Downhole **GRA**vity **S**lip **S**eparator
Project report

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Contents

1 Preface

This report is the presentation and conclusion of the work done by a group of 5 students in a subject called “Experts in Teams” (EiT). The project started out as an idea from the group. We wanted to study Downhole Oil-Water Separation (DOWS) systems and see if they were applicable to some of Statoils existing installations.

This report is the result of a study of petroleum technology in general and DOWS and the Downhole GRAvity Slip Separator (DGRASS) in special. We are satisfied with the result, considering how little time we had available, and how limited the groups knowledge about oil recovery was before we started. We hope that the results are useful in the future work of professor Michael Golan, post doctor Pascal Klebert, Benjamin Bourgeois and of course Statoil. We were told that Statoil is about to launch a larger study of DOWS systems and DGRASS, and we hope our report will be a valuable contribution to that.

We would like to thank professor Jon Kleppe, professor Michael Golan and Jan Ivar Jensen at the Department of petroleum engineering and applied geophysics (IPT) at NTNU, and Lars-Even Hauge at Statoil for providing data on attractive wells at Gullfaks. We would also like to thank post doctor Pascal Klebert and Benjamin Bourgeois for providing valuable input to the project, the teaching assistants Andreas Våge and Tora Bøhn Søreide for valuable advice and knowledge about teamwork and the group process, and anyone else who helped us along the way but was forgotten here.

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2 Project description

The majority of oil reservoirs start to produce water as they mature. The water/oil ratio, i.e. the water cut, varies with the geographical location, the geology, and the age of the reservoir. As the number of mature fields increase, the industry is facing a need for techniques that ensure economical and efficient production of oil with increasing water cut.

The lifecycle cost for an oil field can be significantly reduced if the available top side process plant is dedicated to oil production all through the life of the field. If the water cut in the incoming stream is reduced, this may create capacity that will allow tie-in of additional wells, or increased production from existing wells. Downhole Oil/Water Separation (DOWS) may enhance the oil production as the increased tubing head pressure resulting from less lifting of water required may be used to increase the flow of oil from the well.

Alternatively the pressure of a first stage separator may be increased, and thus the gas flashed off in the first stage separator will need less compression before being reinjected or exported. While downhole oil/water separation technology so far has been dominated by concepts employing electrical submersible pumps (ESPs) and cyclone separators, downhole gravity separation has generated considerable interest from the industry in recent years [15].

The overall goal for this project is to show that DGRASS is a feasible separation technology which will provide improved oil recovery. To achieve this goal, we have defined the following goals as our main goals:

- Select candidates for DGRASS installation at the Gullfaks oil field
- Perform a production analysis of DGRASS using data from the selected wells
- Suggest a well completion with DGRASS

3 Prestudy of DOWS systems

3.1 Introduction

Oil wells produce a lot of water in addition to oil. The water cut in Statoils Gullfaks field is up to 96% on certain wells, while customers want the water cut to be below a certain limit (typically 0.5%). This requires the oil producers to separate the water from the oil in a very fine grained manner. Extensive research is done to make this process cheaper, and one of the areas that are being researched is the use of Downhole Oil-Water Separation (DOWS) installations of different types [6].

DOWS installations will not necessearily be cost efficient for all wells, but for some candidates it can be possible to increase the production rate with more than 100%. It is crucial that the specific DOWS used is perfectly fitted for the well in which it is to be implemented. If it is not, the production rate may decrease, which may result in only water production [6].

The track record of existing installations world wide is mixed. Some DOWS remain in service for more than two years, but others fail within a few days. This is one of the main concerns with DOWS. They are extremely costly to implement, replace, and fix if failures occur. This leads to reduced income due to production stops as well as the repair related expenses. The Gullfaks field is relatively old, so any DOWS that is to be used must be relatively cheap because of the limited lifetime of the reservoir.

3.2 Different DOWS systems

This section gives a brief discussion of the different DOWS systems that are currently available.

3.2.1 Electric coalescence

Electric coalescence is an efficient separation of water from crude oil using an electric AC field and turbulent flow. The electric field makes the smaller oil droplets collide and form drops. This leads to increased buoyancy of the crude oil, and therefore decreases the settling time and increases the settling velocity of the crude oil from water. Electric coalescence is used both on land and sub sea. An illustration of electric coalescence is shown in figure 1 [2].

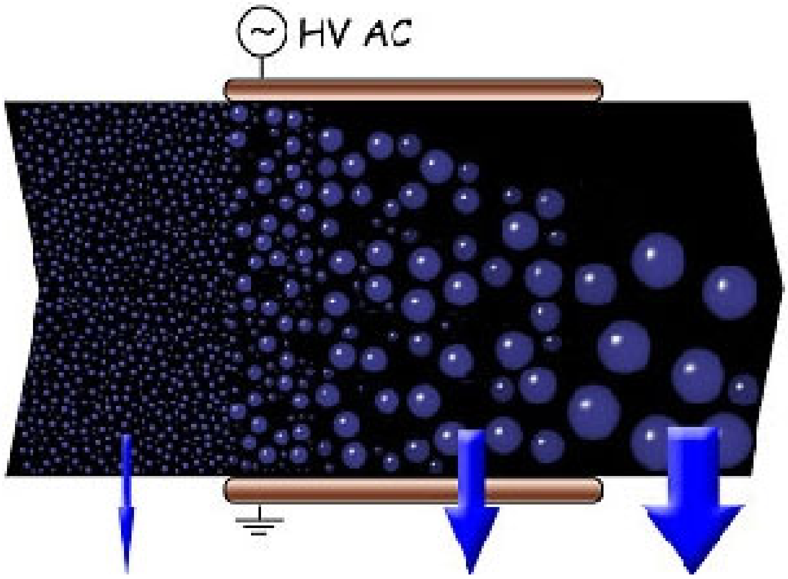

Figure 1: Electric coalescence

Compact separation by electric coalescence works best with the following resources:

- High AC voltage
- Turbulent liquid flow with high velocity
- Crude quality (asphaltene content, surface tension, conductivity, salinity in water phase, etc.)

The effects used in separation by electric coalescence originate from charges on the conductive water drops carried by insulating oil induced by the applied AC field. When two droplets get close, the droplet pair will align with the electric field and a strong electric field and attractive force will occur between them. The field augments the coalescence process by creating surface instabilities. The droplets are kept in contact, either thinning the surface layers at the interface or creating electric discharges. Turbulent motion in the liquid results in frequent collisions between droplets.

The fact that AC voltage is used, and that the charges are induced on the droplets (no net charge) allows using electric insulation on the electrodes, thus avoiding breakdown from water “plugs”.

Advantages of using electric coalescence:

- Reduces the space needed for already existing separation systems
- Increases drop sizes to a tenfold, which leads to faster separation of crude oil
- Reduces the time needed to separate
- No moving parts
- Relatively easy to implement
- Little space consumption
- Energy consumption is low
- Avoids chemical emulsion breakers/inhibitors
- Decreasing discharges of chemicals to waste water

Disadvantages of using electric coalescence:

- Requires electricity
- The mechanism in the electric coalescence process is still somewhat unknown

3.2.2 Gravity separators

One type of equipment for separating water from crude oil are gravity separators; large tanks or pipes where the water is allowed to sediment out of the oil. The gravity separators take advantage of the difference in density of water, oil and gas and use those to separate the different substances, which will form a layered cross section. Water will reside in the bottom layer, the oil in the middle layer, and gases at the top [4].

These separators operate with high pressures to decrease the volume of compressible gas. Reduced volume yields smaller tanks, which are crucial on an oil production facility such as a platform, where the available space is very limited.

Gravitational separation is used both on land, on platforms and on the seabed. The separators can be either tanks or long pipes. Long pipes are mostly used sub surface. Tanks are mainly used on land and on platforms.

Separation tanks

The separation tank separates large volume of crude oil, water and gas. This is the most common separator, and it demands a relatively large space. These types of tanks come in many different forms, shapes and technical spesifications. They can be used as a seabed separator, but due to difficulties in maintenance and cleaning, they are relatively inpreferable. [8] .

An illustration of a separation tank is shown in figure 2.

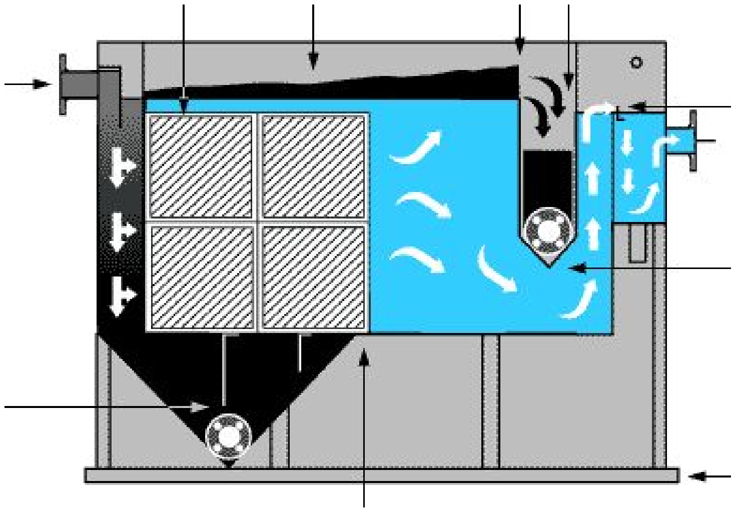

Figure 2: Separation tank

A brief outline of the process in a separation tank is as follows:

1. Settle the liquid
2. Produce gas on the top of the tank
3. Produce oil in the middle of the tank
4. Produce water on the bottom of the tank

The separation tank is a well known technology with which most oil companies have lots of experience. They are also relatively efficient and cheap to use. The disadvantages of using a separation tank is that the tank is difficult to clean and repair.

Seabed separators

Seabed separators consist of a long pipe. Such a pipe usually has a stratified flow regime. A flow regime is a description of how the flow behaves. Flow regimes are graded from stratified to turbulent. In a stratified flow the liquids are separated in layers. In a turbulent flow the liquids are totally mixed. Flow regimes depend on the angle of the flow trajectory[1], velocity, and pressure. Different flow regimes are shown in figure 3.

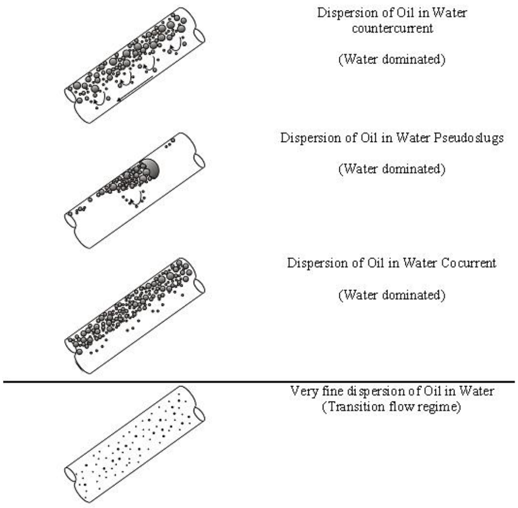

Figure 3: Different flow regimes

The advantages of separating oil from water on the seabed are as follows:

- Less pressure drop of the liquid column
- Energy saving (less mass pumped up to the platform)
- Possible to reinject produced water directly as pressure support
- The reinjection of water is beneficial for the environment
- Possible to save space on the platform
- Easy to clean with a pig[2], without the need for divers or other resources

[1]Gravity makes the lighter compounds seek up, and the heavier seek down.
[2]A pig is a cleaning device used in piping.

The disadvantages of seabed systems are as follows:

- Sub sea systems are costly to implement
- The technology is new, which increases the risks involved with implementing it
- It requires a relatively young reservoir, due to the costs

The Troll pilot is an example of a successful seabed separator. After one year of operation, the Troll Pilot seabed separation system has been given top marks for increasing production capacity on Troll C and improving the environment surroundings. A picture of the Troll pilot is shown in figure 4 [9].

Electric coalescence is used at the inlet of the pipe. The liquid moves rapidly, and is separated in the end of the long pipe. It is relatively easy to establish a stratified flow, because the pipe is placed in the horizontal plane.

The system, which is installed on the seabed at a depth of 340 metres some 3.5 kilometres from the platform, uses the gravitation method to separate produced water from the oil and gas stream emanating from four of the 39 wells currently in operation on Troll C. The water is then reinjected into the reservoir, while the separated oil and gas are piped up onto the platform. Produced water is the water which follows the oil and gas to the platform [9].

Well gravitational tanks

Well gravitational separators are based on a long vertical well hole, which is used to separate oil and gas from the water. The oil and gas is then pumped up to the surface, while the water is directly reinjected to the reservoir. It is a simple concept, and works as a small separation tank.

This system has been implemented, and it did not work properly. The reason for its failure was probably that it required too long time before the liquid settled into its respective phases. This reduced the production too much [13].

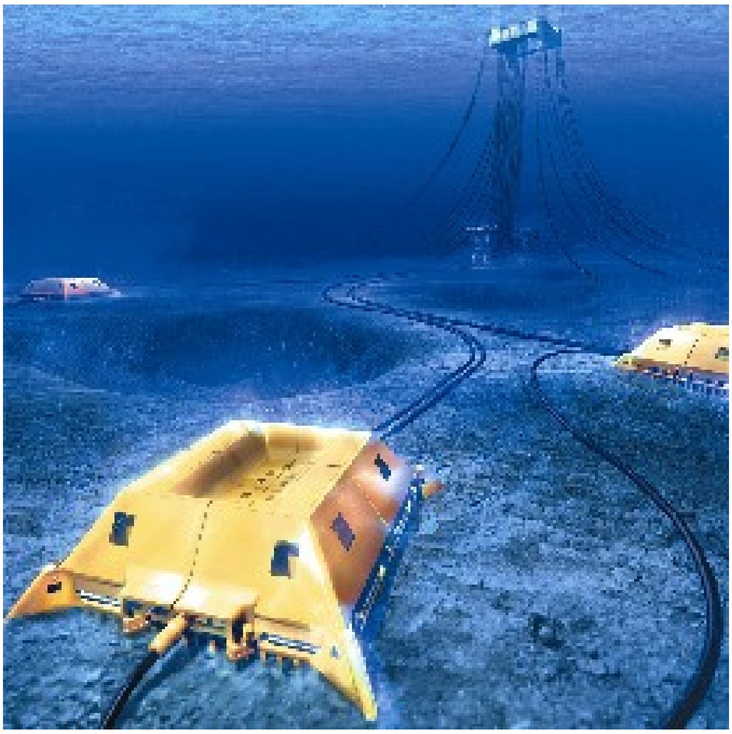

Figure 4: The Troll pilot

3.2.3 Hydro cyclones

Hydro cyclones have been and are still used in DOWS, but only on land. On the surface they are present in most separation systems because of their simplicity, efficiency and space saving properties [11].

Hydro cyclones for oil/water separation have inlets on their sides. The liquid circulates rapidly around the centre of the cyclone, which results in a centripetal acceleration which leads the lighter oil and gas to the centre, and gives a fast separation of oil and water. The relatively heavy water is pushed out against the wall of the cyclone. The water can then be removed through the outlet on the bottom, and the oil and gas can be tapped through the top outlet. Smooth internal geometry gives minimal turbulence and maximal efficiency. A hydrocyclone is shown in figure 5 [6].

The advantages of using hydro cyclones are as follows:

- No moving parts
- Compact and light weight construction

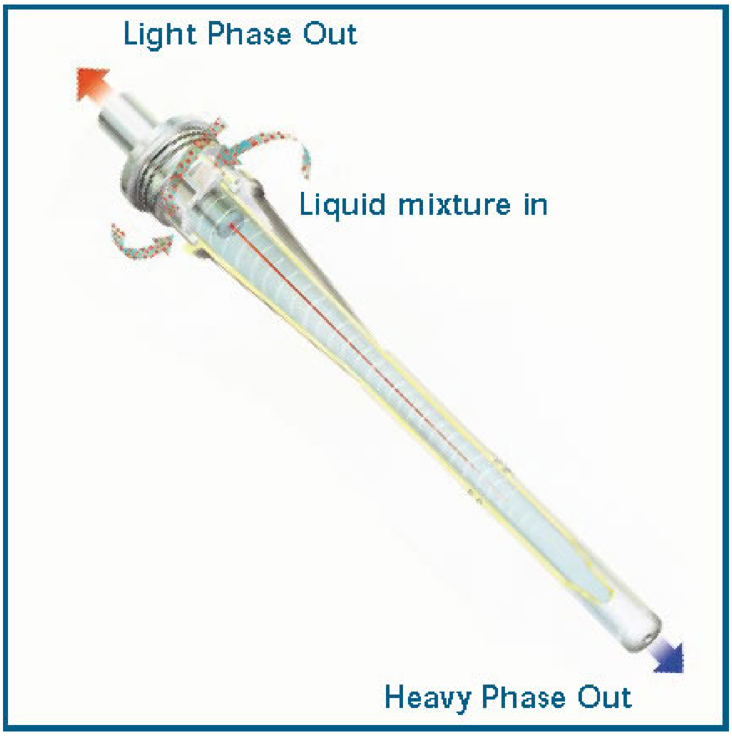

Figure 5: A hydrocyclone

- Flangeless construction to simplify maintenance procedures

The disadvantages of using hydro cyclones are as follows:

- Can easily become clogged
- Needs an electric submersible pump (ESP) in DOWS systems
- Difficult to repair in DOWS systems
- Relatively space demanding in DOWS systems

3.2.4 Membrane technology

A membrane is a product consisting of very small pores. The pores will allow oil to penetrate, but not the water. This happens because the crude oil has less surface tension than water, and sticks to the surface and penetrates the pores in the membrane. The surface tension of the water makes it able to resist the pressure of penetration [4].

An illustration of a membrane is shown in figure 6.

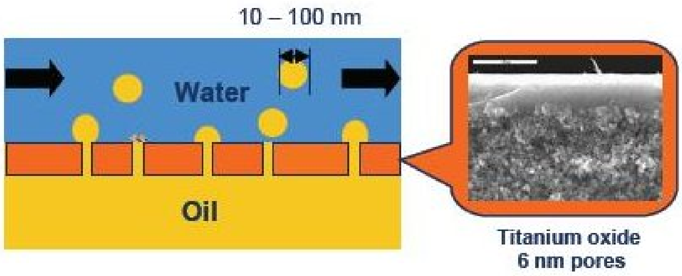

Figure 6: Membrane technology principal sketch

The advantages of membrane technology are as follows:

- Excellent for removal of suspended oil droplets ($< 1\mu m$ can be separated)
- Results in a very clean product

The disadvantages are as follows:

- Sophisticated, complicated technology
- Demands regular chemical regeneration to restore flux
- Problems regarding permanent loss of flux
- High energy consumption
- Does not separate dissolved components
- Very expensive

3.3 Conclusion

Different DOWS systems have been researched. Several advantages and disadvantages have been identified. The use of DOWS systems results in less space required for separation facilities at the surface. Energy consumption can be reduced due to the hydrostatic pressure drop caused by DOWS. The produced water can be pumped directly down in an aquifer, and operate as pressure support.

DOWS have a great potential to save money and reduce the environmental impacts of managing produced water at the surface. The technology is still in its infancy; many aspects require more research. Some trials have been very successful and have paid back costs in a few months. Other trials have failed. The cost of installing DOWS equipment, including the well workover, is substantial. Given the extremely low price of oil in mid-1998, operators have been hesitant to invest in this sort of new equipment. As oil prices rise, and increased oil recovery becomes more important, DOWS systems are likely to become more popular.

4 DGRASS

4.1 Introduction to DGRASS

DGRASS is based on gravitational separation of oil from water. What makes it so interesting is the fact that it is the production pipe itself. Figure 7 shows a sketch of DGRASS.

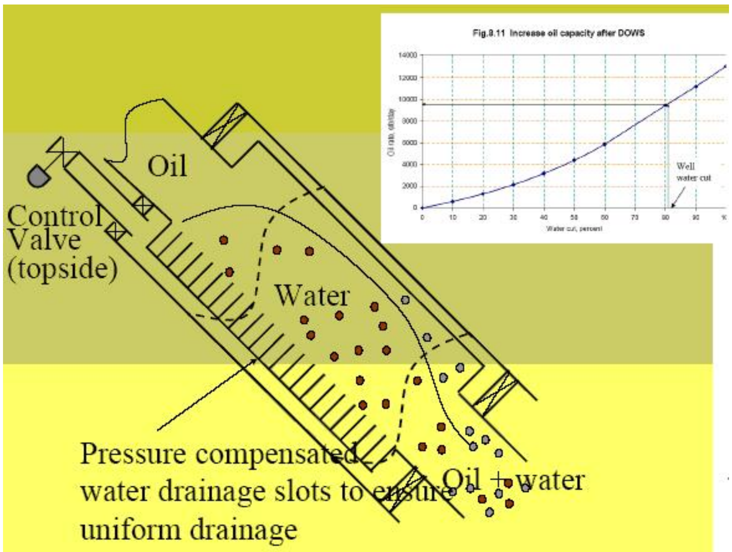

Figure 7: A sketch of DGRASS

A special challenge for downhole separation is the separator diameter restriction. While separator lengths of tens of meters are easy to implement, their diameter is usually restricted to below $0.3m$. A challenge is then to develop a design where the small diameter may be compensated by extended length. The piping in a well consists of sections that are $10m$ long. Three of these sections are put together, forming a total length of $30m$. DGRASS may consist of as many of these $30m$ sections as desired. Thus, DGRASS solves the extended length challenge of downhole separation [15].

Installing DGRASS may have several positive effects:

- Higher production rate due to lower well pressure increases the flow towards the well
- Increases the reservoir lifetime, as it can produce with economical benefits on high water cuts

- No gas in the water phase makes it energy saving when it pumpes the major water phase up to lower pressure
- Faster separation on the platform

4.2 Principles of DGRASS

Figure 8 shows a principal drawing of a simplified DGRASS separator based on three tapping points. An actual separator will contain a large number of tapping points. The tapping points are numbered sequentially from 1 to n, and are assumed to be equidistant. The total distance between the first and the last tapping point is L. The inner diameter of the tubing and casing are D_t and D_a, respectively. The tubing thickness is T [16].

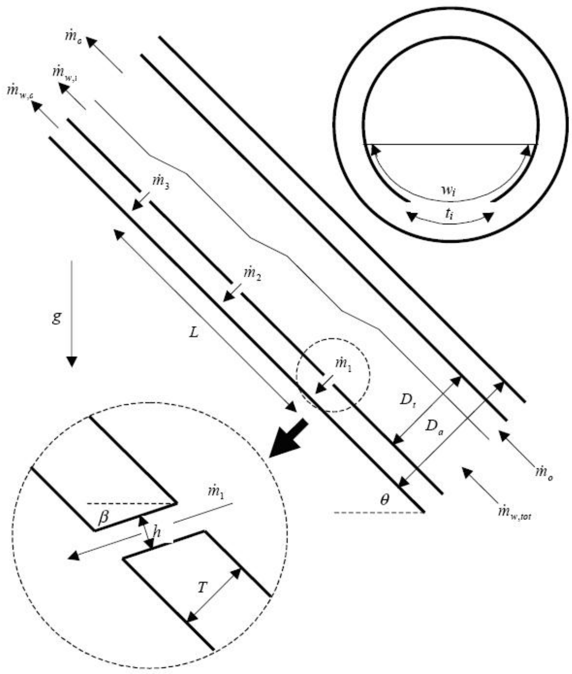

Figure 8: DGRASS principal manner of operation

The inclination angle for the separator and for the tapping points is as shown in figure 8. Both θ and β are defined such that zero angle means horizontal flow and 90° angle means vertical upward flow. Negative angle therefore means that the flow through the tapping point is in the downward direction. All the tapping points are assumed to have the same inclination angle.

4.3 DGRASS research work

ABB has done previous work on DGRASS, indicating that it may be a useful method for downhole separation. However, it needs more testing before implementation. ABB identified the tapping points and design of the DGRASS as the main challenges. They also found that the flow behaviour is altered after each tapping point. This influences the flow regime and separation quality.

Post doctor Pascal Klebert and Benjamin Buorgeois at the Department of petroleum engineering and applied geophysics (IPT) at NTNU are doing research on a DGRASS system using an inclined oil/water flow with separation of the water phase. The preliminary lab results show that the separator is functioning well with an inclination up to 40°. With a watercut of 80% and an inclination of 30°, it will probably be possible to separate out over 90% of the water. The problem they face with higher inclinations are the flow regimes.

The flow regime depends on the mixture, velocity and angle. A horizontal flow will give a stratified flow regime, even with relatively high velocities. This means that there is no turbulence, and it is easy to separate with high quality. A vertical flow will give a turbulent flow regime. Results so far show that with an angle of up to 40° it will be possible to separate, even with some turbulence, as the water still seeks towards the bottom of the pipe. With angles above 40° the flow becomes highly turbulent, and a good separation is difficult to establish. Various flow regimes that may occur are shown in figure 9.

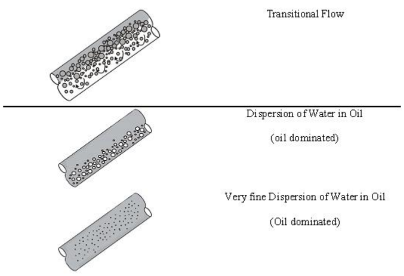

Figure 9: Various flow regimes that may occur in DGRASS

DGRASS has not yet been installed in an operating well, so some negative effects may be hiding in the dark. One of them could be clogging of the tapping points. This factor will depend on the properties of the well fluids. In the future it will be necessary to drill the wells most suitable for installing DGRASS to increase the benefits even further.

4.4 Conclusion

DGRASS is a very simple separation system. The idea is promising, and the results from laboratory research are good so far. DGRASS may be suitable for the wells on Gullfaks with the right trajectory, and may increase the lifetime of old wells due to the reduced bottom hole pressure. These statements will be investigated further in this report.

5 Choice of candidates for DGRASS at Gullfaks

This chapter presents the wells from Gullfaks A that have been selected as candidates for DGRASS installation. It presents the criteria that were considered in our analysis, a previous analysis done by Statoil, and our comparison of the data from that analysis with the latest available data from the wells. Finally, it concludes by presenting the wells that have been selected as candidates.

5.1 Criteria for selection

When selecting wells as candidates for DGRASS installation, there are many criteria that need to be taken into account.

The wells must have a high water cut ($> 70\%$). Without this, there is little need for installing a DGRASS system. The gain would be too small to justify the cost of an installation and implicit production stop.

The sand production rate must be low. DGRASS cannot handle high sand production rates, because they are likely to cludge the tapping points. In addition, wells with high sand production rates are generally unstable and more exposed to damaged piping.

The well trajectory needs to be inclined, preferably with an angle of less than $40°$. If this requirement is not met, there is little or no use installing DGRASS, due to the gravitational separation method.

Last, but certainly not least, the production must be taken into account. Wells with good production are not candidates for DGRASS installation, again because the gain is to small to justify the cost.

5.2 Selection of candidates

After an initial discussion with Michael Golan and engineers from Statoil, and a subsequent discussion with Michael Golan, it was decided that an analysis done by Statoil during the period from January to March 2004 would serve as the basis of our candidate selection.

5.2.1 Analysis

The analysis from Statoil was done by Lars-Even Hauge in March 2004. It was based on averaged data from the period from January to March 2004. A plot showing a comparison of the wells is shown in figure 10. The key data from the analysis are included in appendix A.

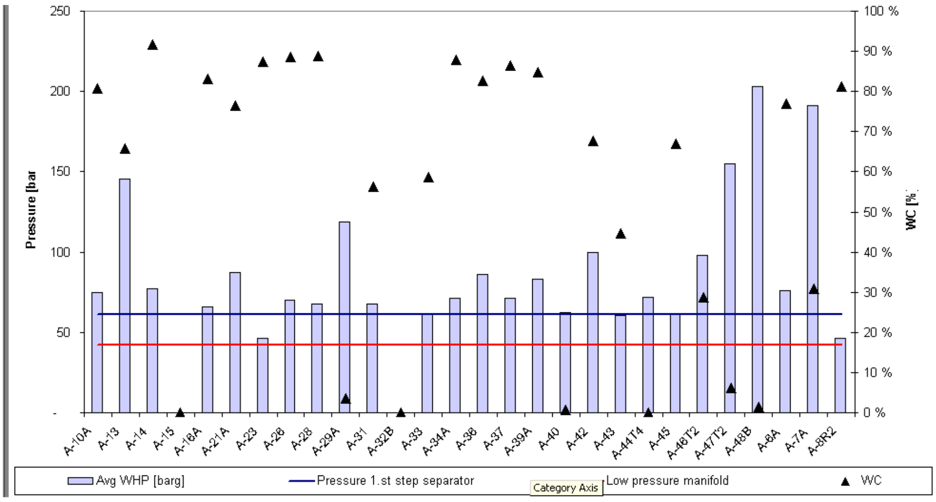

Figure 10: Comparison graph for the wells at Gullfaks A

The initial phase of the analysis gathered the necesseary data and considered *the water cut*, *the gas versus oil ratio (GOR)*, the *production*, and *the well head pressure* of the wells. When taking these criteria into account, five wells were considered as possible candidates:

1. A-8R2
2. A-16A
3. A-23
4. A-33
5. A-43

The initial analysis did not include the sand production rate, which is a crucial criteria for the selection. Knut Nilsen, also from Statoil, provided sand production rates for the three wells A-8R2, A-16A and A-23. All were within the acceptable limits. Since no data were available for the two last wells, these were not selected as candidates.

Therefore, the final selection consisted of these three wells:

1. A-8R2
2. A-16A
3. A-23

5.3 Comparison with data from 2005

The data from 2004 was also compared with data from the same period in 2005 to see if there were any major differences rendering one or more of the well unsuitable for DGRASS installation. The key data for 2005 are included in appendix B.

A summary of the differences from 2004 to 2005 is shown in tables 1, 2 and 3.

A-8R2	Alloc GOR	Alloc Net Oil Vol	Alloc Water	Alloc Gas	Avg Gas	Avg WHP	Avg BHP	WC
Units	Sm^3/Sm^3	Sm^3	m^3	Sm^3	$\frac{Sm^3}{d}$	bar	bar	%
2004	108.6	430.2	1861.6	47813.9	0.0	46.4	0.0	81.2
2005	110.6	449.4	1855.6	49692.8	0.0	46.7	0.0	80.5
Difference	2.0	19.2	6.0	1878.9	0.0	0.3	0.0	-0.7

Table 1: Summary of key data for well A-8R2

A-16A	Alloc GOR	Alloc Net Oil Vol	Alloc Water	Alloc Gas	Avg Gas	Avg WHP	Avg BHP	WC
Units	Sm^3/Sm^3	Sm^3	m^3	Sm^3	$\frac{Sm^3}{d}$	bar	bar	%
2004	601.4	540.5	2648.8	316537.8	0.0	65.7	0.0	83.1
2005	140.3	503.0	1585.6	70564.8	0.0	61.9	0.0	75.9
Difference	-461.1	-37.5	-1063.2	-245973.0	-3.8	-7.3		

Table 2: Summary of key data for well A-16A

A-23	Alloc GOR	Alloc Net Oil Vol	Alloc Water	Alloc Gas	Avg Gas	Avg WHP	Avg BHP	WC
Units	Sm^3/Sm^3	Sm^3	m^3	Sm^3	$\frac{Sm^3}{d}$	bar	bar	%
2004	108.6	426.7	2983.2	46361.8	0.0	46.2	0.0	87.5
2005	109.9	399.9	2369.5	43953.3	0.0	46.7	0.0	85.5
Difference	1.3	-26.7	-613.7	-2408.5	0.0	0.46	0.0	-1.9

Table 3: Summary of key data for well A-23

5.3.1 Analysis

As the summary table shows, there is only one major change in the data from 2005 compared to 2004. The well A-16A has had a reduction in its gas production. This reduction, however, only makes it more suitable for DGRASS and also more similar to the other two wells. We discussed the differences with Lars-Even Hauge, and he agreed with us. There are only improvements in the key data.

It should be noticed that data on the sand production in the wells has not been gathered for 2005. It is however likely that these data have not changed much.

5.4 Conclusion

The wells were chosen in 2004 mainly because of their high water cut and low sand production rate. The key data from the three selected wells was from January - March 2004. They have been compared with data from the same period in 2005, and the conclusion is that only improvements in the data can be observed.

We therefore choose the following three wells as candidates for DGRASS installation:

1. A-8R2
2. A-16A
3. A-23

6 DGRASS production analysis

6.1 Introduction

When implementing a new tool in a well it is of great importance to know how it affects the well in every possible way. You have to know at what depth the tool should be implemented, and how implementation at that specific depth would affect your production performance. Our goal was to give a production analysis for the selected Gullfaks A wells that would serve as the basis of an evaluation of the feasibility of installing DGRASS in those wells.

To do this, we designed a production analysis spreadsheet to ease the work related to these evaluations. The spreadsheet evaluates the placement of DGRASS at different depths with different pressures and flow rates at different fluid and tubing properties. Results are presented as pressure, flow and velocity data at certain depths as well as an estimated gained oil production from implementing DGRASS at that specific depth.

6.2 Functionality

The main goal of DGRASS is to enhance oil production by lowering the bottom hole flowing pressure P_{wf}. By reducing P_{wf}, the flow from the reservoir will increase due to the increased pressure difference between the reservoir and the well. To meet the system demands top side, this reduction is made possible by dividing the mixed flow into separate flows of oil and water from the DGRASS installation and up.

The spreadsheet allows you to determine pressure, fluid, well and tubing data as well as the desired DGRASS depth. All calculations are made under the assumption of one phase, non compressive flow. The pressure is calculated in three different tubes, and the flow in each tube is considered single phase. From the reservoir and up to the DGRASS installation the liquid is mixed. From the separator and up we consider two separate tubes; one contains oil and the other contains water.

The spreadsheet is designed around the built-in solver function in Microsoft Excel, changing the depths and other variables to estimate a depth where implementation of DGRASS yields the highest oil production. The user has to assume a P_{wf} where the calculations can start, and a maximum allowed calculated P_{wf} value.

There are two ways of running the evaluation. The user can evaluate a certain depth of the DGRASS installation, and then run the solver routine several times adjusting the depth manually each time. Alternatively the user can ask the spreadsheet to solve for a matrix of input depths, performed by pressing the “Range Solve” button. The maximum number of test series is 40. By pressing a radio button you can decide which separator pressure, oil or water, to keep unchanged. Please view appendix F for excerption of the main input and calculation area.

The results will be presented in separate sheets; one shows the pressure, another shows the oil flow and a third shows the flow velocity versus depth. Plots of the different results are generated automatically. When the user has completed his analysis of the results, they can be removed easily by pressing the “Clear” button.

6.3 Data flow diagram

The data flow diagram in figure 11 gives a simple overview of the spreadsheet functionality. The diagram shows the range solve process, and what data flows to and from it.

The processes and data stores in the data flow diagram are analogous to the various buttons and charts with the same names in the spreadsheet. The data flow diagram is meant to provide an understanding of how the spreadsheet works, and how to use the spreadsheet to perform a production analysis of DGRASS.

The “Range Solve” process is an automated way of calculating the pressure, oil flow and velocity for a given range of input data. “Range Solve” takes the range of input data from the data store “In data”, and calculates results from it, which it puts back in the appropriate stores.

The “Range Solve” process consists of the processes “Solve” and “Save”. “Solve” calculates results from the data in “In data” and writes it to the “Calculations” data store. The “Save” process puts the results from “Calculations” to appropriate stores in the spread sheet. The “Solve” and “Save” processes can also be invoked without the use of “Range solve”, to do a single calculation.

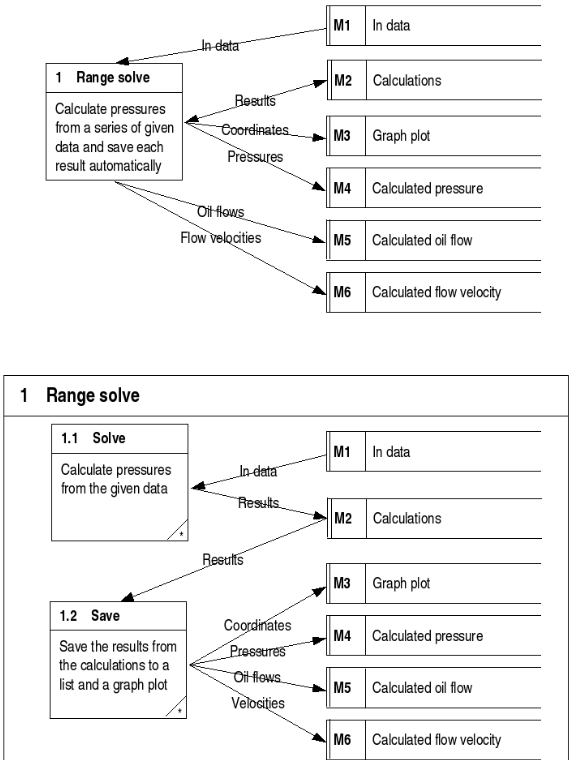

Figure 11: Production analysis data flow diagram

6.4 Equations

The spreadsheet is built around some basic equations. The assumption of one phase, non-compressive flow is applied through the whole spreadsheet using the equations in table 4.

The pressure at the DGRASS installation is calculated separately for each tube as shown in table 5. Herein, the different pressure losses are calculated with their respective material properties, true vertical depth (TVD), measured depth (MD) and percentage of water. The different depths are described in figure 12.

Name	Equation
Productivity index [5]	$Q = J * (P_r - P_{wf})$
Reynolds number [12]	$R_e = \frac{\rho D u}{\mu}$
Haalands equation [12]	$f_m = \frac{1}{(-1.8log(\frac{6.9}{R_e} + (\frac{e}{3.7D}})^{1.11})^2$
Pressure loss due to friction [5]	$\Delta P_f = \frac{1}{2} f_m * \rho * u^2 * \frac{h}{D}$
Pressure loss due to hydrostatical head [5]	$\Delta P_h = \rho g h$

Table 4: Production analysis equations

Tube	Equation
Tube A	$P_{dgrass} = P_{wf} - (\Delta P_f + \Delta P_h)$
Tube B	$P_{grass} = P_{soil} + (\Delta P_f + \Delta P_h)$
Tube C	$P_{grass} = P_{swater} + (\Delta P_f + \Delta P_h)$
Reference tube	$P_{wf} = P_{sep} + (\Delta P_f + \Delta P_h)$

Table 5: Equations for the different tubes

6.5 Analysis

Production analysis has been performed evaluating placement depth of DGRASS in three possible candidate wells at the Gullfaks field. Further analysis of gain versus placement depth due to influence from water cut and annulus diameter is also performed.

6.5.1 Implementation depth in Gullfaks wells

By applying real well data from Statoil as input, an analysis with regards to placement depth versus production results is performed. A selection of the best range of depth in which to implement DGRASS is chosen for each well. Please see chapter 7 for further information. The range of depth is then solved in the production analysis spreadsheet by application of the Range Solve option. The main production data for the three wells is presented in table 6. Additional data for all wells may be found in appendixes G, H and I. During all evaluations casing diameter, giving the equivalent annulus diameter, has been assumed equal throughout the whole well.

The analysis strongly indicates that implementation of DGRASS is highly profitable in the three candidate wells A-8R2, A-16A and A-23. Gained oil production may be viewed in figures 13, 14 and 15. A comparison of flow rates of oil and water, with and without implementation of DGRASS

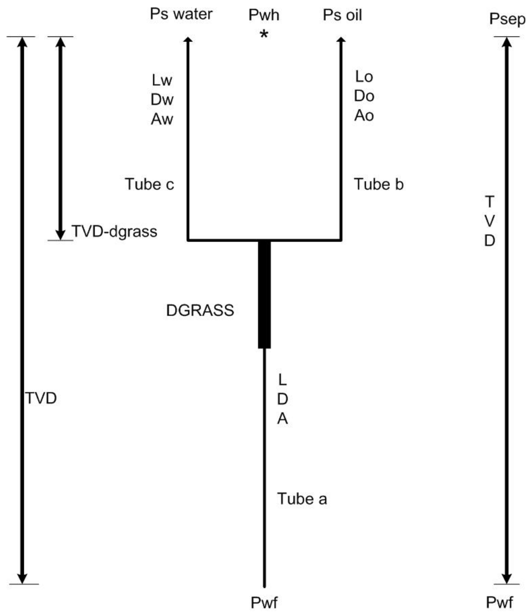

Figure 12: Production analysis model

Well	Productivity index	Reservoir pressure	Water cut
A-8R2	$0.00038\frac{m^3}{s*bar}$	$274.96 bar$	80.5%
A-16A	$0.00046\frac{m^3}{s*bar}$	$299.92 bar$	75.9%
A-23	$0.00417\frac{m^3}{s*bar}$	$299.92 bar$	85.5%

Table 6: Main production data for the Gullfaks A wells

is displayed in figure 16. The ratio between the oil and water production remains unchanged with and without DGRASS, but the increased production is significant. A shared tendency is that the gained oil production grows as the implementation depths go deeper. This is due to the fact that splitting the fluid flow at the deepest possible depth yields the largest pressure loss.

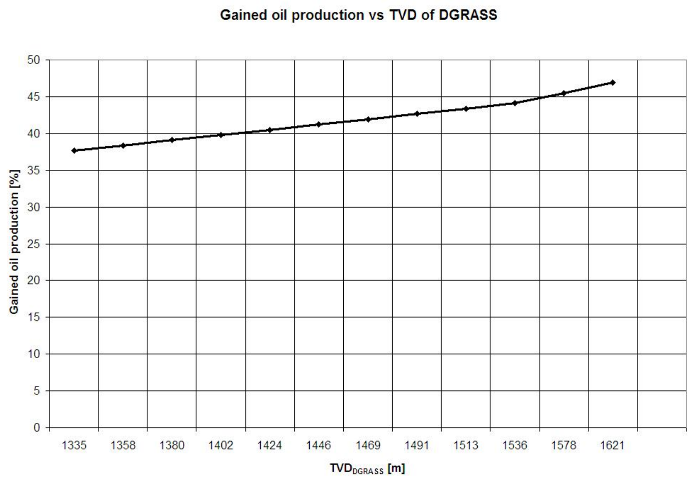

Figure 13: Gained oil production from implementation of DGRASS in well A-8R2

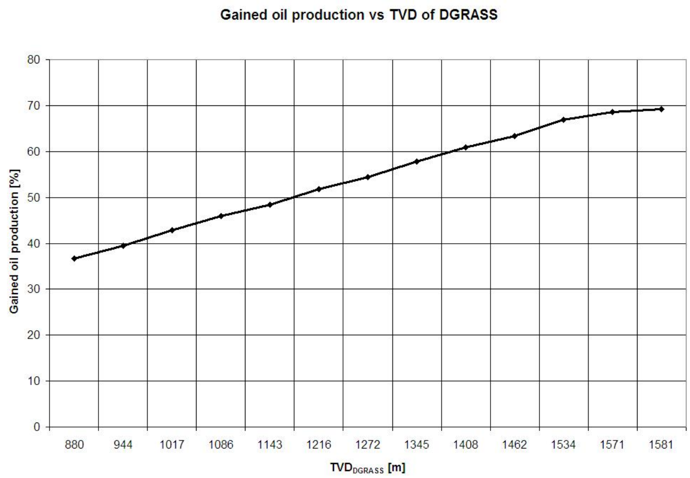

Figure 14: Gained oil production from implementation of DGRASS in well A-16A

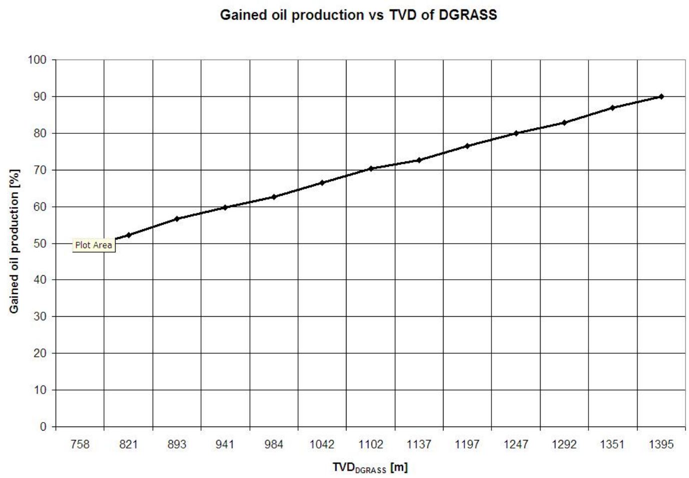

Figure 15: Gained oil production from implementation of DGRASS in well A-23

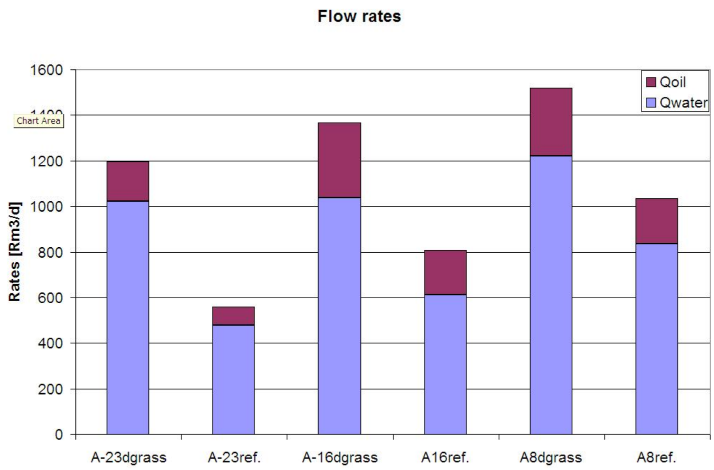

Figure 16: Flow rates of oil and water, with and without implementation of DGRASS

6.5.2 Annulus diameter impact on produced oil

To perform evaluation of annulus diameter impact on produced oil, the least profitable well A-8R2 is chosen. Fixing DGRASS to the most beneficial depth and then varying annulus diameter gives information about the annulus diameter dependency. Varying the diameter between 0.06 and 0.10 meters yields the results presented in figures 17, 18, and 19. Additional data from the annulus diameter impact analysis data can be found in appendix J.

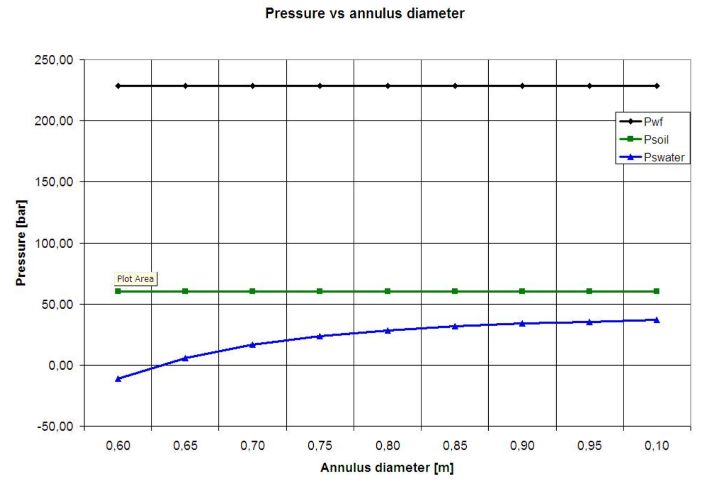

Figure 17: Pressures at different annulus diameters for well A-8R2

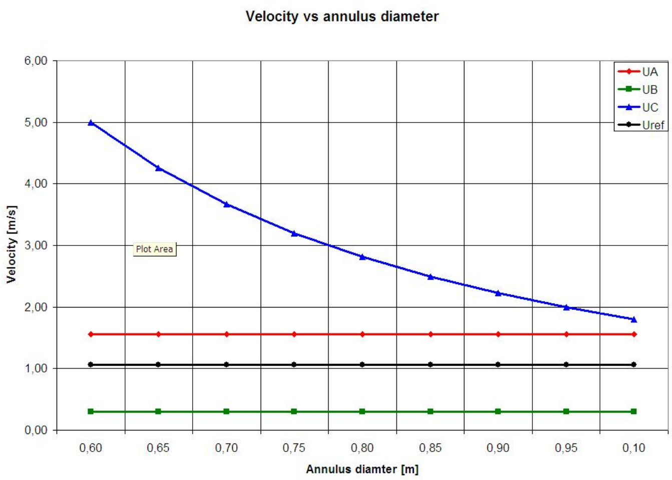

Figure 18: Flow velocities at different annulus diameters for well A-8R2

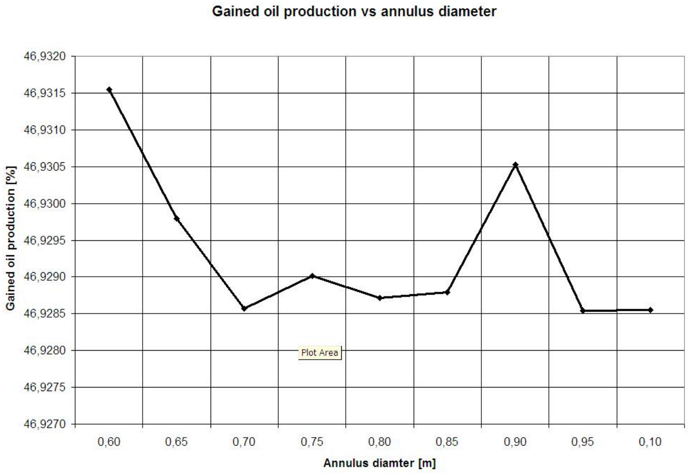

Figure 19: Gained oil production at different annulus diameters for well A-8R2

Annulus diameter has a large effect on water separator pressure. Smaller annulus diameter yields lower possible pressure of water separator. In fact, if the diameter is too small, vacuum is created. However, annulus diameter has no significant impact on gained oil production.

6.5.3 Water cut impact on produced oil

Water cut impact is evaluated by viewing the amount of produced oil at different water cuts for the least profitable well, A-8R2. DGRASS remains fixed to the most beneficial depth and then the water cut is changed from 0 to 100%. The gained oil production displayed in figure 20 is as expected highest at the highest water cut. Additional data from the annulus diameter impact analysis data can be found in appendix J.

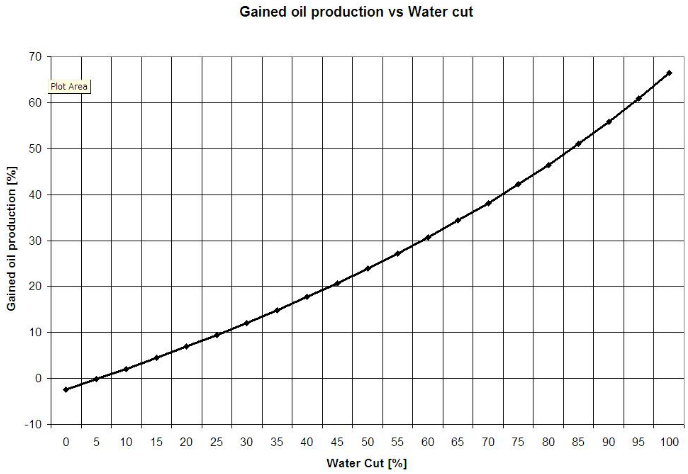

Figure 20: Gained oil production versus water cut in well A-8R2

6.6 Conclusion

The production analysis spreadsheet has proven to be a powerful tool in terms of production analysis of DGRASS implementation. Our evaluation shows that depth is the main factor influencing gained oil production with DGRASS. Water cut is also of importance. Annulus diameter has no significant effect on gained oil production, but is important regarding top side modifications necessary to implement the DGRASS. This is due to the annulus diameter being the most important variable related to water pressure drop in the annulus from DGRASS to top side.

7 Well completion with DGRASS

7.1 Introduction

For mature wells, additional new completion with DGRASS will be limited. The existing production tubing will be taken out and a production tubing with modifications for the DGRASS separator will be installed. The production flow will then be started. Since the technical data for the separator (technical drawing, part list, and dimensions) is confidential, we will not go into these details here. We will do the completion in more general terms, based on the already existing completion schematics.

7.2 DGRASS dimensioning and positioning

One of the benefits with DGRASS is that it gives higher capacity than present technologies for downhole oil/water separation, while still keeping the separation device simple and easy to install. The installation can be done during workover, which is usually planned one year ahead for each well. This is an advantage since the production then does not have to be stopped more than it would have been anyway. DGRASS cannot be installed in a horizontal or vertical part of the well; it has to have an inclination.

The separator can be installed somewhere between the production packer and the DownHole Safety Valve (DHSV)[3], but there is a lower authorized Measured Depth (MD) that is a bound on where the separator can be inserted. This is where the coupling $5in$ casing to the $7in$ casing is. The DGRASS separator can be as long as possible, as long as the conditions are right (see section 4). However, the tapping points in the separator do not have to be placed in the same pipe. There can be several parts with draining holes connected together. This is because the length of what can be inserted in the well in one time limit the lengths of the parts. The limiting length is about $45m$, which is the maximum length that they can lift in vertical position and then insert in the drilled hole [10]. Since the well trajectory inclination can change with $1° - 2°$ in the places where DGRASS is suitable, this makes it possible to adapt the separators to each well.

If it would turn out, after installation, that this separation method does not

[3]A downhole safety valve is a device that isolates wellbore pressure and fluids in the event of an emergency or catastrophic failure of surface equipment [14].

work as good as expected, the separator can be removed and the production can continue as before. Alternatively, the tapping points may be closed and the DGRASS separator may be used as ordinary production tubing.

In figure 21 you get a general view of where DGRASS will be put and how the oil and water are brought separately to the separators at the platform.

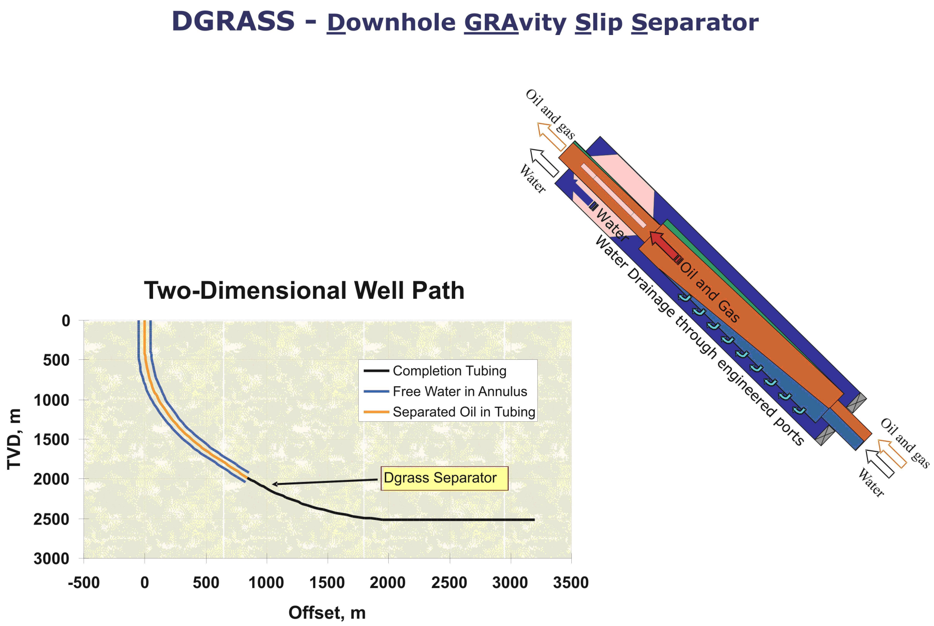

Figure 21: DGRASS sketch with well trajectory

Figure 22 show a schematic drawing of the main equipment that has to be in the well, but the proportions are not real.

There may also be need for modifications on the platform. With DGRASS the separated water and oil will go to separate low and high pressure separators at the platform deck, so there may be need for another separator.

7.3 Operating DGRASS

The drainage of DGRASS will be controlled by an operator on the platform. His goal will be to find the different drainage rates which suites the different flow regimes in the separator best. This is done by adjusting the back pressure (surface controlled). Since the flow rates for all the holes not will be the same, an appropriate back pressure, assuring maximum water drainage

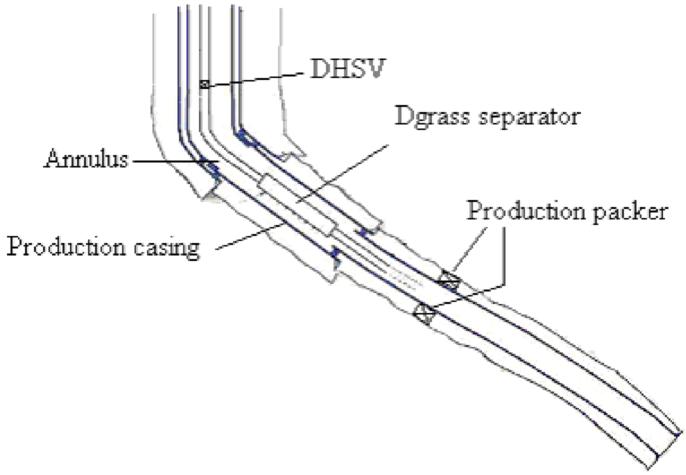

Figure 22: Main equipment in a well with DGRASS

from each tapping point, will have to be found. Taking into account that the layer of water will become smaller and smaller for each hole. The flow regimes will differ depending on the angle of inclination, water cut and flow rate inside the separator. Additional adjustments of the tapping points and optional shut-down of the DGRASS, if found useless, can be performed by valves at each tapping point. The valves will be controlled by actuators operated either by a hydraulic, electrical or combined system. This depends on how the existing completion and control systems in the candidate well are designed. Valve control is preferably performed by utilizing extra capacity in existing control systems.

7.4 Flow of oil and water

The efficiency of the separator depends on several factors. To get the best possible separation, the DGRASS has to be fitted to each single well. What should be taken into consideration is emulsion[4] in the flow and improved coalescence[5] before the DGRASS separation. The reason for this is that we want to drain out as few as possible of the droplets to achieve efficient separation, and emulsion works against this.

[4]Emulsion is a mixture of a fluid as undissolved droplets in another fluid, in this case oil in water.

[5]Coalescence constists of crashing droplets to make bigger droplets so they can be separated more easily.

There are several possible solutions to this problem. One possibility is to add emulsion breakers[6] to the oil/water, but these generally contain components of varying toxicity and collapsibility and have to be special made for each type of crude oil [3]. To reduce the need for emulsion breakers we can adjust the construction better, so the turbulence is reduced. The flow velocity, the well trajectory inclination and the “entrance” conditions affect turbulence. The inclination angle is set, but the flow velocity and DGRASS can be adapted to decrease turbulence.

It is also possible to insert an electric field to improve the coalescence (see section 3.2.1), but this will probably not be relevant in this case. At this moment it seems that adapting DGRASS and the flow velocity will give good enough results.

The flow velocity will also affect the efficiency. To get a high fraction of the water drained out the flow velocity has to be low.

What is wanted is a flow that gives a high fraction of the water drained out. A flow pattern map[7] for a flow with angle of 45° shows what kind of flow regime we will get with the different oil/water contents, at this angle [10].

Figure 23 shows the flow map for an inclination angle of 45°. Figure 24 gives an explaining picture for each of the different flows.

A definition of the angles is shown in figure 25. In the three well candidates the water cut is $75.9 - 85.5$ %. That would be in the blue area, which is the type of flow regime that we desire. When making the map for 30° and 60° the internal boundaries for the blue region will be changed, but for the red and green ones they will not. Thus, it is expected that inclinations at 30°, 45° and 60° will not change a lot at this flow pattern. This needs confirmation in a lab experiment. This is good for our candidates, which have an average inclination angle of about 35°, 47° and 53°.

7.5 Results

We have used the completion schematics in appendixes C, D, and E, data from Excel sheets and the Excel sheet made in the production analysis for the three wells to find out where it could be possible to insert a DGRASS

[6]Emulsion breakers are chemicals designed for separating oil-in-water and water-in-oil emulsions in industrial process and waste streams [1]

[7]A flow pattern map shows what flow regimes we will get in the tube for different amounts of water and oil for a given inclination angle

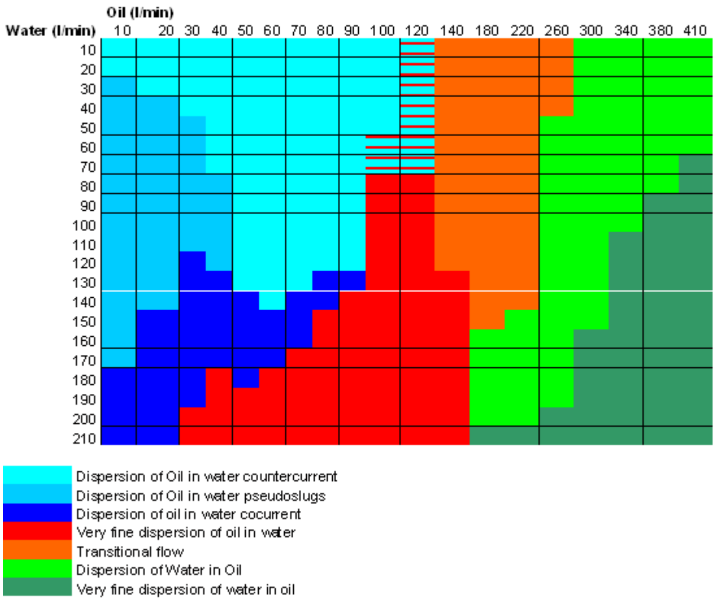

Figure 23: Flow map for a 45-degree inclination angle

separator and what outcome this will give [7]. We have also plotted the two-dimensional well trajectory, and marked with green dots, between which is the part of the well that is suited for the DGRASS separator. The upper limit, DSV, is called a Surface Controlled Sub surface Safety Valve (SCSSV) on the completion schematics named (see appendixes C, D, and E). This valve is placed so high up in the wells that the angle at this point, in well A-8R2, A-16A, and A-23, is respectively 0.4°, 11.1° and 15.1°.

These angles are too small for the DGRASS separators; we will have to move further down in the wells until the angles are at least 30°.

The numbers used here are taken from the calculations with $P_{soil} = 60bar$, since this gave the best results. At all the wells the best place to put the separator is at the bottom of the possible area.

7.5.1 Gullfaks A-8R2

This well is the shortest in MD (Measured Depth) and TVD (True Vertical Depth). The lower authorized MD is 1718.90m, and the TVD is 1621.03m.

At the relevant part of the well we have:

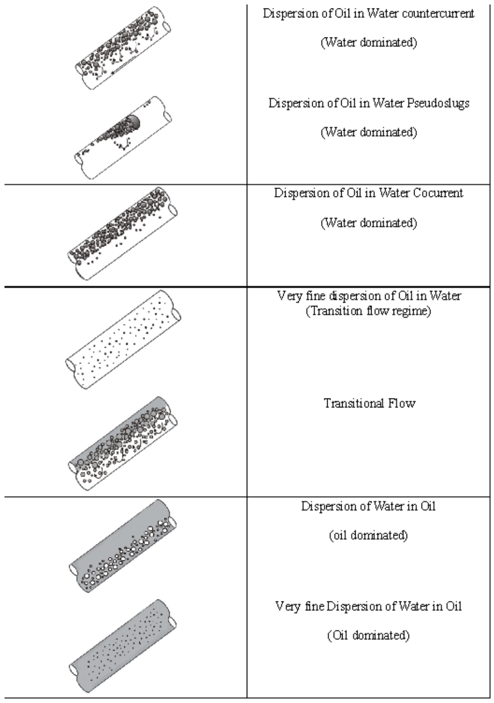

Figure 24: Explanation of the different flowregimes

- Inclination angle: $31.6° - 36.7°$, only a small part has $31° - 34°$ before mainly about $35° - 36°$
- TVD: From about $1335m$ to about $1621m$
- Length: About $1718m - 1367m = 351m$, but for the part where the inclination angle is most stable the length is $1718m - 1421m = 297m$

The well trajectory for well A-8R2 is shown in figure 26.

From the production analysis we found that placing the separator at a TVD of about $1620m$ and MD of about $1718m$ would give:

- P_{swater}: $28.25bar$
- Calculated outflow: $0.0034\frac{m^3}{s}$
- U_a (flow velocity into the separator): $1.553\frac{m}{s}$
- Gained oil production: about 47%
- Diameter, D: $0.12m$

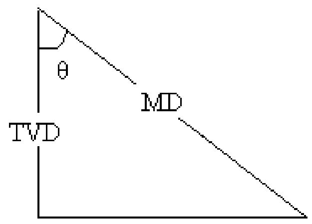

Figure 25: Definition of the angles used in the completion

7.5.2 Gullfaks A-16A

This well has the longest TVD. The lower authorized MD is $1925.03m$, and the TVD is $1582.14m$.

The relevant part to insert the separator in has the following values:

- Inclination angle: $36.1° - 47.5°$
- TVD: $880m - 1581m$
- Length: $1924m - 916m = 1008m$

There is also a part further up that has an inclination angle above 30°, but the angle varies very much here, so since the part where it is more stable is so long, it is not necessary to use that part.

The well trajectory for well A-16A is shown in figure 27.

From the production analysis we found that placing the separator at a TVD of $1581m$ and MD of $1924m$ would give:

- P_{swater}: $30.96bar$
- Calculated outflow: $0.0038\frac{m^3}{s}$

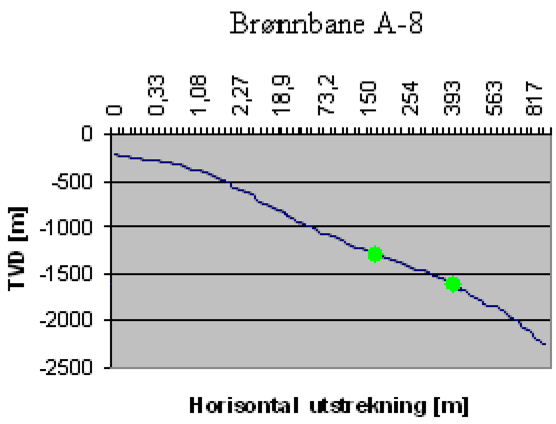

Figure 26: The well trajectory for Gullfaks A-8R2

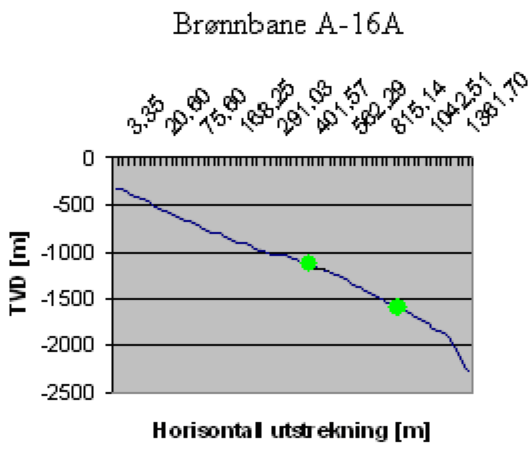

Figure 27: The well trajectory for Gullfaks A-16A

- U_a (flow velocity into the separator): $1.398\frac{m}{s}$
- Gained oil production: about 69%
- Diameter, D: $0.12m$

7.5.3 Gullfaks A-23

This well has the longest MD. The lower authorized MD is about $2508m$, and the TVD is $1731m$.

The relevant part to insert the separator in has the following values:

- Inclination angle: 51.3° - 59.8°
- TVD: From about $758m$ to about $1731m$
- Length: $2509m - 785m = 1724m$

The well trajectory for well A-23 is shown in figure 28.

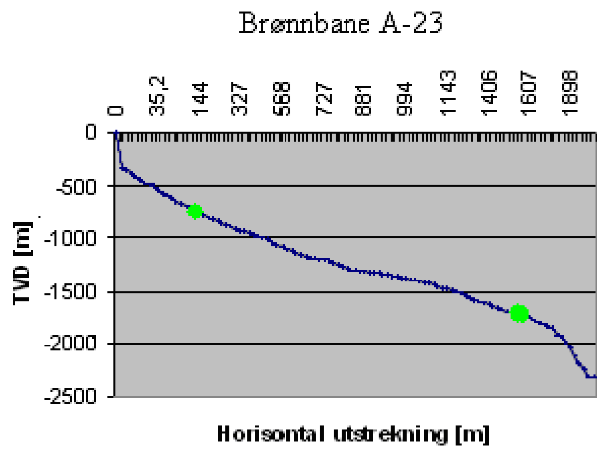

Figure 28: The well trajectory for Gullfaks A-23

From the production analysis we found that placing the separator at a TVD of $1731m$ and MD of $2509m$ would give:

- P_{swater}: $26.18bar$
- Calculated outflow: $0.0020\frac{m^3}{s}$
- U_a (flow velocity into the separator): $1.224\frac{m}{s}$
- Gained oil production: 114%
- Diameter, D: $0.12m$

As we see from these figures and data there is more then enough space to place the DGRASS separator, in relation to the inclination angle and the length of the well part. In the production analysis the length of the separator has not been taken into account. Thus, we will not consider how long the separator in each well should be, and what the results will be then. Still, it is desirable to have it long, to get as much as possible separated.

7.6 Conclusion

We get the best effect of the DGRASS separator when it is placed as close to the reservoir as possible. This matches the theory of having a separator pressure as close to the reservoir pressure as possible gives the best separation. The water and oil will blend more and more before separation the further away from the reservoir the DGRASS separator is.

From a completion point of view the DGRASS separator is a good alternative. It can be implemented in already existing wells during workover and if it turns out to be a failure it is possible to go back to the old separation method.

8 Final conclusion

Our production analysis performed on the three Gullfaks wells A-8R2, A-16A and A-23 concludes that implementation of the DGRASS system will give significant gained oil production figuring between 40% and 90% for these three wells. Installation of the DGRASS system in the deepest part of the evaluated well bore yields maximum oil recovery. Our analysis shows that depth is the main factor influencing gained oil production with DGRASS. Water cut is also of importance. Annulus diameter has no significant effect on gained oil production, but is however important regarding top side modifications necessary to implement the DGRASS system.

The DGRASS system is brilliant in its simplicity and may have a very promising future. The lifetime of old wells can be significantly prolonged by few installation efforts. Based on our results we highly recommend a field trial of this novel technology.

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List of Figures

List of Tables

A Well candidate data from 2004

Key data for well A-8R2 January – March 2004								
Date	Alloc GOR	Alloc Net C	Alloc Wate	Alloc Gas \	Avg Gas Li	Avg WHP	Avg BHP	WC
	[Sm³/Sm³]	[Sm³]	[m³]	[Sm³]	[Sm³/d]	[barg]	[barg]	[%]
11.03.04	104.5	466	2,073	48,717		44.6		82%
10.03.04	104.3	466	2,070	48,580		44.6		82%
09.03.04	103.7	467	2,076	48,422		44.6		82%
08.03.04	104.6	470	2,089	49,125		44.6		82%
07.03.04	106.2	459	2,040	48,746		44.7		82%
06.03.04	98.2	453	2,016	44,529		52.1		82%
05.03.04	105.2	464	2,061	48,778		44.5		82%
04.03.04	107.4	467	2,077	50,188		44.5		82%
03.03.04	110.7	467	2,074	51,669		44.5		82%
02.03.04	110.8	466	2,073	51,671		44.5		82%
01.03.04	110.7	466	2,073	51,594		44.5		82%
29.02.04	119.1	440	1,955	52,369		44.6		82%
28.02.04	117.8	442	1,965	52,067		44.6		82%
27.02.04	117.3	444	1,973	52,067		44.5		82%
26.02.04	116.5	447	1,986	52,055		44.5		82%
25.02.04	116.2	439	1,951	51,004		44.6		82%
24.02.04	115.2	443	1,969	51,017		49.8		82%
23.02.04	113.8	447	1,985	50,822		52.4		82%
22.02.04	111.7	326	1,394	36,424		51.4		81%
21.02.04	114.5	420	1,795	48,119		47.5		81%
20.02.04	113.9	420	1,795	47,851		47.7		81%
19.02.04	113.6	421	1,799	47,819		47.8		81%
18.02.04	113.7	421	1,798	47,838		47.8		81%
17.02.04	113.5	418	1,787	47,472		51.5		81%
16.02.04	114.5	420	1,795	48,110		45.6		81%
15.02.04	113.7	420	1,794	47,748		45.6		81%
14.02.04	116	421	1,798	48,801		45.6		81%
13.02.04	102.9	424	1,811	43,640		45.8		81%
12.02.04	114.3	423	1,806	48,307		46.5		81%
11.02.04	102.6	423	1,807	43,377		51.7		81%
10.02.04	114	421	1,800	47,845		45.7		81%
09.02.04	113	421	1,798	47,534		45.7		81%
08.02.04	114	420	1,793	47,903		45.7		81%
07.02.04	111	420	1,793	46,525		45.8		81%
06.02.04	111	421	1,799	46,654		45.8		81%
05.02.04	112	420	1,793	47,196		46		81%
04.02.04	112	419	1,790	47,129		46		81%
03.02.04	112	421	1,798	47,308		46.4		81%
02.02.04	107	421	1,800	45,186		58.1		81%
01.02.04	95	339	1,447	32,314		57.6		81%
31.01.04	107	429	1,832	45,848		44.8		81%
30.01.04	106	429	1,834	45,703		44.8		81%
29.01.04	105	436	1,862	45,675		44.8		81%
28.01.04	105	433	1,852	45,397		45		81%
27.01.04	102	427	1,824	43,709		45.1		81%
26.01.04	102	435	1,857	44,281		45.1		81%
25.01.04	97	424	1,810	41,243		51.3		81%
24.01.04	104	391	1,669	40,729		44.9		81%
23.01.04	105	423	1,807	44,320		44.9		81%
22.01.04	104	424	1,812	44,247		44.9		81%
21.01.04	104	425	1,816	44,268		44.9		81%
20.01.04	105	424	1,810	44,432		44.9		81%
19.01.04	104	424	1,812	44,112		44.9		81%

18.01.04	100	425	1,818	42,724		44.9		81%
17.01.04	105	429	1,833	44,924		45.1		81%
16.01.04	107	430	1,836	46,085		45.2		81%
15.01.04	107	432	1,845	46,167		45.2		81%
14.01.04	106	431	1,842	45,610		45.2		81%
13.01.04	104	426	1,821	44,105		45.2		81%
12.01.04	106	424	1,810	44,974		45.5		81%
Average	108.6	430.2	1 861.6	47 813.9		46.4		81.2 %

Key data for well A-16A January – March 2004								
Date	Alloc GOR	Alloc Net C	Alloc Wate	Alloc Gas V	Avg Gas Li	Avg WHP	Avg BHP	WC
	[Sm³/Sm³]	[Sm³]	[m³]	[Sm³]	[Sm³/d]	[barg]	[barg]	[%]
11.03.04	370	719	2,787	266,126		63.3		79%
10.03.04	369.3	719	2,785	265,511		63.4	65.82	79%
09.03.04	367.2	721	2,794	264,846		63.4		79%
08.03.04	370.2	730	2,826	270,059		63.7		79%
07.03.04	376.2	714	2,765	268,428		63.9		79%
06.03.04	347.7	633	2,451	219,985		66		79%
05.03.04	372.5	721	2,794	268,658		63.9		79%
04.03.04	380.3	727	2,819	276,676		64		79%
03.03.04	392.1	726	2,813	284,682		64		79%
02.03.04	392.2	658	2,549	258,065		65.2		79%
01.03.04	391.8	726	2,814	284,571		64		79%
29.02.04	421.6	685	2,656	288,987		64		79%
28.02.04	417	691	2,676	287,956		64.1		79%
27.02.04	415.3	693	2,683	287,607		64		79%
26.02.04	412.5	705	2,732	290,863		64.8		79%
25.02.04	424	467	2,628	198,181		64.6		85%
24.02.04	432.4	471	2,651	203,868		64.5		85%
23.02.04	439.4	478	2,689	210,117		64.9		85%
22.02.04	443	475	2,669	210,266		64.9		85%
21.02.04	466.6	474	2,666	221,168		65		85%
20.02.04	476.2	474	2,663	225,499		64.9		85%
19.02.04	487	476	2,674	231,602		65.1		85%
18.02.04	499.4	475	2,669	237,055		65		85%
17.02.04	510.7	476	2,676	243,049		65.1		85%
16.02.04	527.4	477	2,680	251,406		65.3		85%
15.02.04	536	476	2,674	254,927		65.2		85%
14.02.04	558.9	478	2,686	267,019		65.4		85%
13.02.04	507.2	483	2,716	244,969		65.6		85%
12.02.04	575.3	481	2,707	276,990		66		85%
11.02.04	527.2	94	531	49,808		76.8		85%
10.02.04	596	457	2,567	272,009		67.2		85%
09.02.04	605	480	2,702	290,527		65.7		85%
08.02.04	623	478	2,690	298,095		65.6		85%
07.02.04	617	481	2,702	296,408		65.9		85%
06.02.04	629	481	2,706	302,498		65.8		85%
05.02.04	650	481	2,705	312,663		66		85%
04.02.04	662	481	2,703	318,124		66		85%
03.02.04	674	484	2,720	325,858		66.2		85%
02.02.04	654	488	2,744	319,202		66.7		85%
01.02.04	592	357	2,010	211,577		69.6		85%
31.01.04	855	492	2,766	420,569		66.1		85%
30.01.04	852	493	2,772	419,893		66.2		85%
29.01.04	838	501	2,817	419,919		66.3		85%
28.01.04	838	497	2,796	416,661		66.2		85%
27.01.04	819	528	2,969	432,284		71.3		85%
26.01.04	815	511	2,872	416,062		67.7		85%
25.01.04	779	449	2,526	349,889		68.2		85%
24.01.04	834	485	2,726	404,275		66.3		85%
23.01.04	838	484	2,719	405,236		65.8		85%
22.01.04	834	484	2,723	404,071		65.8		85%
21.01.04	833	485	2,729	404,327		65.8		85%
20.01.04	839	483	2,718	405,487		65.7		85%
19.01.04	832	482	2,712	401,253		65.5		85%

18.01.04	803	487	2,741	391,567		66		85%
17.01.04	837	487	2,737	407,636		65.3		85%
16.01.04	858	488	2,743	418,277		65.4		85%
15.01.04	855	495	2,785	423,403		66		85%
14.01.04	828	710	2,327	587,893		65.3		77%
13.01.04	792	699	2,292	553,982		65.1		77%
12.01.04	794	697	2,286	553,680		65.3		77%
Average	601.4	540.5	2 648.8	316 537.8		65.7		83.1 %

Key data for well A-23 January – March 2004								
Date	Alloc GOR	Alloc Net C	Alloc Wate	Alloc Gas \	Avg Gas Li	Avg WHP	Avg BHP	WC
	[Sm³/Sm³]	[Sm³]	[m³]	[Sm³]	[Sm³/d]	[barg]	[barg]	[%]
11.03.04	103.8	439	3,006	45,612		44.5		87%
10.03.04	103.7	439	3,003	45,484		44.6		87%
09.03.04	103.1	440	3,010	45,336		44.6		87%
08.03.04	103.9	443	3,030	45,994		44.6		87%
07.03.04	105.6	432	2,958	45,639		44.6		87%
06.03.04	97.6	424	2,903	41,394		51.5		87%
05.03.04	104.5	437	2,990	45,669		44.5		87%
04.03.04	106.7	440	3,013	46,989		44.5		87%
03.03.04	110	440	3,008	48,376		44.5		87%
02.03.04	110.1	439	3,008	48,378		44.5		87%
01.03.04	110	439	3,007	48,306		44.5		87%
29.02.04	118.3	414	2,836	49,032		44.6		87%
28.02.04	117	417	2,851	48,749		44.5		87%
27.02.04	116.6	418	2,862	48,749		44.5		87%
26.02.04	115.8	421	2,881	48,737		44.5		87%
25.02.04	115.5	413	2,829	47,753		44.5		87%
24.02.04	114.5	417	2,856	47,766		45.9		87%
23.02.04	113.1	421	2,879	47,583		56		87%
22.02.04	111	375	2,644	41,600		52.8		88%
21.02.04	113.9	426	3,002	48,454		47.5		88%
20.02.04	113.3	425	3,002	48,198		47.4		88%
19.02.04	113	426	3,008	48,179		47.4		88%
18.02.04	113.1	426	3,007	48,211		47.4		88%
17.02.04	113	424	2,989	47,856		50.9		88%
16.02.04	114	426	3,003	48,513		45.5		88%
15.02.04	113.3	425	3,000	48,161		45.5		88%
14.02.04	115.5	426	3,007	49,237		45.5		88%
13.02.04	102.6	429	3,029	44,042		45.6		88%
12.02.04	113.9	428	3,020	48,766		46.3		88%
11.02.04	102.3	428	3,022	43,801		51.6		88%
10.02.04	113	427	3,011	48,326		45.6		88%
09.02.04	113	426	3,006	48,025		45.5		88%
08.02.04	114	425	2,999	48,412		45.5		88%
07.02.04	111	425	2,999	47,032		45.5		88%
06.02.04	111	426	3,008	47,175		45.6		88%
05.02.04	112	425	2,998	47,737		45.6		88%
04.02.04	112	424	2,994	47,682		45.6		88%
03.02.04	112	426	3,006	47,876		46		88%
02.02.04	107	427	3,010	45,741		57.9		88%
01.02.04	95	343	2,420	32,720		57		88%
31.01.04	108	434	3,064	46,976		44.3		88%
30.01.04	108	435	3,067	46,827		44.4		88%
29.01.04	106	441	3,114	46,798		44.5		88%
28.01.04	106	439	3,097	46,514		44.5		88%
27.01.04	104	432	3,051	44,785		44.5		88%
26.01.04	103	440	3,106	45,370		44.5		88%
25.01.04	99	429	3,026	42,258		51.1		88%
24.01.04	105	396	2,792	41,731		44.5		88%
23.01.04	106	428	3,022	45,411		44.5		88%
22.01.04	106	430	3,031	45,336		44.5		88%
21.01.04	105	430	3,037	45,357		44.5		88%
20.01.04	106	429	3,027	45,525		44.5		88%
19.01.04	105	429	3,030	45,197		44.5		88%

18.01.04	102	431	3,040	43,776		44.6		88%
17.01.04	106	435	3,066	46,029		44.6		88%
16.01.04	108	435	3,071	47,219		44.6		88%
15.01.04	108	437	3,086	47,303		44.6		88%
14.01.04	107	437	3,080	46,732		44.6		88%
13.01.04	105	432	3,045	45,190		44.6		88%
12.01.04	107	429	3,028	46,081		44.7		88%
Average	108.6	426.7	2 983.2	46 361.8		46.2		87.5 %

B Well candidate data from 2005

Key data for well A-8R2 January – March 2005								
Date	Alloc GOR	Alloc Net O	Alloc Wate	Alloc Gas V	Avg Gas Li	Avg WHP	Avg BHP	WC
	[Sm³/Sm³]	[Sm³]	[m³]	[Sm³]	[Sm³/d]	[barg]	[barg]	[%]
03/10/2005	105.0	476	1 950	50,009		45.1		80.4 %
03/09/2005	104.2	478	1 959	49,843		45.1		80.4 %
03/08/2005	103.9	483	1 976	50,149		45.1		80.4 %
03/07/2005	105.1	483	1 976	50,705		45.1		80.4 %
03/06/2005	107.0	479	1 959	51,207		45.1		80.4 %
03/05/2005	106.7	479	1 961	51,083		45.1		80.4 %
03/04/2005	109.0	478	1 958	52,104		45.1		80.4 %
03/03/2005	107.4	478	1 955	51,310		45.1		80.4 %
03/02/2005	103.9	479	1 962	49,784		45.1		80.4 %
03/01/2005	106.0	480	1 965	50,864		45.2		80.4 %
02/28/2005	113.2	444	1 817	50,230		50.1		80.4 %
02/27/2005	110.9	450	1 842	49,901		44.9		80.4 %
02/26/2005	109.3	448	1 835	49,003		44.9		80.4 %
02/25/2005	110.8	452	1 852	50,124		44.9		80.4 %
02/24/2005	110.1	456	1 866	50,192		45.0		80.4 %
02/23/2005	107.5	451	1 848	48,524		44.9		80.4 %
02/22/2005	112.1	451	1 847	50,584		44.9		80.4 %
02/21/2005	110.5	450	1 841	49,685		45.1		80.4 %
02/20/2005	111.5	450	1 842	50,169		45.2		80.4 %
02/19/2005	110.3	451	1 846	49,736		45.2		80.4 %
02/18/2005	98.9	334	1 366	33,016		51.5		80.4 %
02/17/2005	113.9	449	1 837	51,117		44.9		80.4 %
02/16/2005	113.2	452	1 852	51,222		44.9		80.4 %
02/15/2005	113.1	454	1 860	51,377		45.1		80.4 %
02/14/2005	113.8	452	1 851	51,450		45.2		80.4 %
02/13/2005	114.2	450	1 844	51,448		49.3		80.4 %
02/12/2005	115.9	392	1 606	45,467		45.2		80.4 %
02/11/2005	116.4	448	1 834	52,153		45.2		80.4 %
02/10/2005	116.2	441	1 807	51,294		50.3		80.4 %
02/09/2005	117.0	448	1 833	52,404		46.9		80.4 %
02/08/2005	110	446	1 825	48,862		49.7		80.4 %
02/07/2005	117	446	1 826	52,368		61.2		80.4 %
02/06/2005	119	438	1 795	51,975		51.1		80.4 %
02/05/2005	119	436	1 785	52,077		45.1		80.4 %
02/04/2005	118	441	1 807	52,296		45.1		80.4 %
02/03/2005	118	445	1 822	52,305		45.1		80.4 %
02/02/2005	116	451	1 847	52,369		45.1		80.4 %
02/01/2005	117	449	1 837	52,300		45.1		80.4 %
01/31/2005	112	462	1 890	51,891		45.1		80.4 %
01/30/2005	113	462	1 892	52,199		49.6		80.4 %
01/29/2005	112	465	1 905	52,062		45.1		80.4 %
01/28/2005	112	461	1 887	51,823		45.2		80.4 %
01/27/2005	113	457	1 870	51,425		56.7		80.4 %
01/26/2005	111	460	1 882	50,876		47.4		80.4 %
01/25/2005	110	460	1 885	50,621		45.1		80.4 %
01/24/2005	109	459	1 878	49,923		45.2		80.4 %
01/23/2005	109	462	1 891	50,132		45.4		80.4 %
01/22/2005	107	462	1 891	49,404		45.4		80.4 %
01/21/2005	106	458	1 874	48,641		45.4		80.4 %
01/20/2005	108	453	1 856	49,173		45.4		80.4 %
01/19/2005	106	456	1 866	48,474		46.2		80.4 %
01/18/2005	107	458	1 874	48,826		55.0		80.4 %
01/17/2005	108	451	1 848	48,801		53.8		80.4 %
01/16/2005	109	417	1 842	45,560		46.2		81.5 %
01/15/2005	106	416	1 838	44,260		46.4		81.5 %
01/14/2005	107	416	1 839	44,327		46.5		81.5 %
01/13/2005	109	418	1 847	45,392		46.5		81.5 %

01/12/2005	111	416	1 840	46,023		46.5		81.5 %
01/11/2005	111	414	1 828	45,822		46.5		81.5 %
01/10/2005	109	413	1 826	45,211		46.5		81.5 %
Average	110.6	449.4	1 855.6	49 692.8		46.7		80.5 %

Key data for well A-16A January – March 2005								
Date	Alloc GOR	Alloc Net O	Alloc Wate	Alloc Gas V	Avg Gas Li	Avg WHP	Avg BHP	WC
	[Sm³/Sm³]	[Sm³]	[m³]	[Sm³]	[Sm³/d]	[barg]	[barg]	[%]
03/10/2005	132.5	519	1 599	68,722		61.5		75.5 %
03/09/2005	131.5	520	1 604	68,423		61.5		75.5 %
03/08/2005	131.1	525	1 619	68,852		61.5		75.5 %
03/07/2005	132.6	525	1 618	69,594		61.5		75.5 %
03/06/2005	135.1	521	1 605	70,340		61.5		75.5 %
03/05/2005	134.6	519	1 599	69,857		61.2		75.5 %
03/04/2005	137.5	517	1 592	71,048		61.1		75.5 %
03/03/2005	135.6	518	1 597	70,259		61.3		75.5 %
03/02/2005	131.1	521	1 604	68,246		61.4		75.5 %
03/01/2005	133.8	521	1 606	69,688		61.3		75.5 %
02/28/2005	142.8	487	1 500	69,494		61.5		75.5 %
02/27/2005	140.0	489	1 507	68,440		61.4		75.5 %
02/26/2005	138.0	486	1 499	67,090		61.3		75.5 %
02/25/2005	139.9	492	1 515	68,767		61.4		75.5 %
02/24/2005	139.0	495	1 526	68,817		61.4		75.5 %
02/23/2005	135.7	491	1 515	66,659		61.5		75.5 %
02/22/2005	141.5	491	1 513	69,493		61.5		75.5 %
02/21/2005	139.5	490	1 511	68,381		61.6		75.5 %
02/20/2005	140.7	490	1 510	68,939		61.5		75.5 %
02/19/2005	139.2	491	1 513	68,346		61.5		75.5 %
02/18/2005	124.9	287	883	35,786		62.1		75.5 %
02/17/2005	143.8	485	1 496	69,797		61.5		75.5 %
02/16/2005	142.9	489	1 508	69,925		61.5		75.5 %
02/15/2005	142.7	491	1 515	70,135		61.5		75.5 %
02/14/2005	143.6	489	1 507	70,245		61.5		75.5 %
02/13/2005	144.2	454	1 398	65,397		61.7		75.5 %
02/12/2005	146.3	424	1 308	62,107		61.6		75.5 %
02/11/2005	147.0	485	1 494	71,246		61.5		75.5 %
02/10/2005	146.7	484	1 493	71,045		61.5		75.5 %
02/09/2005	147.7	444	1 369	65,621		61.8		75.5 %
02/08/2005	138	485	1 496	67,183		61.6		75.5 %
02/07/2005	148	490	1 509	72,553		62.0		75.5 %
02/06/2005	150	484	1 491	72,396		62.4		75.5 %
02/05/2005	151	480	1 480	72,390		62.2		75.5 %
02/04/2005	150	487	1 500	72,780		62.3		75.5 %
02/03/2005	148	491	1 513	72,804		62.3		75.5 %
02/02/2005	147	497	1 532	72,839		62.3		75.5 %
02/01/2005	147	454	1 398	66,719		62.5		75.5 %
01/31/2005	142	506	1 560	71,787		62.3		75.5 %
01/30/2005	143	507	1 562	72,282		62.4		75.5 %
01/29/2005	141	510	1 573	72,078		62.4		75.5 %
01/28/2005	142	506	1 559	71,776		62.4		75.5 %
01/27/2005	142	503	1 551	71,529		62.7		75.5 %
01/26/2005	140	506	1 558	70,609		62.5		75.5 %
01/25/2005	139	505	1 558	70,131		62.4		75.5 %
01/24/2005	137	506	1 561	69,550		62.8		75.5 %
01/23/2005	137	507	1 562	69,428		62.4		75.5 %
01/22/2005	135	567	1 915	76,760		62.3		77.2 %
01/21/2005	135	559	1 889	75,527		62.0		77.2 %
01/20/2005	138	547	1 848	75,697		61.3		77.2 %
01/19/2005	136	559	1 888	76,081		62.2		77.2 %
01/18/2005	137	472	1 595	64,696		62.1		77.2 %
01/17/2005	139	561	1 895	78,177		62.2		77.2 %

01/16/2005	141	559	1 889	79,024		62.4		77.2 %
01/15/2005	138	554	1 874	76,567		63.0		77.2 %
01/14/2005	139	499	1 687	69,216		63.0		77.2 %
01/13/2005	142	562	1 898	79,615		62.5		77.2 %
01/12/2005	145	557	1 883	80,672		62.3		77.2 %
01/11/2005	146	559	1 889	81,332		62.9		77.2 %
01/10/2005	144	562	1 898	80,931		63.2		77.2 %
Average	140.3	503.0	1 585.6	70 564.8		61.9		75.9 %

Key data for well A-23 January – March 2005								
Date	Alloc GOR	Alloc Net O	Alloc Wate	Alloc Gas V	Avg Gas Li	Avg WHP	Avg BHP	WC
	[Sm³/Sm³]	[Sm³]	[m³]	[Sm³]	[Sm³/d]	[barg]	[barg]	[%]
03/10/2005	104.3	417	2 434	43,512		45.2		85.4 %
03/09/2005	103.5	419	2 444	43,368		45.2		85.4 %
03/08/2005	103.2	423	2 467	43,634		45.1		85.4 %
03/07/2005	104.4	423	2 466	44,118		45.2		85.4 %
03/06/2005	106.3	419	2 445	44,554		45.1		85.4 %
03/05/2005	106.0	419	2 447	44,447		45.1		85.4 %
03/04/2005	108.3	419	2 443	45,335		45.1		85.4 %
03/03/2005	106.8	418	2 440	44,644		45.1		85.4 %
03/02/2005	103.2	420	2 449	43,316		45.1		85.4 %
03/01/2005	105.3	420	2 452	44,256		45.2		85.4 %
02/28/2005	112.4	391	2 284	44,010		48.7		85.4 %
02/27/2005	110.2	394	2 299	43,418		45.0		85.4 %
02/26/2005	108.6	393	2 291	42,636		45.0		85.4 %
02/25/2005	110.1	396	2 311	43,612		45.0		85.4 %
02/24/2005	109.4	399	2 328	43,672		45.0		85.4 %
02/23/2005	106.8	395	2 307	42,220		45.1		85.4 %
02/22/2005	111.4	395	2 305	44,012		45.1		85.4 %
02/21/2005	109.8	394	2 297	43,230		45.0		85.4 %
02/20/2005	110.8	394	2 299	43,652		45.0		85.4 %
02/19/2005	109.6	395	2 304	43,274		45.0		85.4 %
02/18/2005	98.3	309	1 801	30,337		51.8		85.4 %
02/17/2005	113.2	393	2 292	44,476		45.0		85.4 %
02/16/2005	112.5	396	2 312	44,567		45.1		85.4 %
02/15/2005	112.4	398	2 321	44,703		45.1		85.4 %
02/14/2005	113.1	396	2 310	44,766		45.1		85.4 %
02/13/2005	113.5	394	2 301	44,764		48.9		85.4 %
02/12/2005	115.2	391	2 281	45,032		47.2		85.4 %
02/11/2005	115.7	392	2 288	45,377		45.0		85.4 %
02/10/2005	115.5	385	2 247	44,473		49.8		85.4 %
02/09/2005	116.3	392	2 288	45,596		46.8		85.4 %
02/08/2005	109	390	2 277	42,514		49.8		85.4 %
02/07/2005	117	391	2 279	45,565		61.4		85.4 %
02/06/2005	118	384	2 240	45,222		51.1		85.4 %
02/05/2005	119	382	2 228	45,312		45.1		85.4 %
02/04/2005	118	387	2 255	45,502		45.0		85.4 %
02/03/2005	117	390	2 274	45,509		45.0		85.4 %
02/02/2005	115	395	2 304	45,566		45.0		85.4 %
02/01/2005	116	393	2 293	45,505		45.0		85.4 %
01/31/2005	112	404	2 359	45,149		45.0		85.4 %
01/30/2005	112	405	2 361	45,417		49.5		85.4 %
01/29/2005	111	407	2 377	45,298		45.1		85.4 %
01/28/2005	112	404	2 355	45,090		45.1		85.4 %
01/27/2005	112	400	2 334	44,744		56.7		85.4 %
01/26/2005	110	403	2 349	44,267		47.4		85.4 %
01/25/2005	109	403	2 353	44,045		45.2		85.4 %
01/24/2005	108	402	2 344	43,437		45.2		85.4 %
01/23/2005	108	404	2 360	43,619		45.2		85.4 %
01/22/2005	106	405	2 360	42,986		45.2		85.4 %
01/21/2005	106	401	2 339	42,321		45.2		85.4 %
01/20/2005	108	397	2 316	42,784		45.2		85.4 %
01/19/2005	106	399	2 329	42,177		46.1		85.4 %
01/18/2005	106	390	2 274	41,303		52.8		85.4 %
01/17/2005	108	407	2 646	43,808		54.7		86.7 %

01/16/2005	109	411	2 667	44,665		46.0		86.7 %
01/15/2005	106	410	2 660	43,422		46.1		86.7 %
01/14/2005	106	410	2 662	43,519		46.2		86.7 %
01/13/2005	108	412	2 674	44,597		46.3		86.7 %
01/12/2005	110	410	2 663	45,249		46.3		86.7 %
01/11/2005	111	407	2 646	45,084		46.3		86.7 %
01/10/2005	109	407	2 644	44,515		46.3		86.7 %
Average	109.9	399.9	2 369.5	43 953.3		46.7		85.5 %

C Well completion schematic for Gullfaks A-8R2

Gullfaks

Well: NO 34/10-A-8 (Oil Producer)

Compl.: 1.00 **Tub.Inst.Date:** 14.08.1990

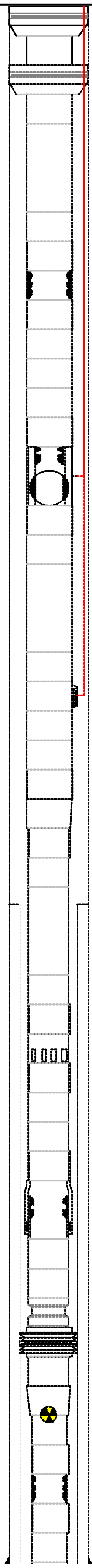
Existing; Completion Schematic

STATOIL

Prep. by: GK/TEB **Date:** 21.09.2000

Rev.: 1.00 **Opr.Fin.Date:** 14.08.1990

Remark: Brønnen er gruspakket og rekomplettert aug. -90.



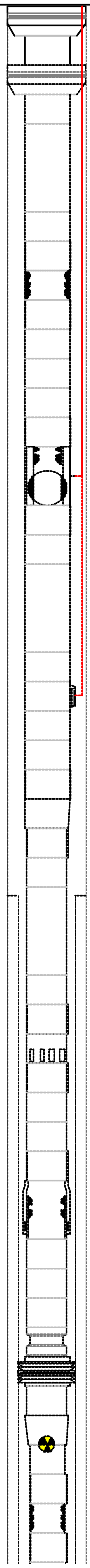
Ass	Symbol Extra Info	MD [RKB] Top [m]	TVD [RKB] [m]	Length [m]	ID [inch]	Description	Angle [Deg]	Comment
		34.35	34.35	0.75	4.778	5 1/2" 20# Tubing Hanger		
Ass 10 2.99		35.10	35.10	2.54	4.778	5 1/2" 20# BDS Pup Joint		
		37.64	37.64	0.45	4.778	5 1/2" 20# Tubing Hanger		
		38.09	38.09	1.39	4.778	5 1/2" 20# BDS Pup Joint		
		39.48	39.48	493.49	4.892	5 1/2" 17# BDS Tubing		
Ass 8 8.23		532.97	532.96	1.91	4.778	5 1/2" 20# BDS Pup Joint	0.3	
		534.88	534.87	1.78	4.778	5 1/2" 20# Flow Coupling	0.3	
		536.66	536.65	0.93	4.562	5 1/2" RH-4-D Communication Nipple	0.3	
		537.59	537.58	1.78	4.778	5 1/2" 20# Flow Coupling	0.3	
		539.37	539.36	1.83	4.778	5 1/2" 20# BDS Pup Joint	0.3	
		541.20	541.19	11.22	4.892	5 1/2" 17# BDS Tubing	0.3	
Ass 7 9.48		552.42	552.41	1.88	4.778	5 1/2" 20# BDS Pup Joint	0.4	
		554.30	554.29	1.78	4.778	5 1/2" 20# Flow Coupling	0.4	
	Control Line: Default	556.08	556.07	2.72	4.437	5 1/2" TRDP-5-RO SCSSV	0.4	
		558.80	558.79	1.79	4.778	5 1/2" 20# Flow Coupling	0.4	
		560.59	560.58	1.31	4.778	5 1/2" 20# BDS Pup Joint	0.4	
		561.90	561.89	1146.52	4.892	5 1/2" 17# BDS Tubing	0.4	
Ass 6 4.28		1708.42	1612.62	2.03	4.778	5 1/2" 20# BDS Pup Joint	36.6	
	Control Line: Default	1710.45	1614.25	0.65	4.778	5 1/2" Gauge Mandrel	36.7	
Ass 5 6.20		1711.10	1614.77	1.60	4.778	5 1/2" 20# BDS Pup Joint	36.7	
		1712.70	1616.05	1.84	4.778	5 1/2" 20# BDS Pup Joint	36.7	
		1714.54	1617.53	1.73	4.778	5 1/2" 20# Flow Coupling	36.7	
		1716.27	1618.92	0.26	4.276	5 1/2" x 5" BDS, X-over	36.7	
		1716.53	1619.12	1.17	4.276	5" 18# Flow Coupling	36.7	
		1717.70	1620.06	1.20	4.276	5" 18# NSCT Pup Joint	36.7	
		1718.90	1621.03	141.42	4.410	5" 15# BDS Tubing	36.7	
Ass 4 6.75		1860.32	1735.18	1.85	4.276	5" 18# NSCT Pup Joint	35.5	
		1862.17	1736.69	1.18	4.276	5" 18# Flow Coupling	35.5	
		1863.35	1737.65	1.38	4.125	5" DB-1-E Sliding Sleeve	35.5	
		1864.73	1738.77	1.17	4.276	5" 18# Flow Coupling	35.5	
		1865.90	1739.72	1.17	4.276	5" 18# NSCT Pup Joint	35.5	
Ass 3 10.42		1867.07	1740.68	1.77	4.276	5" 18# NSCT Pup Joint	35.5	
		1868.84	1742.12	1.18	4.276	5" 18# Flow Coupling	35.5	
		1870.02	1743.08	6.46	4.000	5" X 20 FT OP Exp. Joint W/4.000 DB-6 Profil	35.5	
		1876.48	1748.33	1.01	4.276	5" 18# NSCT Pup Joint	35.6	
Ass 2 12.16		1877.49	1749.15	1.87	4.276	5" 18# NSCT Pup Joint	35.6	
		1879.36	1750.67	0.21	3.875	5" RHR Stinger	35.6	
		1879.57	1750.84	1.57	3.875	7 " x 3 7/8" HSP-1 Packer	35.6	
		1881.14	1752.12	1.59	4.276	5" 18# Millout Extension	35.6	
		1882.73	1753.41	0.30	3.920	5" BDS x 4 1/2" TDS, X-over	35.6	
	R.A.Tag: 1883.03	1883.03	1753.66	1.88	3.920	4 1/2" 13.5# TDS Pup Joint	35.6	w/R.A.Tag
		1884.91	1755.19	1.21	3.920	4 1/2" 13.5# Flow Coupling	35.6	
		1886.12	1756.17	0.46	3.813	4 1/2" DB-6 Landing Nipple	35.6	
		1886.58	1756.54	1.16	3.920	4 1/2" 13.5# Flow Coupling	35.6	
	Casing: 9 5/8 0.0 - 1891.00	1887.74	1757.49	1.91	3.920	4 1/2" 13.5# TDS Pup Joint	35.6	

Completion String Design

D Well completion schematic for Gullfaks A-16A

Gullfaks	**Existing; Completion Schematic**	**Page 1 of 3** STATOIL
Well: NO 34/10-A-16 A (Oil Producer)		**Prep. by:** TEB/AA **Date:** 19.09.2000
Compl.: 1.00 **Tub.Inst.Date:** 10.11.1989		**Rev.:** 1.01 **Opr.Fin.Date:** 24.07.1996

Remark: Satt GP-Straddle @ 2288 til 2305.97 og fra @ 2315 til 2329.97 m MD. Min. id=1.995" @ 2291.5 m



Ass	Symbol Extra Info	MD [RKB] Top [m]	TVD [RKB] [m]	Length [m]	ID [inch]	Description	Angle [Deg]	Comment
		35.09	35.09	0.00	6.260	7" Upper Hanger		
		35.09	35.09	2.48	4.778	5 1/2" 20# BDS Pup Joint		
		37.57	37.57	0.65	6.184	7" Lower Hanger		
		38.22	38.22	1.23	4.778	5 1/2" 20# BDS Pup Joint		
		39.45	39.45	481.69	4.892	5 1/2" 17# BDS Tubing		
		521.14	520.11	1.67	4.778	5 1/2" 20# BDS Pup Joint	10.0	
		522.81	521.76	1.71	4.778	5 1/2" 20# Flow Coupling	10.1	
Ass 11 7.08		524.52	523.44	0.92	4.562	5 1/2" RHH-2-D Communication Nipple	10.2	
		525.44	524.35	1.70	4.778	5 1/2" 20# Flow Coupling	10.2	
		527.14	526.02	1.08	4.778	5 1/2" 20# BDS Pup Joint	10.3	
		528.22	527.08	11.96	4.892	5 1/2" 17# BDS Tubing	10.4	
		540.18	538.83	1.76	4.778	5 1/2" 20# BDS Pup Joint	10.9	
		541.94	540.56	1.78	4.778	5 1/2" 20# Flow Coupling	11.0	
Ass 10 9.20	Control Line: Default	543.72	542.31	2.70	4.562	5 1/2" TRDP-5-STAT-D SCSSV	11.1	
		546.42	544.96	1.80	4.778	5 1/2" 20# Flow Coupling	11.2	
		548.22	546.72	1.16	4.778	5 1/2" 20# BDS Pup Joint	11.3	
		549.38	547.86	1365.26	4.892	5 1/2" 17# BDS Tubing	11.4	
		1914.64	1575.12	1.76	4.778	5 1/2" 20# BDS Pup Joint	47.5	
Ass 9 4.47	Control Line: Default	1916.40	1576.31	0.94	4.771	5 1/2" 17# Gauge Carrier	47.5	
		1917.34	1576.95	1.77	4.778	5 1/2" 20# BDS Pup Joint	47.5	
		1919.11	1578.14	1.68	4.778	5 1/2" 20# BDS Pup Joint	47.5	
		1920.79	1579.28	1.51	4.778	5 1/2" 20# Flow Coupling	47.5	
Ass 8 5.92		1922.30	1580.30	0.26	4.276	5 1/2" x 5" BDS, X-over	47.5	
		1922.56	1580.47	1.18	4.276	5" 18# Flow Coupling	47.5	
		1923.74	1581.27	1.29	4.276	5" 18# NSCT Pup Joint	47.5	
		1925.03	1582.14	212.34	4.410	5" 15# BDS Tubing	47.5	
		2137.37	1732.25	1.76	4.276	5" 18# NSCT Pup Joint	34.2	
		2139.13	1733.70	0.98	4.276	5" 18# Flow Coupling	34.0	
Ass 7 6.45		2140.11	1734.52	1.38	4.125	5" DB-1-E Sliding Sleeve	33.8	
		2141.49	1735.67	1.17	4.276	5" 18# Flow Coupling	33.7	
		2142.66	1736.64	1.16	4.276	5" 18# NSCT Pup Joint	33.5	
		2143.82	1737.61	1.78	4.276	5" 18# NSCT Pup Joint	33.4	
		2145.60	1739.10	1.17	4.276	5" 18# Flow Coupling	33.2	
Ass 3 12.55		2146.77	1740.08	8.44	4.000	5" X 20 FT OP Exp. Joint W/4.000 DB-6 Profil	33.0	
		2155.21	1747.20	1.16	4.276	5" 18# NSCT Pup Joint	31.9	
		2156.37	1748.18	11.40	4.410	5" 15# BDS Tubing	31.8	
		2167.77	1757.95	1.76	4.276	5" 18# NSCT Pup Joint	30.3	
		2169.53	1759.47	0.22	3.875	5" RHR Stinger	30.1	
		2169.75	1759.66	1.57	3.875	7 " x 3 7/8" HSP-1 Packer	30.1	
		2171.32	1761.02	1.59	4.276	5" 18# Millout Extension	29.9	
		2172.91	1762.40	0.30	3.833	5" BDS x 4 1/2" TDS, X-over	29.7	
Ass 2 10.88	R.A.Tag: 2173.21	2173.21	1762.66	1.30	3.920	4 1/2" 13.5# TDS Pup Joint	29.6	
		2174.51	1763.79	1.21	3.920	4 1/2" 13.5# Flow Coupling	29.5	
		2175.72	1764.84	0.45	3.813	4 1/2" DB-6 Landing Nipple	29.4	
		2176.17	1765.23	1.20	3.920	4 1/2" 13.5# Flow Coupling	29.3	

Completion String Design

E Well completion schematic for Gullfaks A-23

Gullfaks

Well: NO 34/10-A-23 (Oil Producer)

Compl.: 1.00 **Tub.Inst.Date:** 29.06.1989

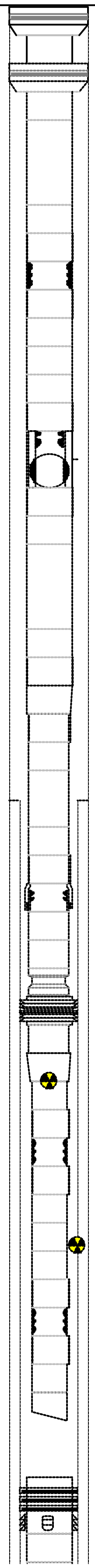
COMPLETION SCHEMATIC

STATOIL

Prep. by: TEB/BLG **Date:** 18.08.1998

Rev.: 1.00 **Opr.Fin.Date:** 29.06.1989

Remark: Knock out isolation valve broached ut til 3.52" 14.06.89.
Tagget dyp 3232 md med 3.5" gauge ring 28.12.91.



Ass	Symbol Extra Info	MD [RKB] Top [m]	TVD [RKB] [m]	Length [m]	ID [inch]	Description	Angle [Deg]
		35.10	35.10	0.75	4.875	5 1/2" 20# Tubing Hanger	
		35.85	35.85	1.80	4.778	5 1/2" 20# BDS Pup Joint	
		37.65	37.65	0.45	4.778	5 1/2" Lower Tubing Hanger	
		38.10	38.10	1.34	4.778	5 1/2" 20# BDS Pup Joint	
		39.44	39.44	485.04	4.892	5 1/2" 17# BDS Tubing	
Ass 6 7.24		524.48	522.56	1.78	4.778	5 1/2" 20# BDS Pup Joint	14.5
		526.26	524.28	1.79	4.778	5 1/2" 20# Flow Coupling	14.6
		528.05	526.01	0.73	4.562	5 1/2" RHH-2-D Communication Nipple	14.6
		528.78	526.72	1.78	4.778	5 1/2" 20# Flow Coupling	14.6
		530.56	528.44	1.16	4.778	5 1/2" 20# BDS Pup Joint	14.7
		531.72	529.57	11.87	4.892	5 1/2" 17# BDS Tubing	14.7
Ass 5 9.56		543.59	541.04	1.75	4.778	5 1/2" 20# BDS Pup Joint	15.0
		545.34	542.73	1.58	4.778	5 1/2" 20# Flow Coupling	15.0
		546.92	544.26	2.76	4.437	5 1/2" TRDP-5-RO SCSSV	15.1
		549.68	546.92	1.78	4.778	5 1/2" 20# Flow Coupling	15.2
		551.46	548.64	1.69	4.778	5 1/2" 20# BDS Pup Joint	15.3
		553.15	550.27	1949.38	4.892	5 1/2" 17# BDS Tubing	15.4
Ass 4 6.05		2502.53	1727.77	1.78	4.778	5 1/2" 20# BDS Pup Joint	54.9
		2504.31	1728.79	1.72	4.778	5 1/2" 20# Flow Coupling	54.8
		2506.03	1729.78	0.25	4.125	5 1/2" x 5" BDS, X-over	54.8
		2506.28	1729.93	1.18	4.276	5" 18# Flow Coupling	54.8
		2507.46	1730.61	1.12	4.276	5" 18# NSCT Pup Joint	54.7
		2508.58	1731.25	93.11	4.410	5" 15# BDS Tubing	54.7
Ass 3 12.83		2601.69	1786.85	1.77	4.276	5" 18# NSCT Pup Joint	51.4
		2603.46	1787.95	1.11	4.276	5" 18# Flow Coupling	51.3
		2604.57	1788.65	8.71	4.000	5" X 20 FT OP Exp. Joint W/4.000 DB-6 Profil	51.3
		2613.28	1794.11	1.24	4.276	5" 18# NSCT Pup Joint	51.1
Ass 2 10.77		2614.52	1794.89	1.77	4.276	5" 18# NSCT Pup Joint	51.0
		2616.29	1796.00	0.21	3.875	5" RHR Stinger	51.0
		2616.50	1796.13	1.58	3.875	7 " x 3 7/8" HSP-1 Packer	51.0
		2618.08	1797.13	1.59	4.276	5" 18# Millout Extension	50.9
	R.A.Tag: 2619.97	2619.67	1798.13	0.30	3.833	5" BDS x 4 1/2" TDS, X-over	50.9
		2619.97	1798.32	1.23	3.920	4 1/2" 13.5# TDS Pup Joint	50.9
		2621.20	1799.10	1.22	3.920	4 1/2" 13.5# Flow Coupling	50.8
		2622.42	1799.87	0.45	3.813	4 1/2" DB-6 Landing Nipple	50.8
		2622.87	1800.15	1.22	3.920	4 1/2" 13.5# Flow Coupling	50.8
		2624.09	1800.92	1.20	3.920	4 1/2" 13.5# TDS Pup Joint	50.8
	R.A. Tag: 2633.00	2625.29	1801.68	9.57	3.920	4 1/2" 13.5# TDS Tubing	50.7
Ass 1 6.22		2634.86	1807.75	1.82	3.920	4 1/2" 13.5# TDS Pup Joint	50.6
		2636.68	1808.91	1.21	3.920	4 1/2" 13.5# Flow Coupling	50.5
		2637.89	1809.68	0.50	3.687	4 1/2" DB-6 Landing Nipple	50.5
		2638.39	1809.99	1.14	3.920	4 1/2" 13.5# Flow Coupling	50.5
		2639.53	1810.72	1.20	3.920	4 1/2" 13.5# TDS Pup Joint	50.5
		2640.73	1811.48	0.35	3.920	4 1/2" Wireline Entry Guide	50.5
		2667.75	1828.84	1.28	4.000	5 1/2" Model 'SC-1L' GP Packer 70B2*40	49.2
		2669.03	1829.68	1.45	4.778	5 1/2" 20# Upper Extension	49.2

Completion String Design

F Production analysis input excerption

DGRASS Downhole GRAvity Slip Separator

Project/ id: Gullfakslandsbyen 2005

Field: Gullfaks
Well: A-23

IN DATA

WELL DATA

Resevoir pressure, Pr	299,92 bar
Well head pressure	45,98 bar
Water cut, wc	85,50 %
MD	3292,00 m
TVD	2316,87 m
Productivity index, J	4,173E-04 m3/s/bar

DGRASS DATA

TVD, TVD_dgrass	1731,25 m
MD below DGRASS, Lbsep	783,42 m

TUBING DATA

MD above DGRAS, oil, Lo	2508,58 m
MD above DGRASS, water, Lw	2508,58 m
Diameter below DGRASS, D	0,12 m
Diameter oil tubing, Do	0,12 m
Diameter water tubing, Dw	0,08 m

Equivalent roughness, e	1,50E-06 m

PRESSURE DATA

Separators:

Oil, Psoil	60 bar
Water, Pswater	20 bar

Well:

Assumed Pwf	100 bar
Maximum allowed Pwf	299 bar

FLUID DATA

	Oil	Water
Density (kg/m3)	880,119	999,00
Viscosity (Pas)	0,00120	0,00100

Gravity constant, g	9,81 m/s2

Choose separator pressure to be unchanged:

(•) Psoil ( ) Pswater

Solve | Save Data | Range Solve

CALCULATIONS

PRESSURES AND PRESSURE LOSSES

Reference tube, natural flow without DGRASS

P_{wf}	$Q_{mixture}$
bar	m3/s
284,4079	0,0065

Tube A: Mixed flow in tube below DGRASS

P_{wf}	$Q_{mixture}$
bar	m3/s
266,8	0,0138

Tube B: Oil flow in tube above DGRASS

P_{soil}	Q_{oil}
bar	m3/s
60,0	0,00201

Tube C: Water flow in tube above DGRASS

P_{swater}	Q_{water}
bar	m3/s
26,2	0,0118

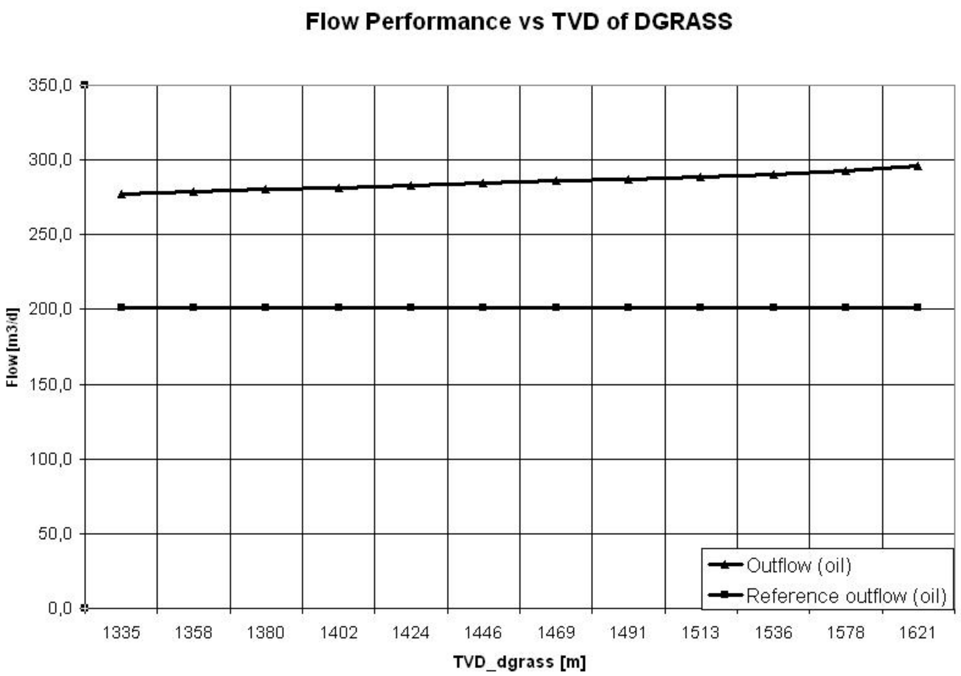
CALCULATED OIL FLOW

Outflow	0,002007 m3/s
Reference outflow	0,000939 m3/s

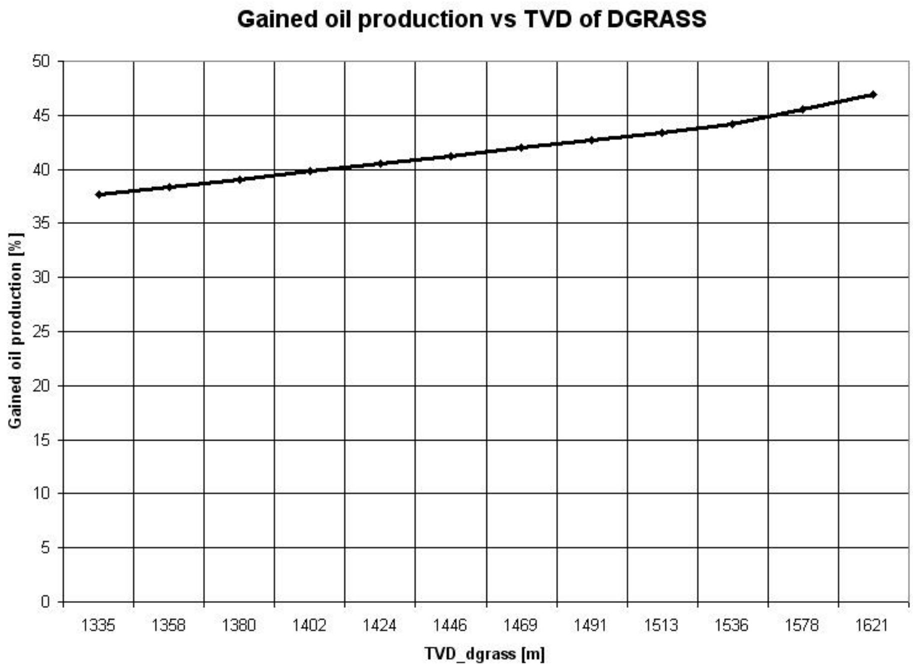
Gained oil production	114 %

G Production analysis data for Gullfaks A-8R2

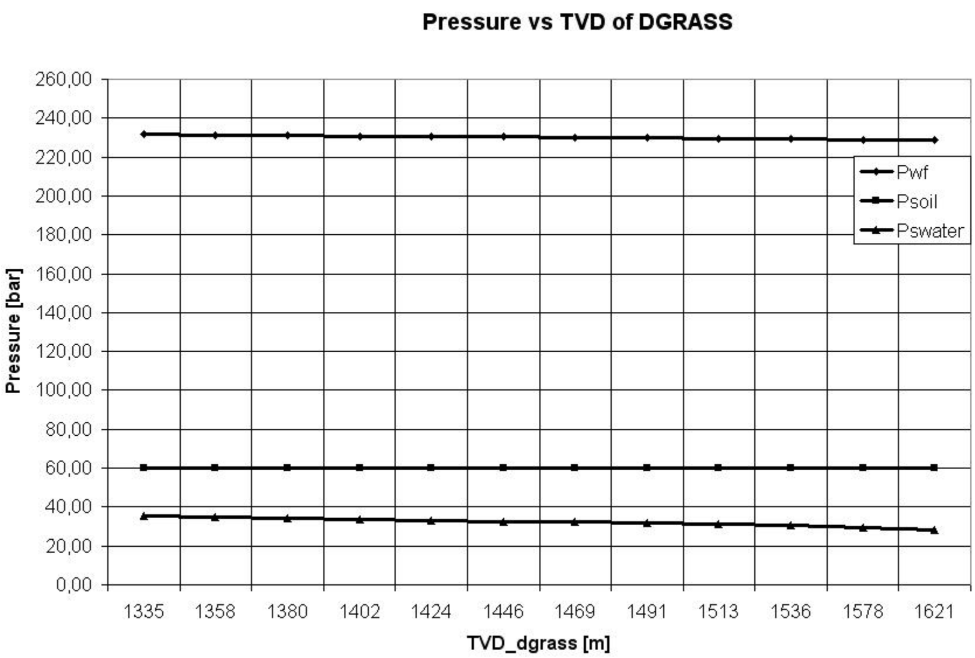
G.1 Flow chart



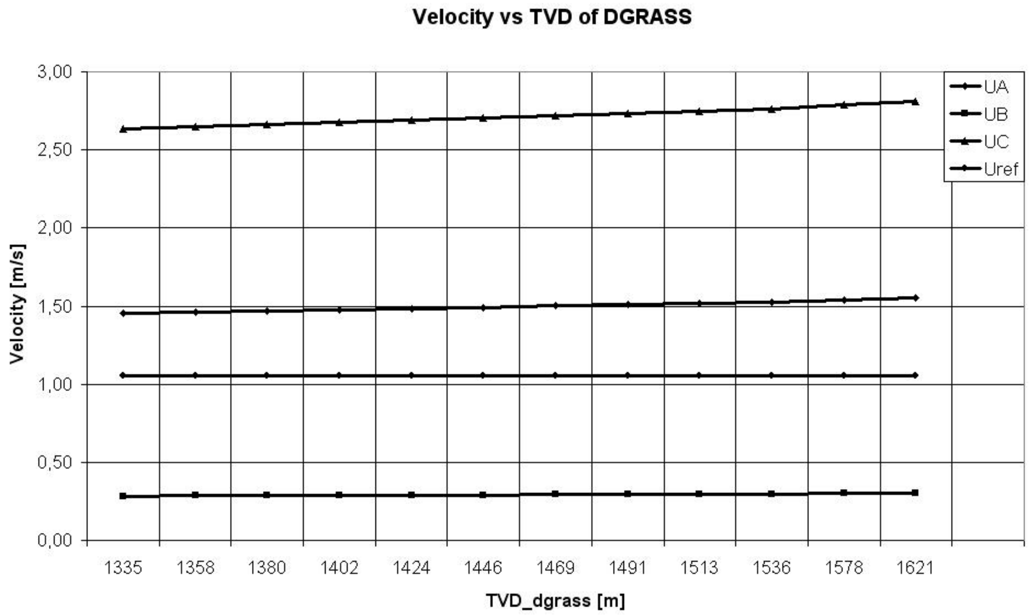
G.2 Gain chart



G.3 Pressure chart



G.4 Velocity chart



G.5 Flow

Nr	TVD_dgrass	Calculated Outflow	Calculated Reference Outflow	Gained Oil Production
	m	m3/d	m3/d	%
1	1335	277,28	201,42	38
2	1358	278,74	201,42	38
3	1380	280,16	201,42	39
4	1402	281,59	201,42	40
5	1424	283,01	201,42	41
6	1446	284,44	201,42	41
7	1469	285,93	201,42	42
8	1491	287,38	201,42	43
9	1513	288,82	201,42	43
10	1536	290,31	201,42	44
11	1578	293,09	201,42	46
12	1621	295,95	201,42	47

G.6 Pressure

Nr.	TVD_dgrass	Pwf	Psoil	Pswater	Pwfref
	m	bar	bar	bar	bar
1	1335	231,48	60,00	35,36	243
2	1358	231,25	60,00	34,83	243
3	1380	231,03	60,00	34,30	243
4	1402	230,80	60,00	33,77	243
5	1424	230,58	60,00	33,23	243
6	1446	230,36	60,00	32,70	243
7	1469	230,12	60,00	32,13	243
8	1491	229,90	60,00	31,58	243
9	1513	229,67	60,00	31,03	243
10	1536	229,44	60,00	30,46	243
11	1578	229,00	60,00	29,38	243
12	1621	228,55	60,00	28,25	243

G.7 Velocity

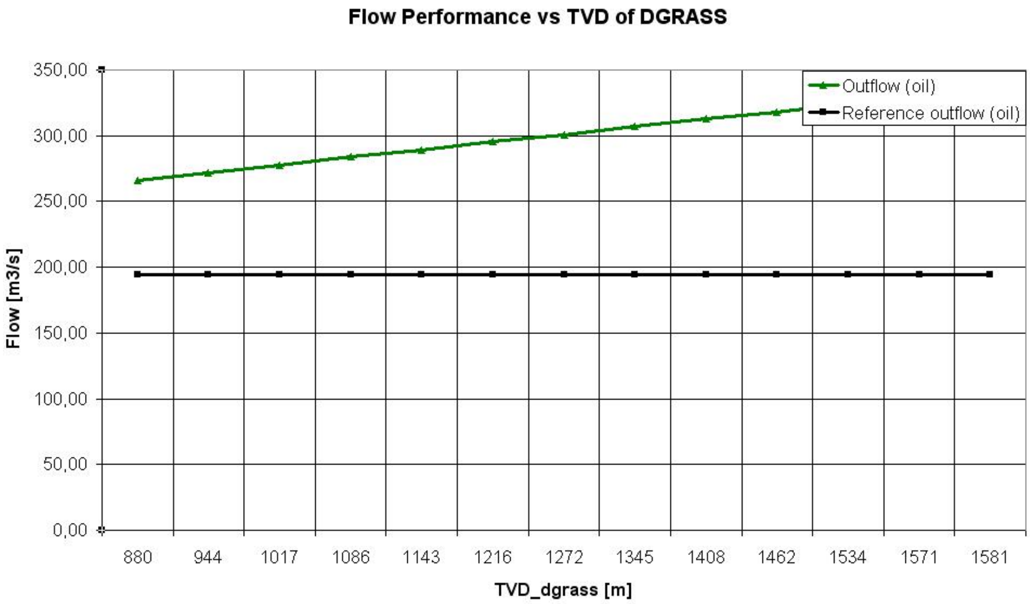
Nr	Depth TVD_dgrass	Velocity Performance UA	UB	UC	Uref
	m	m/s	m/s	m/s	m/s
1	1335	1,455	0,284	2,636	1,057
2	1358	1,463	0,285	2,650	1,057
3	1380	1,470	0,287	2,663	1,057
4	1402	1,478	0,288	2,677	1,057
5	1424	1,485	0,290	2,690	1,057
6	1446	1,493	0,291	2,704	1,057
7	1469	1,501	0,293	2,718	1,057
8	1491	1,508	0,294	2,732	1,057
9	1513	1,516	0,296	2,745	1,057
10	1536	1,524	0,297	2,760	1,057
11	1578	1,538	0,300	2,786	1,057
12	1621	1,553	0,303	2,813	1,057

G.8 Test data

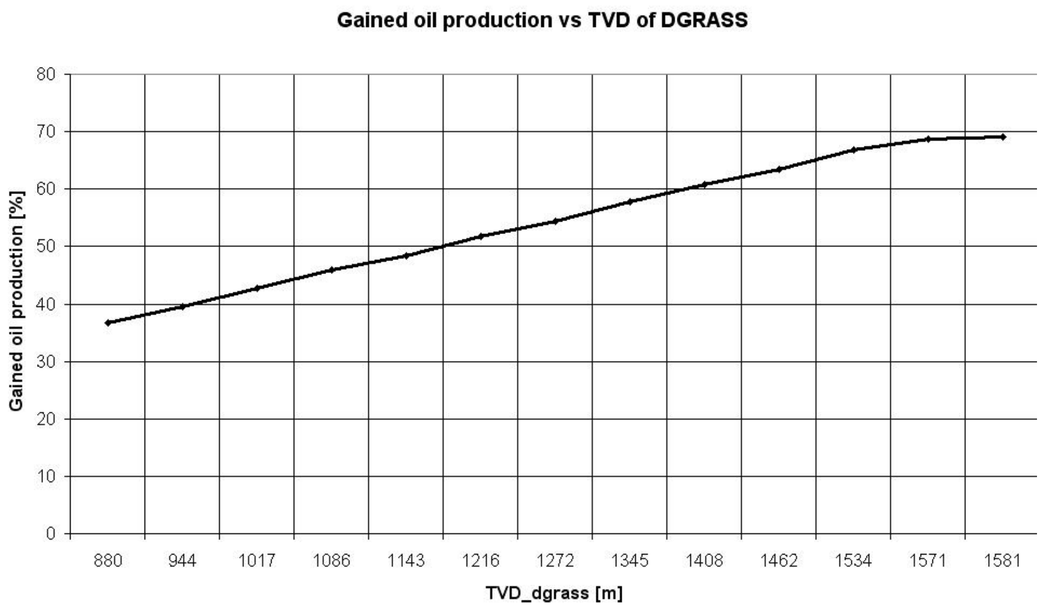
Nr.	Pressure				Depth				Diameter		
	Pwf_a	Pwf_max	Psoil	Pswater	Tvd_dgrass	Lbsep	Lo	Lw	D	Do	Dw
	bar	bar	bar	bar	m	m	m	m	m	m	m
1	100,00	274,00	60,00	20	1335,26	1549,00	1367,00	1367,00	0,12	0,12	0,12
2	100,00	274,00	60,00	20	1357,93	1522,00	1394,00	1394,00	0,12	0,12	0,12
3	100,00	274,00	60,00	20	1380,11	1495,00	1421,00	1421,00	0,12	0,12	0,12
4	100,00	274,00	60,00	20	1402,15	1468,00	1448,00	1448,00	0,12	0,12	0,12
5	100,00	274,00	60,00	20	1424,19	1441,00	1475,00	1475,00	0,12	0,12	0,12
6	100,00	274,00	60,00	20	1446,21	1414,00	1502,00	1502,00	0,12	0,12	0,12
7	100,00	274,00	60,00	20	1469,10	1386,00	1530,00	1530,00	0,12	0,12	0,12
8	100,00	274,00	60,00	20	1491,29	1359,00	1557,00	1557,00	0,12	0,12	0,12
9	100,00	274,00	60,00	20	1513,35	1332,00	1584,00	1584,00	0,12	0,12	0,12
10	100,00	274,00	60,00	20	1536,04	1304,00	1612,00	1612,00	0,12	0,12	0,12
11	100,00	274,00	60,00	20	1578,36	1252,00	1664,00	1664,00	0,12	0,12	0,12
12	100,00	274,00	60,00	20	1621,30	1197,10	1718,90	1718,90	0,12	0,12	0,12

H Production analysis data for Gullfaks A-16A

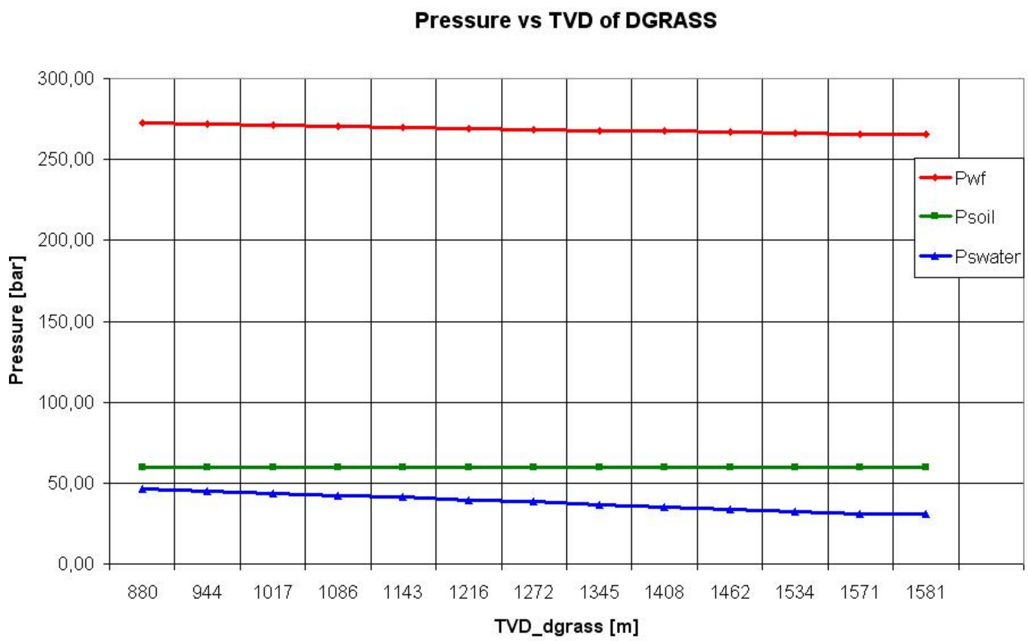
H.1 Flow chart



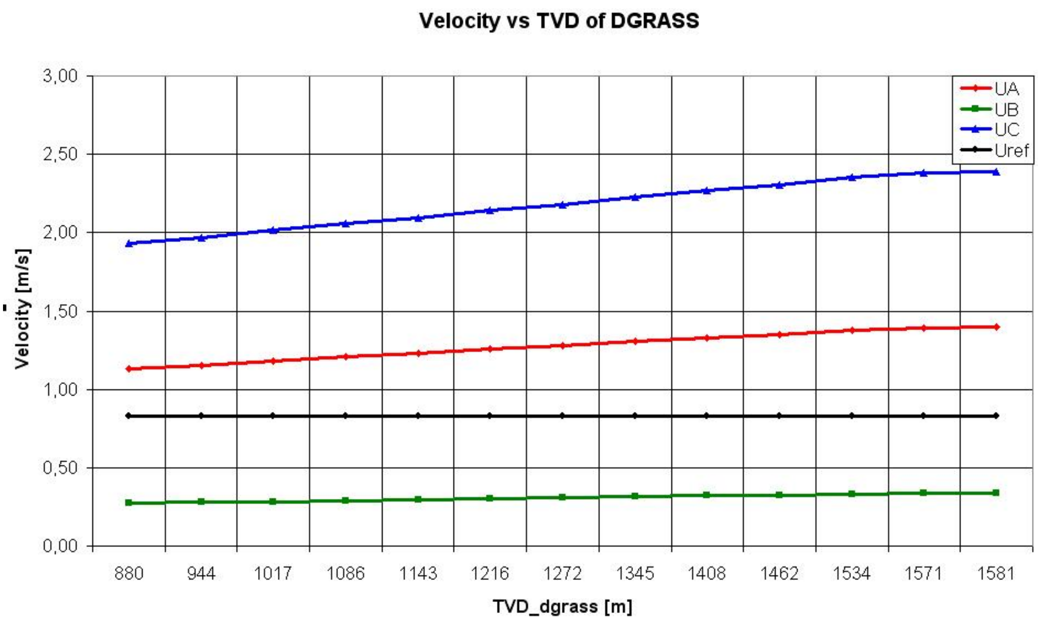
H.2 Gain chart



H.3 Pressure chart



H.4 Velocity chart



H.5 Flow

Nr	TVD_dgrass	Calculated Outflow	Calculated Reference Outflow	Gained Oil Production
	m	m3/s	m3/s	%
1	880	266,06	194,57	37
2	944	271,49	194,57	40
3	1017	277,84	194,57	43
4	1086	283,83	194,57	46
5	1143	288,86	194,57	48
6	1216	295,39	194,57	52
7	1272	300,45	194,57	54
8	1345	307,09	194,57	58
9	1408	312,92	194,57	61
10	1462	317,96	194,57	63
11	1534	324,69	194,57	67
12	1571	328,17	194,57	69
13	1581	329,16	194,57	69

H.6 Pressure

Nr.	TVD_dgrass	Pwf	Psoil	Pswater	Pwfref
	m	bar	bar	bar	bar
1	880	272,26	60,00	46,30	280
2	944	271,70	60,00	45,12	280
3	1017	271,04	60,00	43,69	280
4	1086	270,41	60,00	42,34	280
5	1143	269,89	60,00	41,15	280
6	1216	269,21	60,00	39,59	280
7	1272	268,69	60,00	38,35	280
8	1345	268,00	60,00	36,70	280
9	1408	267,39	60,00	35,22	280
10	1462	266,87	60,00	33,92	280
11	1534	266,17	60,00	32,16	280
12	1571	265,80	60,00	31,23	280
13	1581	265,70	60,00	30,96	280

H.7 Velocity

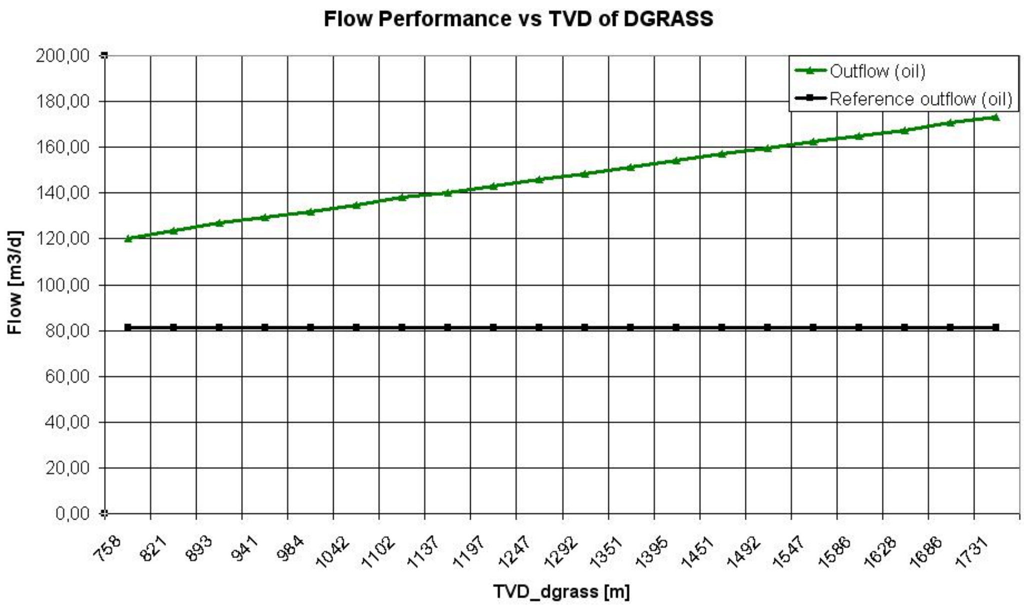
	Depth	Velocity Performance			
Nr	TVD_dgrass	UA	UB	UC	Uref
	m	m/s	m/s	m/s	m/s
1	880	1,130	0,272	1,929	0,826
2	944	1,153	0,278	1,969	0,826
3	1017	1,180	0,284	2,015	0,826
4	1086	1,205	0,290	2,058	0,826
5	1143	1,227	0,296	2,095	0,826
6	1216	1,254	0,302	2,142	0,826
7	1272	1,276	0,307	2,179	0,826
8	1345	1,304	0,314	2,227	0,826
9	1408	1,329	0,320	2,269	0,826
10	1462	1,350	0,325	2,306	0,826
11	1534	1,379	0,332	2,355	0,826
12	1571	1,394	0,336	2,380	0,826
13	1581	1,398	0,337	2,387	0,826

H.8 Test data

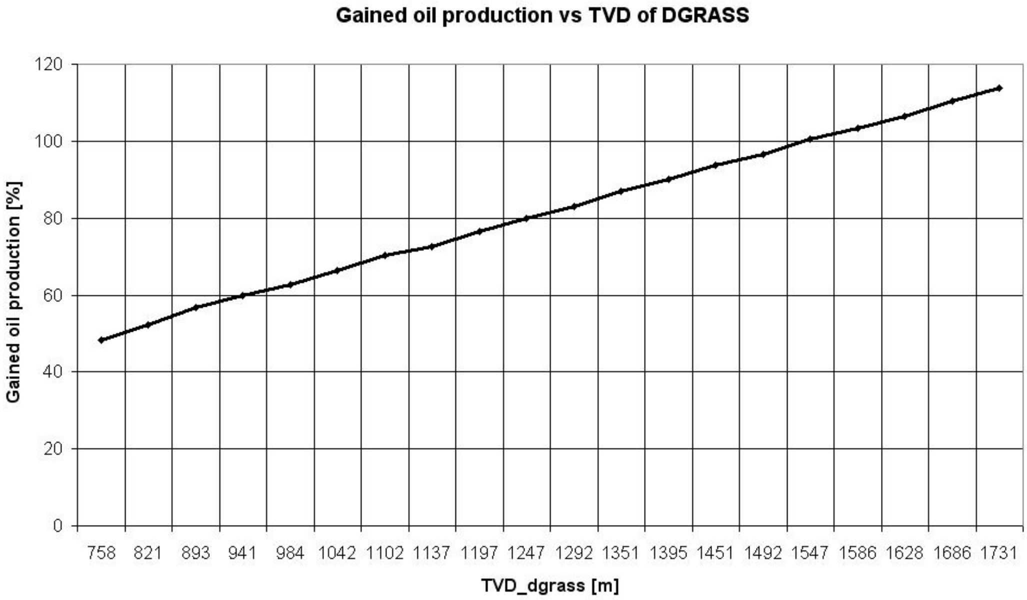
	Pressure				Depth				Diameter		
Nr.	Pwf_a	Pwf_max	Psoil	Pswater	Tvd_dgrass	Lbsep	Lo	Lw	D	Do	Dw
	bar	bar	bar	bar	m	m	m	m	m	m	m
1	100,00	299,00	60,00	20	880,06	2000,00	916,00	916,00	0,12	0,12	0,12
2	100,00	299,00	60,00	20	943,67	1918,00	998,00	998,00	0,12	0,12	0,12
3	100,00	299,00	60,00	20	1017,23	1820,00	1096,00	1096,00	0,12	0,12	0,12
4	100,00	299,00	60,00	20	1086,23	1730,00	1186,00	1186,00	0,12	0,12	0,12
5	100,00	299,00	60,00	20	1143,15	1648,00	1268,00	1268,00	0,12	0,12	0,12
6	100,00	299,00	60,00	20	1216,07	1540,00	1376,00	1376,00	0,12	0,12	0,12
7	100,00	299,00	60,00	20	1272,11	1457,00	1459,00	1459,00	0,12	0,12	0,12
8	100,00	299,00	60,00	20	1345,01	1349,00	1567,00	1567,00	0,12	0,12	0,12
9	100,00	299,00	60,00	20	1408,27	1254,00	1662,00	1662,00	0,12	0,12	0,12
10	100,00	299,00	60,00	20	1462,45	1172,00	1744,00	1744,00	0,12	0,12	0,12
11	100,00	299,00	60,00	20	1534,12	1064,00	1852,00	1852,00	0,12	0,12	0,12
12	100,00	299,00	60,00	20	1570,99	1009,00	1907,00	1907,00	0,12	0,12	0,12
13	100,00	299,00	60,00	20	1581,27	992,26	1923,74	1923,74	0,12	0,12	0,12

I Production analysis data for Gullfaks A-23

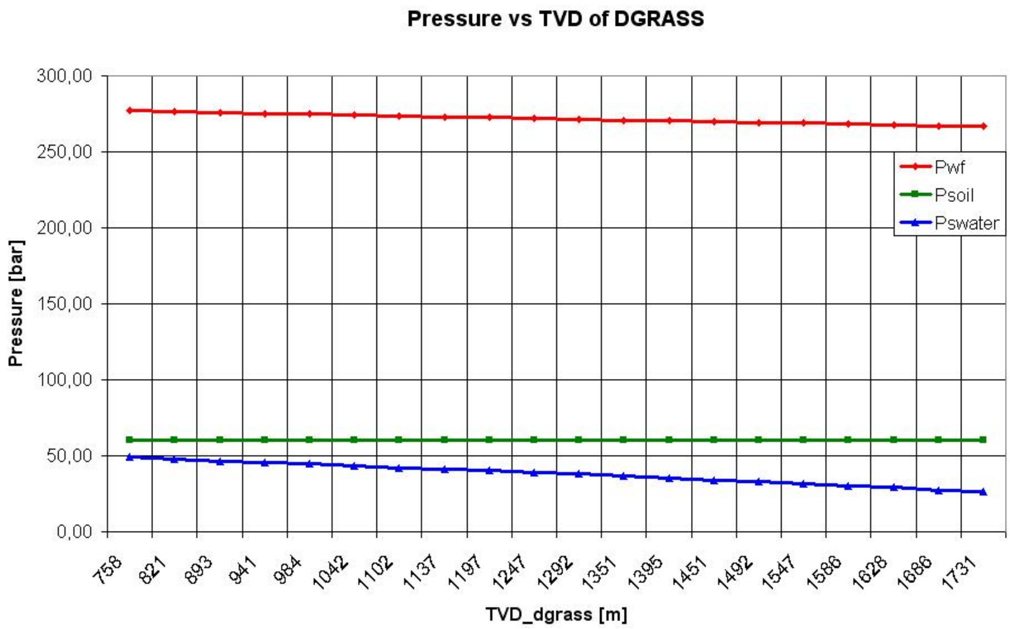
I.1 Flow chart



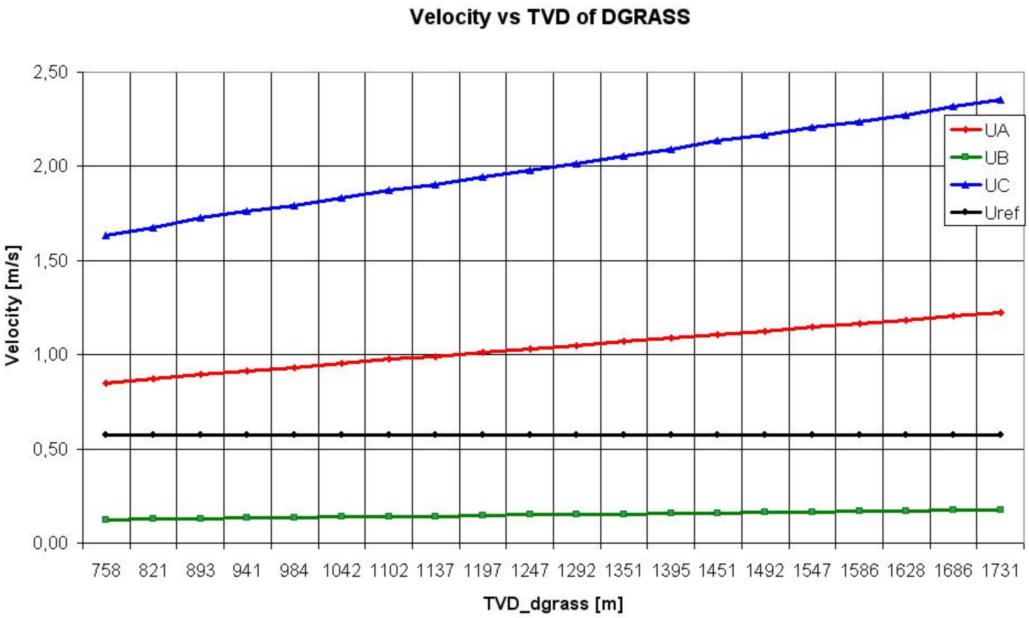
I.2 Gain chart



I.3 Pressure chart



I.4 Velocity chart



I.5 Flow

Nr	TVD_dgrass	Calculated Outflow	Calculated Reference Outflow	Gained Oil Production
	m	m3/d	m3/d	%
1	758	120,26	81,10	48
2	821	123,43	81,10	52
3	893	127,11	81,10	57
4	941	129,61	81,10	60
5	984	131,85	81,10	63
6	1042	134,96	81,10	66
7	1102	138,13	81,10	70
8	1137	139,99	81,10	73
9	1197	143,21	81,10	77
10	1247	145,90	81,10	80
11	1292	148,36	81,10	83
12	1351	151,57	81,10	87
13	1395	154,03	81,10	90
14	1451	157,19	81,10	94
15	1492	159,51	81,10	97
16	1547	162,67	81,10	101
17	1586	164,89	81,10	103
18	1628	167,32	81,10	106
19	1686	170,72	81,10	111
20	1731	173,38	81,10	114

I.6 Pressure

Nr.	TVD_dgrass	Pwf	Psoil	Pswater	Pwfref
	m	bar	bar	bar	bar
1	758	276,92	60,00	48,95	284
2	821	276,31	60,00	47,87	284
3	893	275,61	60,00	46,56	284
4	941	275,13	60,00	45,63	284
5	984	274,70	60,00	44,76	284
6	1042	274,11	60,00	43,54	284
7	1102	273,50	60,00	42,27	284
8	1137	273,14	60,00	41,53	284
9	1197	272,53	60,00	40,24	284
10	1247	272,01	60,00	39,12	284
11	1292	271,54	60,00	38,06	284
12	1351	270,93	60,00	36,67	284
13	1395	270,46	60,00	35,53	284
14	1451	269,85	60,00	34,12	284
15	1492	269,41	60,00	33,02	284
16	1547	268,81	60,00	31,51	284
17	1586	268,38	60,00	30,42	284
18	1628	267,92	60,00	29,23	284
19	1686	267,27	60,00	27,53	284
20	1731	266,76	60,00	26,18	284

I.7 Velocity

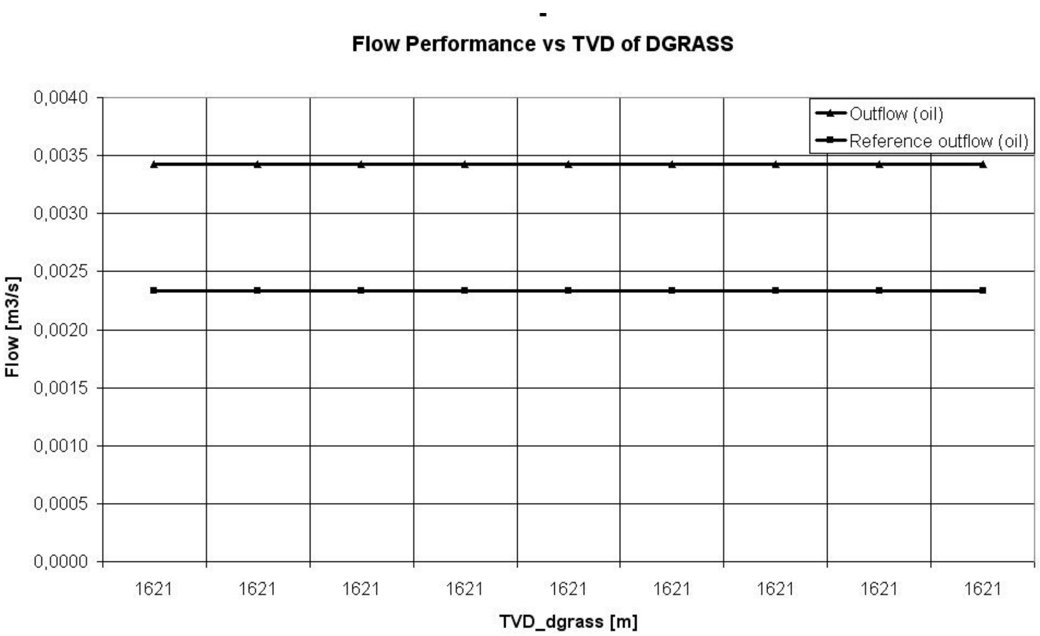
Nr	Depth		Velocity Performance		
	TVD_dgrass	U_A	U_B	U_C	Uref
	m	m/s	m/s	m/s	m/s
1	758	0,849	0,123	1,633	0,572
2	821	0,871	0,126	1,676	0,572
3	893	0,897	0,130	1,726	0,572
4	941	0,915	0,133	1,760	0,572
5	984	0,931	0,135	1,790	0,572
6	1042	0,953	0,138	1,832	0,572
7	1102	0,975	0,141	1,875	0,572
8	1137	0,988	0,143	1,901	0,572
9	1197	1,011	0,147	1,944	0,572
10	1247	1,030	0,149	1,981	0,572
11	1292	1,047	0,152	2,014	0,572
12	1351	1,070	0,155	2,058	0,572
13	1395	1,087	0,158	2,091	0,572
14	1451	1,109	0,161	2,134	0,572
15	1492	1,126	0,163	2,166	0,572
16	1547	1,148	0,166	2,209	0,572
17	1586	1,164	0,169	2,239	0,572
18	1628	1,181	0,171	2,272	0,572
19	1686	1,205	0,175	2,318	0,572
20	1731	1,224	0,177	2,354	0,572

I.8 Test data

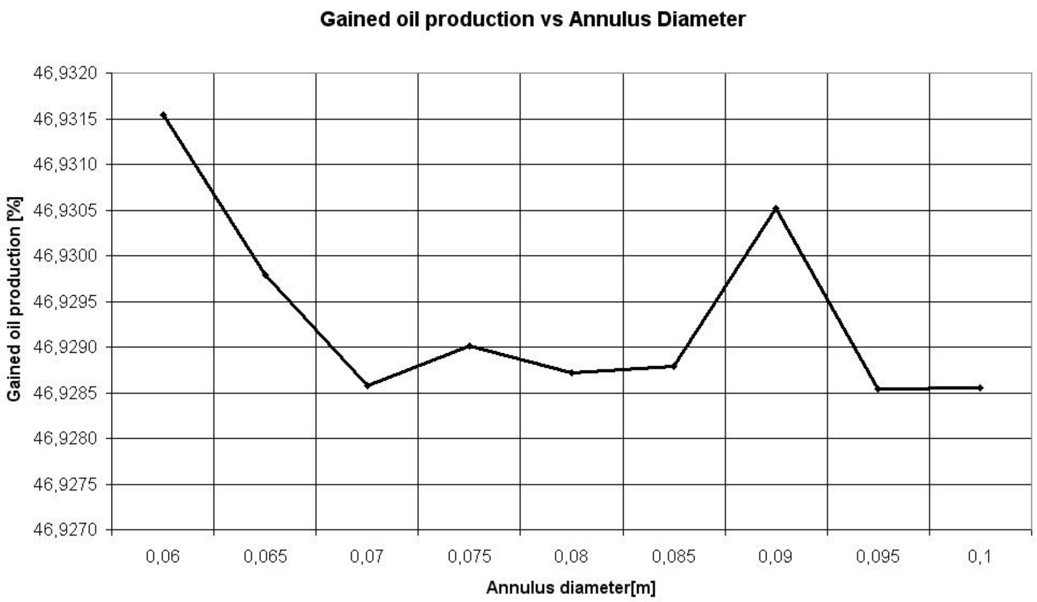
Nr.	Pressure				Depth				Diameter		
	Pwf_a	Pwf_max	Psoil	Pswater	Tvd_dgrass	Lbsep	Lo	Lw	D	Do	Dw
	bar	bar	bar	bar	m	m	m	m	m	m	m
1	100,00	299,00	60,00	20	758,48	2507,00	785,00	785,00	0,12	0,12	0,12
2	100,00	299,00	60,00	20	821,37	2425,00	867,00	867,00	0,12	0,12	0,12
3	100,00	299,00	60,00	20	893,23	2317,00	975,00	975,00	0,12	0,12	0,12
4	100,00	299,00	60,00	20	941,23	2235,00	1057,00	1057,00	0,12	0,12	0,12
5	100,00	299,00	60,00	20	983,51	2153,00	1139,00	1139,00	0,12	0,12	0,12
6	100,00	299,00	60,00	20	1042,23	2045,00	1247,00	1247,00	0,12	0,12	0,12
7	100,00	299,00	60,00	20	1101,58	1937,00	1355,00	1355,00	0,12	0,12	0,12
8	100,00	299,00	60,00	20	1136,76	1879,00	1413,00	1413,00	0,12	0,12	0,12
9	100,00	299,00	60,00	20	1197,29	1784,00	1508,00	1508,00	0,12	0,12	0,12
10	100,00	299,00	60,00	20	1247,38	1699,00	1593,00	1593,00	0,12	0,12	0,12
11	100,00	299,00	60,00	20	1292,32	1617,00	1675,00	1675,00	0,12	0,12	0,12
12	100,00	299,00	60,00	20	1350,87	1514,00	1778,00	1778,00	0,12	0,12	0,12
13	100,00	299,00	60,00	20	1394,57	1422,00	1870,00	1870,00	0,12	0,12	0,12
14	100,00	299,00	60,00	20	1451,44	1324,00	1968,00	1968,00	0,12	0,12	0,12
15	100,00	299,00	60,00	20	1492,26	1243,00	2049,00	2049,00	0,12	0,12	0,12
16	100,00	299,00	60,00	20	1547,37	1135,00	2157,00	2157,00	0,12	0,12	0,12
17	100,00	299,00	60,00	20	1585,90	1059,00	2233,00	2233,00	0,12	0,12	0,12
18	100,00	299,00	60,00	20	1627,78	978,00	2314,00	2314,00	0,12	0,12	0,12
19	100,00	299,00	60,00	20	1686,14	869,00	2423,00	2423,00	0,12	0,12	0,12
20	100,00	299,00	60,00	20	1731,25	783,42	2508,58	2508,58	0,12	0,12	0,12

J Annulus diameter impact analysis data

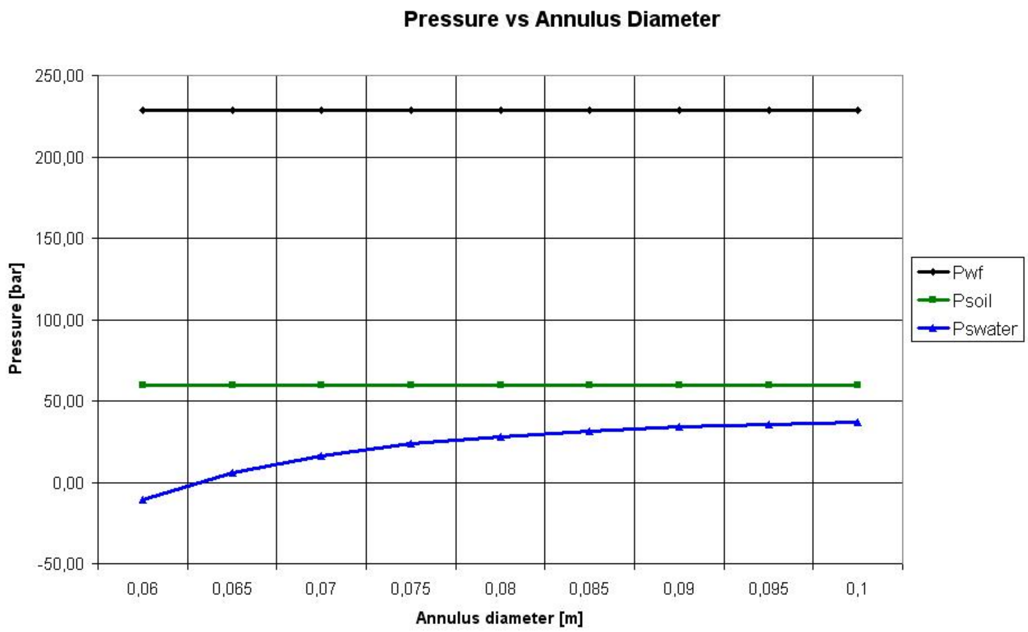
J.1 Flow chart



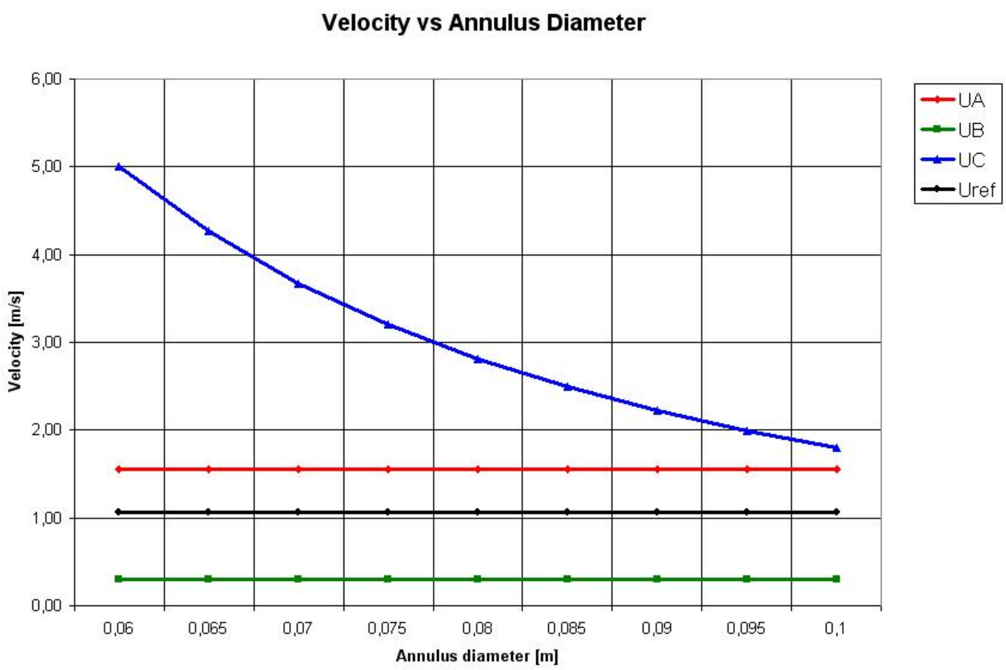
J.2 Gain chart



J.3 Pressure chart



J.4 Velocity chart



J.5 Flow

Nr	TVD_dgrass	Calculated Outflow	Calculated Reference Outflow	Gained Oil Production
	m	m3/s	m3/s	%
1	1621	0,0034	0,0023	46,9315
2	1621	0,0034	0,0023	46,9298
3	1621	0,0034	0,0023	46,9286
4	1621	0,0034	0,0023	46,9290
5	1621	0,0034	0,0023	46,9287
6	1621	0,0034	0,0023	46,9288
7	1621	0,0034	0,0023	46,9305
8	1621	0,0034	0,0023	46,9285
9	1621	0,0034	0,0023	46,9286

J.6 Pressure

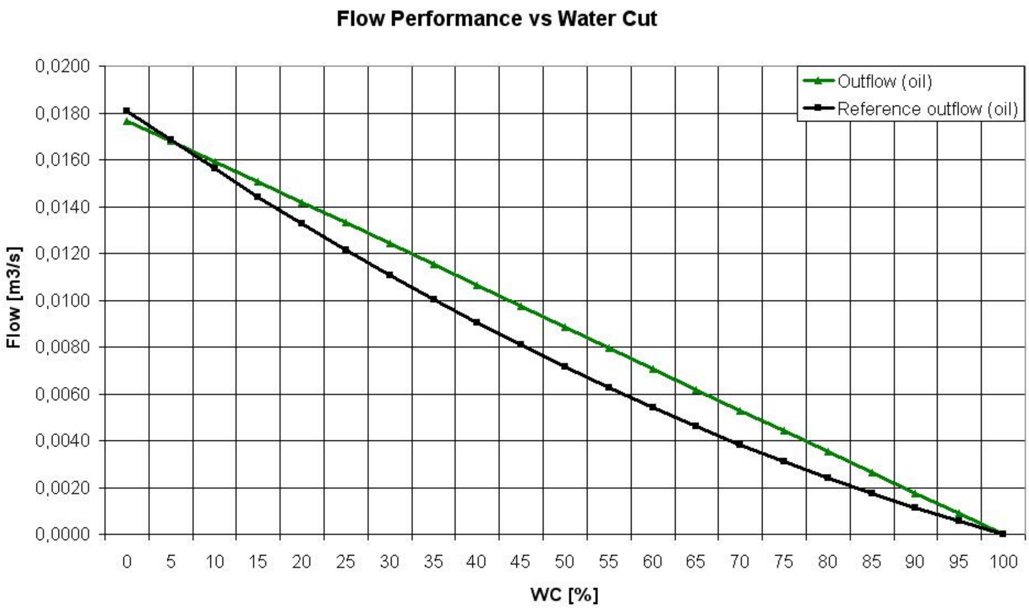
Nr.	TVD_dgrass	Pwf	Psoil	Pswater	Pwfref
	m	bar	bar	bar	bar
1	1621	228,55	60,00	-10,87	243
2	1621	228,55	60,00	5,86	243
3	1621	228,55	60,00	16,51	243
4	1621	228,55	60,00	23,51	243
5	1621	228,55	60,00	28,25	243
6	1621	228,55	60,00	31,54	243
7	1621	228,55	60,00	33,88	243
8	1621	228,55	60,00	35,56	243
9	1621	228,55	60,00	36,80	243

J.7 Velocity

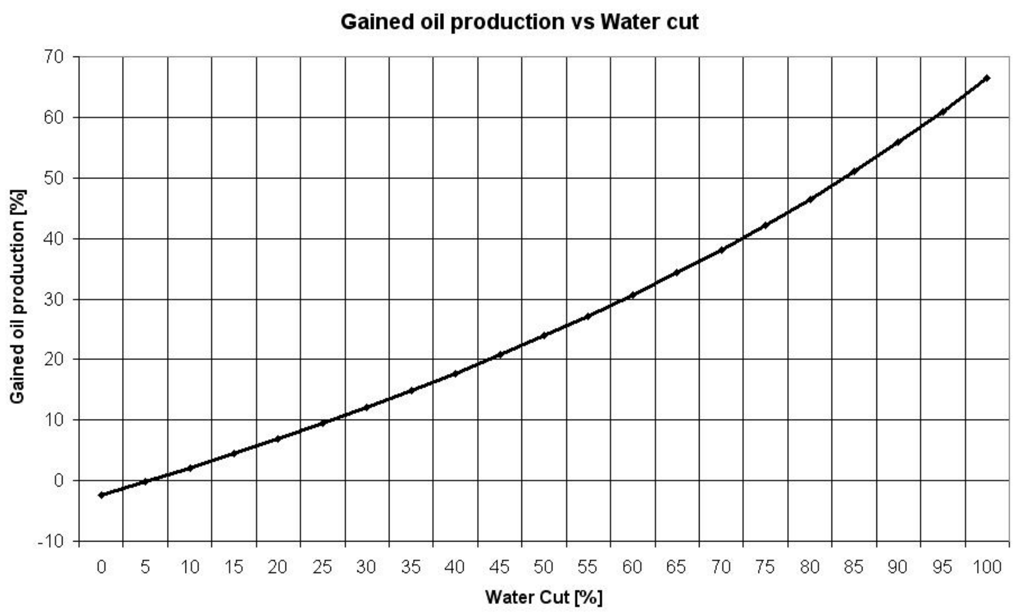
Nr	Depth	Velocity Performance			
	TVD_dgrass	U_A	U_B	U_C	Uref
	m	m/s	m/s	m/s	m/s
1	1621	1,553	0,303	5,001	1,057
2	1621	1,553	0,303	4,261	1,057
3	1621	1,553	0,303	3,674	1,057
4	1621	1,553	0,303	3,201	1,057
5	1621	1,553	0,303	2,813	1,057
6	1621	1,553	0,303	2,492	1,057
7	1621	1,553	0,303	2,223	1,057
8	1621	1,553	0,303	1,995	1,057
9	1621	1,553	0,303	1,800	1,057

K Water cut impact analysis data

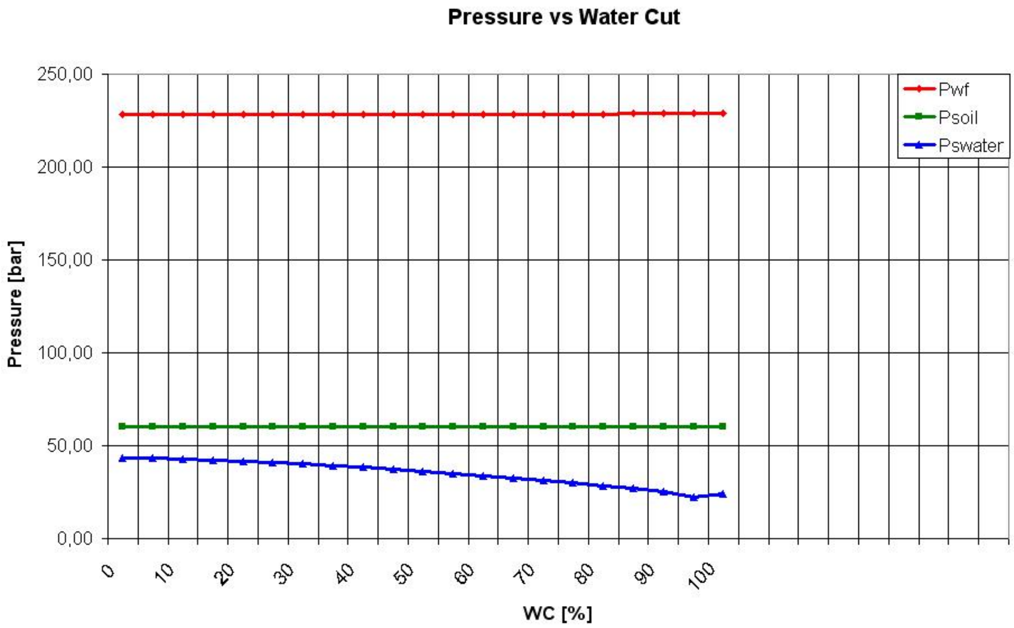
K.1 Flow chart



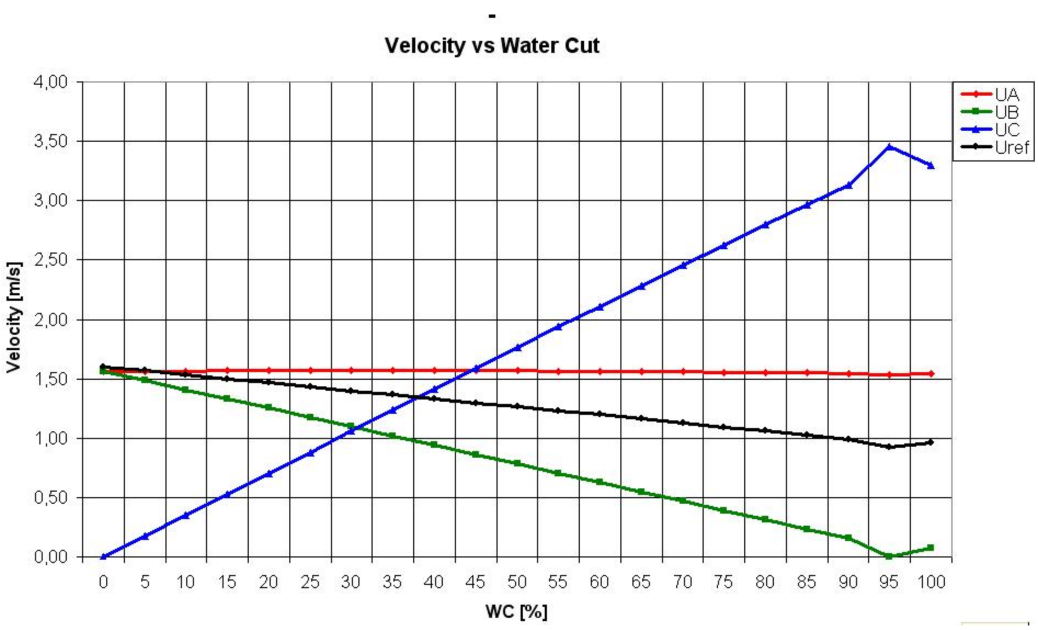
K.2 Gain chart



K.3 Pressure chart



K.4 Velocity chart



K.5 Flow

Nr	TVD_dgrass	Calculated Outflow	Calculated Reference Outflow	Gained Oil Production
	m	m3/s	m3/s	%
1	1621	0,0177	0,0181	-2
2	1621	0,0168	0,0168	0
3	1621	0,0159	0,0156	2
4	1621	0,0151	0,0144	4
5	1621	0,0142	0,0133	7
6	1621	0,0133	0,0121	9
7	1621	0,0124	0,0111	12
8	1621	0,0115	0,0100	15
9	1621	0,0106	0,0090	18
10	1621	0,0097	0,0081	21
11	1621	0,0089	0,0071	24
12	1621	0,0080	0,0063	27
13	1621	0,0071	0,0054	31
14	1621	0,0062	0,0046	34
15	1621	0,0053	0,0038	38
16	1621	0,0044	0,0031	42
17	1621	0,0035	0,0024	46
18	1621	0,0026	0,0017	51
19	1621	0,0017	0,0011	56
21	1621	0,0009	0,0005	61
20	1621	0,0000	0,0000	66

K.6 Pressure

Nr.	TVD_dgrass	Pwf	Psoil	Pswater	Pwfref
	m	bar	bar	bar	bar
1	1621	228,30	60,00	43,67	227
2	1621	228,25	60,00	43,35	228
3	1621	228,21	60,00	42,91	229
4	1621	228,17	60,00	42,38	230
5	1621	228,14	60,00	41,75	231
6	1621	228,13	60,00	41,03	232
7	1621	228,12	60,00	40,23	233
8	1621	228,11	60,00	39,35	234
9	1621	228,12	60,00	38,40	235
10	1621	228,14	60,00	37,37	236
11	1621	228,17	60,00	36,27	237
12	1621	228,20	60,00	35,11	238
13	1621	228,25	60,00	33,88	239
14	1621	228,31	60,00	32,59	240
15	1621	228,37	60,00	31,25	241
16	1621	228,45	60,00	29,85	242
17	1621	228,54	60,00	28,40	243
18	1621	228,64	60,00	26,91	244
19	1621	228,76	60,00	25,37	245
20	1621	229,03	60,00	22,21	247
21	1621	228,89	60,00	23,80	246

K.7 Velocity

Nr	Depth TVD_dgrass	Velocity Performance			
		U_A	U_B	U_C	Uref
	m	m/s	m/s	m/s	m/s
1	1621	1,562	1,561	0,000	1,600
2	1621	1,563	1,485	0,176	1,566
3	1621	1,565	1,408	0,352	1,533
4	1621	1,566	1,331	0,528	1,499
5	1621	1,567	1,253	0,705	1,466
6	1621	1,567	1,176	0,882	1,432
7	1621	1,568	1,097	1,058	1,399
8	1621	1,568	1,019	1,235	1,365
9	1621	1,568	0,941	1,411	1,331
10	1621	1,567	0,862	1,587	1,298
11	1621	1,566	0,783	1,762	1,264
12	1621	1,565	0,704	1,937	1,230
13	1621	1,563	0,625	2,111	1,196
14	1621	1,561	0,546	2,284	1,162
15	1621	1,559	0,468	2,456	1,129
16	1621	1,557	0,389	2,627	1,095
17	1621	1,553	0,311	2,796	1,060
18	1621	1,550	0,233	2,965	1,026
19	1621	1,546	0,155	3,131	0,992
20	1621	1,537	0,000	3,458	0,924
21	1621	1,542	0,077	3,296	0,958