could have a shorter installment time.

The group wants to use folding plates that are installed on the side of the opening, as the first cover (these plates already have an open hole that correspond to the well slot on the lower deck). Then to secure the open holes in the plates, we will use horizontal nets on top of it as the second cover. There will be an electric riley to operate both folding plates and net covers to open or close. Figure 14 shows the general description of this idea.



Figure 14 Sketch of folding plates with nets

# 4.4.1 Design

## 1. Folding plates

Figure 15 shows the design of the folding plates. These plates have open holes in them which correspond to the well slot position of the lower deck. For strength considerations, these plates could consist of more than one layer with different materials for each layer.



Figure 15 Folding plate

# 2. Nets

Four nets will be placed on top of the folding plates. Each net is installed on the frame side (rolled on a reel system). The objective of this arrangement is to secure the open holes in the folding plates from any dropping object. Please refer to Figure 16 for detail.



Figure 16 Four nets on top of the folding plate

#### NTNU

## 3. Frame to be installed

A frame will be needed to attach/hold the folding plates and nets. This frame will be installed on the open space that we need to cover. Figure 17 shows a detailed drawing of this frame.



Figure 17 Frame with net and plate

# 4. Reel system (net winder)

When the nets are not used, they will be rolled on the reel system. This system could be operated using an automatic control. The detailed drawings are presented in Figure 18.



Figure 18 Reel system for the net

# 4.4.2 Procedures

## Setting-up (installment) Procedure

- 1. Spread out the folding plates from one side to the other side. Keep in "lock" position.
- 2. Set up the drillstring through the open hole in the folding plates.
- 3. Move out the nets from the reel systems until the area around the drill string is closed. Keep in "lock" position. Turn the reel in the opposite direction if the nets need more tension.
- 4. Ready for drilling operations.

## **Un-installment Procedure**

- 1. Roll-in the nets to the reel system.
- 2. Pull-out the drillstring from the well. Drillstring could go through the open hole on the folding nets.
- 3. Move the folding plates to the side.
- 4. Un-installment procedure completed.

## Pros

+ Short set-up time due to automatic control

+Flexible due to folding plates and nets

+Higher strength due to simultaneous use of plates and nets

# Cons

-Strong material needed to withstand hard impacts and large forces.

-WL rig-up height will be limited due to the closed net

-May be expensive

# **5 IDEAS WITH HORIZONTAL NETS**

The ideas are in their first stage; are explained in principle and do not contain details. Each idea has a pros and cons section at the end of each chapter.

# 5.1 The slope-catch net

This idea involves a net suspended from the drilling rig, with ends attached to pulleys on the rig underneath. The net is mounted so that there is a hole underneath the drilling rig, permitting the drillstring to go through at all times. Falling objects (FO) are deviated by sliding on the net and following the slope to the net end, where there is a reinforcement to take the impact. Look at figure 19 for sketch.



Figure 19 Principle sketch of the Slope-Catch Net

The net itself will be attached to the middle deck with pulleys in the corners (figure 20); alternatively pulley cylinders (figure 21).



Figure 20 Slope-catch net with pulley arrangement



Figure 21 Slope-catch net with pulley cylinders

When the drilling tower is moved to be repositioned (on the same shaft); we relieve the stress on the line during the positioning, and then afterwards turn the pulleys to put the net in the desired tension. Excess net will be stored in containers suspended from the middle deck (figure 22).



#### Figure 22 Tensioning of rope and storage of excess net

The hole of the net will be fastened to the drilling skid, around the hole for operations. When the skid is moved, so will the net; thanks to the movable hook system (MHS), see figure 23.



Figure 23 The Movable Hook System

The system is permanent on one shaft, but must be moved and reattached if the drilling rig is skidded to another shaft. A solution to this is to install a net on both shafts and only detaching the upper net end, and leave the net in complete tension, catching all excess net in the containers during skidding to another shaft.

Pros	Cons
+Workers safe from falling objects (excluding FO during WL rig-up).	-Must be removed and reattached if the drilling skid is to be moved to the other shaft.
+Easy system to operate	-Requires minicrane
+Low-cost system	-Difficult to attach/detach from drilling skid
+ BOP-deck access is unrestricted (except from minicrane)	-Feasibility of the pulleys system. It may be difficult to wind the net.
+Limited fall height of FO, less tougher and expensive net needed	

# 5.2 Horizontal net under drilling rig

The idea is really basic and it consists in closing the open hole just below the drilling deck with a horizontal net. See figure 24 for illustration.



Figure 24 Principle sketch of the horizontal net under drilling rig

It is a basic horizontal net with an open hole in it to let the drillstring go through. It is fixed to pulleys on the extremities of the drilling deck. The lines continue down to the middle deck where more pulleys are located. This increases the maneuverability of the solution. In order to move with the drilling rig when changing slots, the net hole must be attached to the mobile hook system or equivalent. One may also consider having one net for each slot.

In order to increase the amount of downward force the net may take, we may want to use the mattress net solution (figure 25). Instead of having a one layer net, the idea is to attach several nets together with springs.



Figure 25 The mattress net

One can also put a hole in the mattress net to let the drillstring go through. We believe that by using this system we could be able to stop much heavier FO.

Pros	Cons		
+Simple	-Toughness of net		
+Low cost +Easily stop and retrieve fallen objects	-WL workers only safe from FO from drilling deck (not middle deck)		
+ No need to set up slope or move the system +Possible to remove it	-May need many lines and pulleys =restricted access between decks		
+Takes minimum space +Small storage room required +We don't need crane to put in place.	<u>Mattress net:</u> -Difficult to wind or fold (storage and positioning issues) -Need to have a different mattress net for each		
+Can stop heavy FO	possible slot		

# 5.3 Horizontal net with zip-lock system

The idea is to put a horizontal net over the middle deck. The net will be composed of several nets with the same size as a slot. Each single net may be removed when operations are needed on the respective slot. The system permits for a regular WL rig up if wanted. See figure 26 for a principle sketch.



Figure 26 Principle sketch of the horizontal net with zip-lock system

In order to be able to remove some of the nets, we use the zip-lock system (figure 27). The net must be relieved in tension so that workers on the deck below may detach the selected net. All nets are attached with zip-locks in-between. Activating/removing the zip lock will easily remove the net; and just as easily permit the crew to reattach the net when needed. One may choose between one or several zip locks (figure 28) for efficiency.



Figure 27 Zip-lock system



Figure 28 Zip-lock system with several zip locks

Alternatively the pieces can be attached together with Velcro (figure 29) or similar fasteners.



Figure 29 Velcro material can alternatively be used as fastener.

To give the net the ability to take an additional amount of falling weight, we have installed the spring system (figure 30). The net extremities are attached to springs, so that the net is more elastic.



Figure 30 Spring system

Pros	Cons
+Workers safe from falling objects	-Fall height
+We can do a standard WL rig-up, if needed	-Toughness of net
+Easy system to operate	-Trampoline effect due to spring system
+Does not limit deck access	-Requires larvacrane for WL rig-up under net
+Low cost	
+Permanent solution	
+Possible to remove it	
+Small storage room required	
Velcro:	Velcro:
+Easy to adapt the net to size requirements	-Maybe not strong enough to withstand a big
+Cheap	impact

#### NTNU

# 5.4 The Horizontal net on the drilling tower

The idea is to have a horizontal net around the drilling tower. Wires in tension are attached to the top of the tower and suspended down to the drilling deck. The nets are attached on one extremity to the wires and on the other extremity to the tower. The nets are put in such a height as not to limit the drilling tower access. See figure 31 for an illustration.



Figure 31 Principle sketch of the horizontal net on the drilling tower

# 6 IDEAS WITH VERTICAL NETS

The ideas in this chapter are most of all based on the use of vertical nets in different ways. The ideas are in their first stage, are explained in principle and do not contain details. Each idea has a pros and cons section at the end of each chapter.

# 6.1 The Net-wall with springs

The idea is to create a wall of nets from the middle deck to the drilling deck. A spring system will permit the wall to be lowered and extended, depending on the operations in progress. This system will prevent objects from falling from the middle deck to the BOP-deck. See figure 32 for an illustration.



Figure 32 Principle sketch of the Net-wall with springs

The wall foundation will be placed around the hole in the middle deck. The springs will be in tension when the wall is undesirable. When the wall is needed, the springs are released. A fastening mechanism may be put on top of the system, so that it may be attached to the drilling deck for stability (figure 33).



Figure 33 Deployment of Net-wall

Pros

Cons

+Permanent solution

+No space restriction on BOP- or drilling-deck

# -Only helps against FO from middle deck to BOP-deck

-When deployed, completely seals of the space between the drilling deck and middle deck

-Does not capture FO, only deviates it to middle deck

# 6.2 Vertical nets sealing off open holes

The idea here is to seal off the area below the open holes by putting one vertical net under each open hole. The FO will then be contained in this area and to avoid the FO to reach too high speed inside the nets, a dampening system can be used. See figure 34 for a sketch.



Figure 34 Vertical nets sealing off the area below the open holes.

The nets here are supposed to guide the FO to some pillows on the WL deck where the FO is stopped harmlessly. The group thought about pillows but it could be something else, like some type of spring. In the nets we thought about a dampening system, which is called the Fall Dampeners, see figure 35. The dampeners are supposed to be pushed away by the FO thus leading to a decrease of its velocity. One should notice that as they are attached to the net they cannot carry a huge load otherwise the net would break. By putting many small dampeners one can overcome this issue.



Figure 35 Sketch of fall dampeners.

The system is not permanent since it must be adapted to the size of open holes. Each time the drilling skid moves, the open holes change and one should make a new configuration of vertical nets.

Pros	Cons
+Workers safe from falling objects (excluding FO during WL rig-up).	-Must be removed, reattached and adapted if the drilling skid is to be moved to another
+Low-cost system at short term (if no	position
intensive use of WL)	-May be difficult to attach/detach from drilling
+No need for a larva crane	skid
	-Large fall height of FO
	-Restricted area on the WL deck

# 6.3 The Goblet

The idea here is to put a cage around the drillstring between the WL deck and the drilling deck and to attach an inclined net to it. See figure 36 for an illustration.



Figure 36 The Goblet rig up.

The thought is to build a cage around the drillstring with some kind of scaffoldings or a permanent cage on wheels to protect the drill string from FOs. This cage has a crucial importance because the net is attached to it. When a FO gets on the net it will be deviated to the cage which will have to stop the FO. As shown in figure 36 one can also add some stabilizer line to the tower to make it able to withstand bigger impacts.

Figure 37 presents the different stages that should be used to mount this protection.



Figure 37 A 3D view of the goblet rig up

Pros

- +WL workers are safe
- +Small restricted area on the WL deck

## Cons

-May be difficult to rig up and to store (time consuming)

-Need to change the configuration for each slot

-If FO are too heavy for the cage it can damage it and the drillstring inside

#### NTNU

# 6.4 Tent / Tipi protection above the WL

The idea is a tilted wall that will prevent the falling object to hit the equipment and workers. The potential falling object will with this construction just slide off and away from the operation area. The material and angle of the wall is crucial in this design. If flexible materials like sheet or nets are used, this would need to be tensioned up, the tent also need to be easy to assemble and disassemble. Figure 38 gives a principal sketch of the idea.



Figure 38 Principle sketch of a tent / tipi protection

Pros

+Flexible

+Fast assembly and disassembly

Cons

-Equipment outside the WL area will not be protected.

-Material choice is crucial

# 6.5 The Spiderwebs

The idea is to seal all or part of the openings in the drilling tower with nets. The nets will be attached to the tower foundation, preventing objects from falling from inside the tower to the deck. See figure 39 for an illustration.



Figure 39 Principle sketch of the Spiderwebs

## Pros

+ Workers safe from falling objects from inside the tower

+Does not restrict access to rest of platform

+No operational changes needed (simple system)

+Permanent solution

+Limited fall height of FO, less tougher and expensive net needed

+Easy to retrieve FO

+Low-cost

# Cons

-Does not help with FO from anything than from inside the tower

-Creates problems for drilling operations (access)

# 7 FINANCIAL BENEFITS

The financial benefits of running WL below the rig are:

- WL and drilling activities can be done simultaneously.
- Avoiding down-time on drilling rig.
- No cost and time loss due to moving/skidding drilling rig to another shaft when we need to do WL.
- No cost and time loss due to tripping out of drillstring when we need to do WL on the same shaft.
- No time delay on drilling schedule. → Avoiding delay on wells' Put-on-Production (POP) schedule.
- Minimizing production loss due to well shut-in.

# 8 CONCLUSION

The project group has worked towards solving the main issues with running WL below the rig. This has been done by getting familiar with a WL rig up and studying the risk assessment matrix analysis given by Statoil. In this process all group members have learned a lot about platform operations and WL.

The group has come up with 15 solutions to the safety problems of falling objects. The group thinks some of the ideas are feasible. Ideas such as the Slope Catch Net and the Metal Plate are solutions which with some changes and more engineering can be feasible.

There have not been developed ideas on other issues from the risk assessment analysis than falling objects.

The group members hope that ideas presented in this project could lead to a functional solution for Statoil.

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# APPENDIX

1) Technical Project Report, Part A

# **EXPERTS IN TEAM GULLFAKS VILLAGE 2011**

# Group 3



# - Part A -

# Norwegian University of Science and Technology

Faculty of Engineering Science and Technology Experts in Teamwork Gullfaks Village 2011

### **REPORT FROM PROJECT IN SUBJECT TPG 4851 SPRING 2011**

Emne: TPG 4851 Experts in Teamwork Gullfaks Village 2011

Title: Improved Oil Recovery from Gullfaks Sør Statfjord

**Project group:** #3

Accessibility: Open

# Group participants: Wynda Astutik Lars Myrvang Gaute Dag Løset Jan Cornet Henrik Sehested Næsgaard Bruck Haile Woldeselassie

Main coordinator: Jon Kleppe & Petter Eltvik

# PREFACE

The Gullfaks Village 2011 has a focus on IOR on the Beta ridge on the western side of Gullfaks. The fields Gullveig, Tordis and Skinfaks are developed by sub-sea wells, while Gulltopp is a long 10 km well drilled from Gullfaks A. The Beta ridge is a group of satellite fields vest of the Gullfaks field. Statoil advisor for the Part A is Petter Eltvik from Statoil.

The main purpose of Part A is to demonstrate an understanding of the challenges related to production with pressure depletion and aquifer support. Based on information provided in part A, the students shall do material balance calculations as a basis for analyzing production and pressure behavior. The procedures to be used are shown in Attachment 1, and the data to be use are shown in Attachment 2 to be used to calculate pressures along the Beta ridge.

Trondheim 09.01.2011

Wynda Astutik

Lars Myrvang

Gaute Dag Løset

Jan Cornet

Henrik Sehested Næsgaard

Bruck Haile Woldeselassie

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# 1 TASK 1

The students shall convert all oil, gas and water volumes to reservoir conditions at 2500 m MSL TVD.

# NOTE:

This task has already been completed by Statoil. And we were given their results as data in excel sheet. These data were used in next task in Part A.

# 2 TASK 2

Based on the data provided, the students shall calculate the average reservoir pressure depletion at the Beta ridge.

# **SOLUTION:**

- A. Data Provided and Facts
- Yearly average of production data (Sm3/day) for fields in The Beta Ridge
- Yearly average of injection data (Sm3/day) for fields in The Beta Ridge
- Yearly average of volume leak (Sm3/day) from The Beta Ridge to Gullfaks Main Field and vice versa
- There is communication between The Beta Ridge and Gullfaks Main Field
- The data start from 1986 until 2025 (Simulation Data?)
- The oil and gas volume is converted to water volume
- **B.** Procedure
- Assumptions:
  - 1. Assume all layers in The Beta Ridge as a single volume (good communication between layer)
  - 2. Initial pressure given = 380 Bar in 1986
  - 3. Water compressibility = 4.5 E-5 1/bar
  - 4. Rock compressibility = 4.5 E-5 1/bar
  - 5. Initial reservoir fluid volume = 8E+9 Sm3

# • Equation used:

Based on simple material balance, we could use equation below to calculate the average pressure depletion at the Beta Ridge:

$$\begin{split} \Delta V &= V_{initial} \times Ct \times \Delta P \\ \Delta V &= V_{initial} \times (Cr + Cw) \times (P_{@t} - P_{initial}) \end{split}$$

By re-arranging

We use this equation in excel for further calculation

### C. Results and Analysis



### Analysis:

This is the resulting plot for task 2.



#### Analysis:

To do a better analysis, we also plot the total inflow and outflow. The relation that we could observe, if we have total inflow higher than total outflow then the reservoir pressure will increase. If our total outflow is higher than total outflow, the pressure will decrease. Or in other words, the reservoir pressue will decrease if there is not enough water injection into the reservoir.

#### **D.** Sensitivity Analysis

Given that there are some uncertainties in this task, we found it is important to include the sensitivity analysis in this part, especially for assumed parameters values (initial pressure, total compressibility, and initial volume).

#### • Initial Pressure Estimation

After we did the pressure calculation using equation (1) and compare it with reference pressure data given at 1993, we noticed that the assumed initial pressure (Pi = 380 bar at 1986) we use is too low. Considering this result, we decide to do sensitivity of initial pressure to find the value that could match with actual reservoir pressure at 1993 (Pr = 389 bar). The results are given in figure below. Based on sensitivity, we found that Pi = 393.5 bar will give a closed match results with reference reservoir pressure at 1993. We will use this Pi value for our further work in Part A tasks.



#### • Total Compressibility Sensitivity

Total compressibility (Ct) is one of uncertainties in our system, especially because we do not have laboratory measurement of Cr and Cw for Beta Ridges. The sensitivity results for total compressibility are shown in graph below:



#### Analysis:

Based on equation (1), we could see that Ct is inversely proportional with pressure change in reservoir. This also shown in our sensitivity results, at certain time, when the Ct value increases the reservoir pressure will increase. If we have higher Ct value, the pressure change in reservoir will be lower that is why we will have a higher reservoir pressure.

#### • Initial Volume Sensitivity

Initial volume is also one of uncertainties in our reservoir. Due to lack of data/information, we just able to assume the initial volume used to complete all task in Part A. To see how big the initial volume affects our system, a sensitivity study is needed. Figure below show the results of our sensitivity study.



#### Analysis:

Based on sensitivity results, we can conclude that the higher initial volume, the higher our reservoir pressure. This because the bigger the initial volume, the smaller the pressure change in the system. We also noticed that the pressure change profile in a bigger volume will not be as sensitive as pressure change profile in smaller volume.

# **3 TASK 3**

Measured reservoir depletion in wells A-32 drilled to the Beta ridge is shown in Attachment 3. Compare this to the calculations under 2 above, and comment on reasons why there are differences between the calculated and the measured pressure.

# **SOLUTION:**

## Given data and facts:

- Attachment showing a plot of simulated pressure versus time for different formations in Gullveig Brent from 1993 to 2005.
- The calculated pressure plot from TASK 2.

## **Procedure:**

- The plot of the calculated pressure was formatted to be superposed on the attachment plot.
- A final plot was then created and analyzed for variations:



#### **Results and reasons for differences:**

We see that the calculated average pressure fits more or less with the measured graphs. By taking a closer look, we see that during some time periods the curves bend in opposite directions. This I true for 1996-1998, were we see the measured graphs experiencing an incline, where we have a decline. In the period 1999-2001, it is the other way around.

We were also made aware that the pressure is seldom equal to the measured pressure; this can be explained by many reasons.

#### **Reasons:**

• Erroneous or bad data

Some of the data given may be erroneous due to damaged logging tools, bad simulations results, or even wrongly performed transformation of oil and gas volumes to water volumes.

There are big uncertainties around some of the data. We are asked to estimate some of the parameters. These include especially the initial volume, initial pressure, and the compressibility. That's why we made a sensitivity analysis.

• Average approximation

The flow rates given are averages for each year. Within a year, rates may vary. This can create erroneous calculation results.

The pressure we calculated and plotted is an average for the whole Beta Ridge. This means that production/injection rates from all other wells in this region may be (and most likely are) different from our plot. Some reasons for these deviations include:

#### -Different reference depths

- -Different reservoir characteristics (porosity, permeability, GOC, WOC, STOIIP, etc...)
- -Surrounding formations are different (overburden pressure, pore pressure, etc...)
- -Gas pockets/Sealed formations/Faults/High-pressure zones

## • Reservoir communication

The differences may be **communication-**related. This includes many sub-categories:

-Production/injection from another well

- -Aquifer influx, Gas cap/formation communication
- -Expansion of rock/pores/fluids

## 4 TASK 4

Make an evaluation if the recovery factor for the various fields to date. How do the fields interfere with each other? Based on the production to date, what are expected recovery factors over the full production life for the fields? Why could there be differences between the different fields?

#### **SOLUTION:**

#### Given data and facts:

The data available were production and injection of all kind of fluids converted into water volumes for each field of the Beta Ridge. The data given up to 2030 have been obtained from simulations but we assume they are correct throughout the task. We also had access to the reservoir management plan of 2007.

#### Procedure

We tried to answer question 4 based on our data. We were asked to estimate the recovery factor for each field but the data we got was already converted to water volumes and as it was risky to estimate a proper value for the different water cuts we preferred not to get entangled into a web of estimations, which would have lead us to an irrelevant recovery factor.

In order to estimate the communication between the fields in the Beta Ridge, we plotted cumulative production and injection for each of them. Then we compared the plots to see if we could find some correlation which would hint to some sort of communication.

#### Analysis

#### • Leakage, Beta Ridge-Gullfaks Main:

The plot below shows a big leakage from Gullfaks to the Beta Ridge compared to the other way round. This first proves us that there is communication between the two but seeing the big discrepancy in the leakages this implies that Gullfaks is "supporting" the Beta Ridge by transferring fluid volumes which most likely indicates that there is a pressure difference. The pressure at the Beta Ridge seams to be lower than the one at main Gullfaks.



### • Gullfaks West:



We can see from the plot that until 2008 there is a clear correlation between injection and production: after an injection peak there will be a peak in the production after some time. The purpose of the injection was to increase the production is achieved.

From 2008 this trend is not true anymore. We clearly see that even though the injection rate is high the impact on production is low. We can therefore assume that some of the injected volumes are leaking to other fields especially to Gullfaks main. As a matter of fact Gullfaks West is situated just nearby Gullfaks main and we see from the plot of the 'Cumulative inflow and outflow between the Beta Ridge and Gullfaks main' that there is an increase in the leak from the Beta Ridge to Gullfaks. It is therefore plausible that part of the injected fluids in Gullfaks West moved to Gullfaks main which would prove the communication.

#### • Other fields from the Beta Ridge





We can see on the plot that even though injection happens or not there is no major change in production. This can be explaining by some communication with the surrounding fields but it can also be caused by the management of the wells.

This observation and deduction can be extended to the other fields of the Beta Ridge.

# **5** CONCLUSION

By using a simple material balance equation, we managed to calculate the reservoir pressure of Beta Ridge. In this calculation, we use converted volume as the input data and assume the initial pressure, total compressibility value, and also initial reservoir volume. Given that there are some uncertainties in assumed input data, we found it is important to include the sensitivity analysis in this work. The sensitivity results are present in Task 2 part in this report.

We also managed to find some tendencies for communication between the fields from the plot that we made from the calculated volume data. The whole project was hindered by the lack of information and the uncertainty of the data given. The fact that the data given are converted volumes (water volumes) is preventing us from doing several other estimations as cumulative oil and gas production which are two of the main parameters in recovery factor calculations.

# **6** ATTACHMENTS



Figure 1. Fields and discoveries in the Gullfaks area with the Beta ridge marked.

