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1.0 Summary

This master`s thesis is called “Pumping of Gelled fluid in Pipeline Applications” and is carried out on request by Halliburton Pipeline & Process Services. The reason this thesis is carried out is that more information is needed to predict accurately the required pumping pressure to encounter when pumping gelled fluids.

A test program was set up to provide data from situations similar to those from real projects. The test program was designed so it would be easy to collect and compare data. It was therefore carried out by pumping different gel plugs of lengths of 50, 100 and 150 meters into three different pipelines of 2, 4 and 6.1 inches in diameter.

The gel used in these gel tests is called Temblok-50™.This is a Halliburton produced gel which is made by mixing a linear gel with a cross-linker. Cross-links are bonds that link one polymer chain to another. The Temblok-50™ is a viscous water based gel with an extremely tough cohesive structure developed for use where a long life material is required. It is formed by cross-linking a natural gum or its derivatives in alkaline pH conditions. Temblok-50™ is also a thixotropic gel because it has a time dependent viscosity.

Fanning`s equation is used for calculating the theoretical pressure needed for moving gel plugs. A rewriting of Fanning`s equation gives the equation which is used in this thesis. This equation is shown below with an explanation of the different characters:

$$P = \frac{4}{D}\tau_W \times L$$

Where:
P = pressure for moving the gel plug [bar]
D = pipe diameter [in]
τ_W = wall shear stress [bar]
L = length of the gel plug [m]

A thorough explanation of this equation and its use is seen in chapter 6.1, Theoretical pressure.

A test program for gathering accurate pumping and pressure data was planned. The aim with these tests was to figure out what pressure is needed to move gel plugs in a pipeline. The different gel plugs were placed inside 2 and 4 inch pipelines at a test site in Risavika Harbor and a 6.1 inch pipeline at IRIS research center`s test site. To figure out how gel plugs move in the pipe, and if it is possible to get water pushing the gel, to flow past the gel plug without moving it, transparent pipes were used in different tests at the University of Stavanger.

Before the tests in Risavika Harbor and at IRIS were carried out, safety margins between pressure safety valves (PSV) and calculated pressure were calculated. It was also calculated how much gel was needed. Initial to the gel tests was a tests set-up containing the P&ID (piping and instrumentation diagram), procedure and a work schedule designed. The test set up in Risavika Harbor was made of two main units, one pumping unit and one pipeline unit. The pumping unit is the same for every test, but the pipeline unit is changed between the 2 and 4 inch pipeline unit depending on which pipeline the test

was carried out in. These pipeline units were made by mounting together pup joints of different lengths to achieve two loops of the total lengths of 350 meters for the 2 inch pipeline and 250 meters for the 4 inch pipeline. At IRIS`s test site there is a 700 meter long and 6.1 inches in diameter permanent pipeline to which the pumping unit was connected. This pipeline is build by mounting together casings.

At the University of Stavanger a transparent pipe with the inner diameter of 1.57 inches was placed vertical and a rubber plug connected to a pole was placed inside the pipe. Linear gel and cross-linker was poured into the pipe. Gel plugs ranging in length from 30 cm to 120 cm were set to settle in the pipe for more than 12 hours. After gel plugs had been settling in the vertical pipe for more than 12 hours the whole pipe was moved and placed horizontally in the test set up. The rubber plug was then removed by pulling it out while rotating the pole.

The test set up consisted of a small Gilson pump, a hose which connected the Gilson pump and the 1.57 inch transparent pipe. The transparent pipe had a t-junction connection in the beginning of it. A pipe was placed vertically from this t-junction and it had a valve connected to the top of it. A hose going upwards was connected to the end of the transparent pipe at the end of the pipe which was in front of the gel plug. The reason for using the vertical pipe from the t-junction and the upwards going hose was to make it possible to fill the pipe with water both in front and behind the gel plug, which was the last to be carried out before a test was run.

The results produced by the tests in Risavika Harbor, IRIS research center and at the University of Stavanger were interpreted and presented in this thesis. There are many variables which have to be considered when interpreting the data from the gel tests. These variables are such as pipe diameter, length of gel plug, temperature, shear stress, cracks, settling time, first and second time the gel plug is set, flow of water pushing the gel plug, remains of gel in the pipeline and uncertainty of the data collected.

From these variables it is discovered that all of them had some influence on the pressure needed to push gel plugs. The variables of first and second time gel plugs are set and remains of gel in the pipeline could be neglected when the pressure needed to start moving gel plugs are calculated. If it is the first or the second time gel plugs are set has almost no influence on the pressure needed to move gel plugs. Remains of gel in the pipeline have a bigger influence on gel plugs when they are already set in motion.

The variables which need to be included, when pressure needed to move gel plugs is calculated, are pipe diameter, length of gel plug, temperature, shear stress, settling time and flow of water pushing the gel plug. It can be concluded that Fanning`s theoretical equation does not contain of enough variables to calculate the correct pressure needed to move gel plugs. This equation contains the variables; pipe diameters, length of gel plug and shear stress. Experience from the test results is that this equation lacks the variables of settling time, temperature and flow rate of water pushing the gel plug.

In the theoretical equation for calculating pressure needed to move the gel plug the influence of length of gel plug and pipe diameter is probably right. The shear stress which is seen in the equation as τ_W has the formula of $\tau_W = \frac{8\mu U}{D}$. This means that the formula for shear stress contains viscosity and velocity of the gel plug, and pipe diameter, but none of the other variables. The influence of these three variables in a new expression for shear stress which will be a part of a new equation for calculating the pressure needed to start moving gel plugs in pipelines is unknown. What is known is that in this new equation temperature, flow rate of water pushing the gel plug and settling time has to be included.

Settling time influences shear stress because the gel plug “sticks” more to the pipe wall when it settles. This will make it harder to move and gives in a way the wall more shear stress because the gel plugs “work” together with the shear stress of the pipe wall and provides more shear stress which the pump has to overcome to push gel plugs forward.

The influence of temperature on the pressure needed to move gel plugs was not measured accurately enough. What can be concluded from the gel tests is that when a pipe with a gel plug inside is exposed to temperatures below zero degrees Celsius, the pressure needed to move gel plugs will be much lower than if the pipe has not been exposed. It can also be concluded that gel plugs will not be destroyed by being moved in or influenced by the pipe being exposed to temperatures below zero degrees Celsius.

Flow rate of water given by the pump does not directly influence the shear stress, but it influences the shear stress indirectly. Too low flow rate will make the water, which is supposed to push the gel plug, flow into the crack between the top of the gel plug and the pipe wall. This crack is made because gel has a higher density than water and therefore water tends to flow on top of the gel. If the flow rate given by the pump is too low, then water will flow past the gel plug on top of it. Water can then either flow all the way across on the top if the gel or it can “drill” itself downwards in the gel plugs if there are air bubbles or bends in the pipe. When the flow rate of water given by the pump is high enough, it will “punch” the end of the gel plug so hard that it will be pushed upwards and seal the crack in top of the gel plug, making it possible to neglect the influence of this crack.

The tests carried out at the University of Stavanger in the transparent pipes showed that there are many coincidences involved in the behavior of gel plugs. It was discovered that the top of the gel plug is the first part of it to be pushed forwards by pressure coming from the water which is pushed by the pump. The whole gel plug therefore starts to move first in the top of the gel plug and last in the bottom of it.

The shape of the end of the gel plugs and if there are bubbles in it influence the pressure needed to move the gel plug. If the end of the gel plug is inclined the flow rate needed to push the end of the gel plug upwards has to be bigger than if the end of the gel plug is vertical. Because the shape of end of the gel plug is not easy to predict, it is hard to figure out if the water is going to flow on top of the gel or push it forwards. If there are air bubbles on top of the gel plug near the end of it the air bubbles will influence the pressure needed to move gel plugs because the air bubbles will help water to flow on top of the gel plug. Both air bubbles and the inclination of the end of the gel plug can cause the gel plug to split into two gel plugs.

The conclusion is that the gel tests have given much information about how gel behaves in pipes and different pressures needed to move different lengths of gel plug in pipes of different sizes. A complete equation for calculating the pressure needed to move gel plugs cannot be calculated from these results because the behavior of the end of the gel plug and the influence of temperature is not well enough documented. There are still many things to be tested before an equation which calculates the pressure needed for moving gel plugs can be constructed, but these gel tests are a step in the right direction.

2.0 Table of contents

2.1 List of characters

Latin characters

P	Pressure [bar]
D	Diameter [in]
L	Length [m]
f	Fanning`s friction factor
f_M	Moody`s friction factor
U	Velocity [m/s]
Re	Reynolds number
$\left(\frac{dp}{dx}\right)$	Fanning`s differential pressure
$\left(\frac{dp}{dx}\right)_M$	Moody`s differential pressure
V	Volume [m^3]

Greek characters

τ_W Wall shear stress [bar]
ρ Density [kg/m^3]
μ Viscosity [Pa×s]

2.2 Table of figures

2.3 Table of tables

3.0 Preface

This thesis is the final part of my master's degree in industrial economics with petroleum drilling and project management as my specializations.

First and foremost I wish to give my gratitude to all the people who have been involved in this project. I would like to give special thanks to Tor Magne Lea at Halliburton for his assistance and guidance through the execution of the gel tests and his valuable advice during the implementation of this thesis. I would also like to thank my supervisors, Rune Wiggo Time at the University of Stavanger and Evy Ann Sola Salte at Halliburton, for their assistance and helpful advice during the implementation of this thesis.

I would also like to thank Halliburton for the opportunity to write this thesis and their economical contribution. And last, but not least, I wish to thank my family, friends and classmates for their friendship, love and support during my master's degree.

4.0 Introduction

This master thesis is called “Pumping of Gelled fluid in Pipeline Applications” and is carried out on request by Halliburton Pipeline & Process Services. The reason for this thesis being carried out is that more information is needed to accurately predict the required pumping pressure to encounter when pumping gelled fluids.

Gelled fluids are typically pumped into pipelines either from a platform based temporary pumping spread or a vessel based temporary equipment spread via a 2 inch line. This line is connected to the pipeline that the gel is going to do some kind of job in.

When a gel plug is settled inside a pipe and stands still in the pipe the gel becomes static. The pressure needed in the pipe to get it moving again is an issue that needs to be considered. Pumping gelled fluids is a very big and complex theme that is big enough to be a dissertation for a doctorate. It is therefore important to set clear borders for this master thesis.

This master thesis is going to contain data considering a gel called Temblok-50™. The gel is a Halliburton produced gel that is being made by mixing a linear gel with a cross-linker. More about the Temblok-50™can be studied in chapter 5.1, Temblok-50™.

A gel is a solid, jelly-like material that can have properties ranging from soft and weak to hard and tough. Gels are defined as a substantially dilute cross-linked system, which exhibits no flow when in the steady state. More about gel and cross-linker can be found in chapters 5.0, Description of properties of the gel. [1]

Experience from Halliburton has shown that it does not take much pressure to keep the gel plug moving when it is first set in motion, compared to setting it in motion from static state. When the gel plug is flowing through the pipe the fluid that originally was in the pipe will be pushed in front of the gel plug. Some of the original liquid will make a thin layer between the pipe wall and the gel plug. This thin layer will prevent the gel from reacting with the pipe wall and therefore it will be easier to push the plug when it is already in motion. [2]

A test program was set up to provide data from situations similar to situations from real projects. The test program was designed so it would be easy to collect and compare data. It was therefore carried out by pumping three different gel plugs of length of 50, 100 and 150 meters into three different pipelines of 2, 4 and 6.1 inches in diameter.

The pipelines with 2 and 4 inches in diameter were mounted together at a test site in Risavika Harbor and the pipeline with 6.1 inches in diameter is a permanent pipeline at IRIS research center`s test site. The pipeline with 2 inches in diameter was 350 meters long, the 4 inches in diameter was 250 meters long and the 6.1 inches in diameter was 700 meters long.

For calculating the theoretical pressure needed to move the gel Fanning`s equation was used. This equation can be seen underneath and be found as equation one with explanation of the equation in chapter 6.0, Application of theoretical formulas.

Fanning`s equation:

$$\left(\frac{dp}{dx}\right) = \frac{4}{D}\tau_W$$

Fanning`s equation is used to determine the expected pressure needed to start moving the gel plug. A complete overview of the expected pressure for the different diameters of pipelines and lengths of gel plug and how the calculations are carried out can be seen in table 2 in chapter 6.1, Theoretical pressure.

The reason for calculating the theoretical pressure is both for design purposes and for using it in a comparison with the data collected from the tests.

This thesis contains an analysis on different variables that influences the pressure needed to move the gel plug. These variables are such as pipe diameter, length of plug, temperature, shear stress, cracks, settling time, first and second time the gel plug is set, flow of the water which is pushing the gel, remains of gel in the pipeline and uncertainty of the data collected. These variables and other variables that were discovered during the test are discussed in this thesis.

5.0 Description of properties of the gel

5.1 Temblok-50™

The gel that is being used in this gel study is the Halliburton produced Temblok-50™. This gel has a wide application area. It can be used among other things to set as a viscous barrier to prevent seawater ingression during tie-in or disconnection of pipelines and spools, in pipeline cleaning operations in combination with mechanical pigs due to its debris carrying capabilities, or to pick up lost objects in a pipeline. A pig is a widely accepted term for any device which is inside a pipeline and which travels freely through it, driven by the product flow. A pig is in effect a free moving piston. More about gels in general can be found in chapter 5.2, Generally about gels. [3, 4]

The Temblok-50™ is a viscous, cross-linked water based gel with an extremely tough cohesive structure developed for use where a long life material is required. It is formed by cross-linking a natural gum or its derivatives in alkaline pH conditions to produce a stable, tough viscous gel. In this system, the gum is hydrated in water prior to adding the complex agent. The base fluid is normally fresh water, but it can also be prepared with seawater and various type of brine. More about cross-linking can be found in chapter 5.3, Cross-linking. [3]

The gel is shear healing, which means it will re-crosslink after it is sheared. This means that the gel is thixotropic and has a time dependent rheology. More about thixotropic gel is found in chapter 5.5, Thixotrophy. [3]

Because of the thixotropic properties the gel is also a non-Newtonian fluid. More about non-Newtonian fluids can be found in chapter 5.4, Non-Newtonian fluids. [3]

Properties of the gel are mainly dependent on temperature. Both lab and field results show that this gel lasts at least a year at 4°C in a pipeline. To prevent freezing during winter time in the North Sea area versions of Temblok-50™ containing Glycol are mixed. Results show also that if Temblok-50™ is heated up to +30°C, this has no impact on the gel strength, but the structure breaks down by approximately 40% of strain. The gel will have some lower gel strength after being heated up and then cooled down again. [3]

A reason for the gels wide area of application is that gel can be pumped through a small restriction while maintaining its gel strength and also that all components are environmentally approved for use in the Norwegian sector of the North Sea with Klif (Klima- og forurensingsdirektoratet) classification yellow or better. Other reasons for the gels wide area of application is because it is non-corrosive and can be applied in all types of completion due to the absent of solid material in the gel. The gel can be premixed onshore and shipped in transport tanks or mixed offshore with temporary equipment on platforms or vessels. [3]

Temblok-50™ is a cross-linked gel that contains a linear gel and a cross-linker. The contents of Temblok-50™ gel and the cross-linker CL-31 that can be made public are found in chapter 12.1, Process, underneath safety sheet for both Temblok-50™ and CL-31.

5.2 Generally about gels

Gels are swollen polymer networks that possess the cohesive properties of solids and the diffusive transport properties of liquids. If some of the bonds holding the gel network together can “make and break” they are called reversible. If the bonds do not dissociate, the gel is called permanent. A permanent gel tends to carry the history of its formation in its stucture, and it is best described as a cross-linked system of clusters. Clusters range from small, starlike molecules to large, heavily cross-linked, and fairly concentrated microgel cores. [5]

Water-based gels can be obtained by cross-linking linear flexible water-soluble polymers by use of transition-metal ions. These gels are highly elastic, with 98 to 99% water content trapped in the 3D polymer structure of the gel. Water-based gels exibit a wide range of static and dynamic physical properties that make them suitable for numerous applications in the oil and gas industry, such as plugging of lost-circulation zones during drilling operations, hydralic fracturing to simulate the production of oil and gas formations, controlling excessive water- and gas-production problems, and plugging depleted wells at the end of their economic life. [5]

5.3 Cross-linking

Temblok-50™ is a cross-linked gel. Cross-links are bonds that link one polymer chain to another. Occasionally the term curing is used to denote cross-linking. The bonds between the polymers can be covalent bonds or ionic bonds. A covalent bond is a form of chemical bonding that is characterized by the sharing of pairs of electrons between atoms, and other covalent bonds. In short, the stable balance of attractive and repulsive forces between atoms when they share electrons is known as covalent bonding. An ionic bond is a type of chemical bond formed through an electrostatic attraction between two oppositely charged ions. Ionic bonds are formed between a cation, which is a positive ion and usually a metal, and an anion, which are a negative ion and usually a nonmetal. Figure 1 shows a vulcanization which is an example of a cross-linking. [6-8]

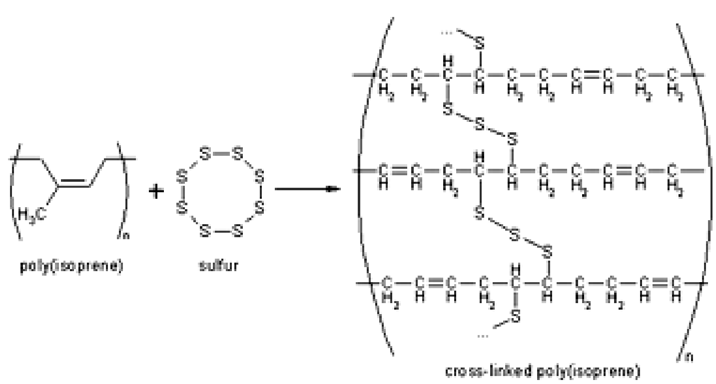

Figure 1: Vulcanization is an example of a cross-linking [7, 9]

Network polymers are also commonly referred to as cross-linked polymers. Temblok-50™ is a polymer. Because of cross-linking the polymer chain lose their ability to flow past one another and the material exhibits a considerable degree of dimensional stability. For example, a liquid polymer, that is where the chains are freely flowing, can be turned into a "solid" or "gel" by cross-linking the chains together. [7]

In polymer chemistry, when a synthetic polymer is said to be "cross-linked", it usually means that the entire bulk of the polymer has been exposed to the cross-linking method. The resulting modification of mechanical properties depends strongly on the cross-link density. Low cross-link densities raise the viscosities of polymer melts. Intermediate cross-link densities transform gummy polymers into materials that have elastomeric properties and potentially high strengths. An elastomer is a polmer with the property of viscoelasticity, generally having notably low Young`s modulus and high yield strain compared with other materials. The term, which is derived from elastic polymer, is often used interchangeably with the term rubber. Very high cross-link densities can cause materials to become very rigid or glassy, such as phenol-formaldehyde materials.[6, 7]

There are a number of ways cross-linking can be brought about, but basically they fall into two categories:

1. Cross-linking during polymerization by use of polyfunctional instead of difunctional monomers.
2. Cross-linking in a separate processing step after the linear polymer is formed.

The cross-links may contain the same structural features as the main chains, which are usually the case with the former, or they may have an entirely different structure, which is characteristic of the latter. [7]

5.4 Non-Newtonian fluids

The properties of Temblok-50™ are of a non-Newtonian fluid. A non-Newtonian fluid is a fluid which shear stress is not directly proportional to shear rate. This means that the properties of a non-Newtonian flow differ in many ways from the Newtonian fluid. A Newtonian fluid, named after Sir Isaac Newton, is a fluid whose stress versus strain rate curve is linear and passes through the origin. The constant of proportionality is known as the viscosity. How a Newtonian fluid is different from a non-Newtonian fluid when it comes to shear stress and shear rate can be seen in figure 2 underneath. [2]

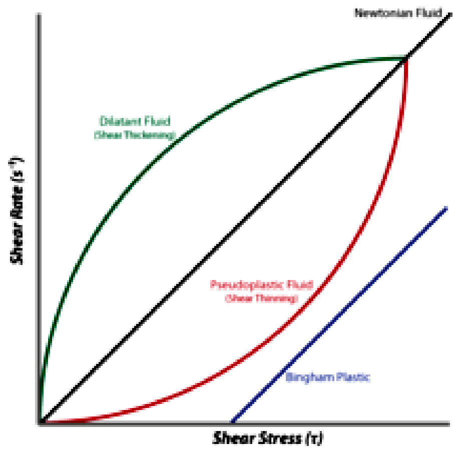

Figure 2: Difference between Newtonian- and non-Newtonian flows [2, 10]

Most commonly the viscosity of non-Newtonian fluids is not independent of shear rate or shear rate history. However, there are some non-Newtonian fluids with shear-independent viscosity, which nonetheless exhibit normal stress-differences or other non-Newtonian behavior. Many salt solutions and molten polymers are non-Newtonian fluids, as are many commonly found substances such as ketchup, custard, toothpaste, starch suspensions, paint, blood, and shampoo.[2]

In a Newtonian fluid, the relation between the shear stress and the shear rate is linear, passing through the origin, the constant of proportionality being the coefficient of viscosity. In a non-Newtonian fluid, the relation between the shear stress and the shear rate is different, and can even be time-dependent. Therefore a constant coefficient of viscosity cannot be defined. Most non-Newtonian fluids have apparent viscosity that is relatively high compared with the viscosity of water. In the case of Temblok-50™ viscosity has not been properly determined and the shear rate is time dependent. [2]

Therefore, although the concept of viscosity is commonly used in fluid mechanics to characterize the shear properties of a fluid, it can be inadequate to describe non-Newtonian fluids. They are best studied through several other rheological properties which relate stress and strain rate tensors under many different flow conditions, such as oscillatory shear, or extensional flow which are measured using different devices or rheometers. [2]

5.5 Thixotrophy

Related to non-Newtonian flow with shear thinning behavior is thixotropic liquids. These liquids which have gel-like properties or a high viscosity at low stress has the property of thinning out and hence become more workable by being stirred. The basic difference between the two is that shear thinning is dependent on shear rate, whereas thixotropic behavior is independent of shear rate, but dependent on time at a fixed shear rate. Temblok-50™ is a thixotropic gel because it has time dependent viscosity. [7]

A reversible time-dependent decrease of viscosity is termed thixotropy and a reversible time-dependent increase in viscosity is called negative thixotropy or anti-thixotropy. It shows a decrease in viscosity with time under a constant applied shear stress. This means that it has certain properties that makes it thick viscous under normal conditions, but becomes thin and less viscous over time when shaken, agitated, or otherwise stressed and can therefore start to flow. [2, 11]

Change of strain rate due to change in temperature must not be interpreted as showing thixotropy. [11]

From a practical viewpoint, thixotropic materials are seldom stable enough for an equilibrium flow curve to be determined with a great precision. During the necessary long periods of shearing, irreversible change occur. However, if an equilibrium state can be reached at a particular shear rate, this state provides a convenient datum from which the effects of resting or shearing at other rates. The initial state of a material is often less well defined because of uncertainties in the amount of unavoidable shear while the instrument is being loaded. [11]

Thixotropic fluid are in a more technical language a non-Newtonian pseudoplastic fluid that shows a time-dependent change in viscosity and the longer the fluid undergoes shear stress the lower its viscosity becomes. A pseudoplastic or shear-thinning fluid is a fluid that has an apparently lower viscosity at higher shear rates. This is usually a fluid consisting of solutions of large polymeric molecules in a solvent with smaller molecules. A thixotropic fluid is a fluid which takes a finite time to attain equilibrium viscosity when introduced to a step change in shear rate. However, this is not a universal definition. The term is sometimes applied to pseudoplastic fluids without a viscosity or time component. Many gels and colloids are thixotropic materials, exhibiting a stable form at rest but becoming fluid when agitated. [11]

The distinction between a thixotropic fluid and a shear thinning fluid is:

- A thixotropic fluid displays a decrease in viscosity over time at a constant shear rate.
- A shear thinning fluid displays decreasing viscosity with increasing shear rate.

Some fluids are anti-thixotropic. These fluids will with a constant shear stress for a time period cause an increase in viscosity or even solidification. Constant shear stress can be applied by shaking or mixing. Fluids which exhibit this property are usually called rheopectic and are much less common. More about how this thixotropy works in this case for Temblok-50™ is seen in chapter 8.0, Results of gel tests. [2, 11]

5.6 Electric van der Waal forces

The forces that occur between the pipe wall and the gel plug are not widely documented. A study of these forces could give a better understanding of the pressure needed to surmount them. After these forces are surmounted it is possible to set the gel plug in motion.

When the gel plugs is set in motion, the forces caused by the bonding between the pipe wall and the gel plugs are broken. The bonding that most likely occurs here is electric bonding called van der Waal bonding. The reason why this is the bonding that probably occurs is that there is no sign of any chemical reaction taking place or traces after a chemical reaction in the pipe or on the gel.

A van der Waal bonding is a bonding in elemental solids theory involving neither the sharing of valence electron, as in covalent bonding, nor their delocalization, as on metallic bonding. It is the sum of attraction or repulsive forces between molecules, or between parts of the same molecule. The van der Waals potential results from interaction of the electric-dipole moments of atoms which are produced by quantum-mechanical fluctuations. Although it exists for all atoms, even those without static electric-dipole moments, its effect becomes dominant at large separations for atoms with filled shells. [12, 13]

A dipole consists of two equal and opposite point charges which is in the literal sense, two poles. One of the poles is positive and the other is negatively charged. Many molecules have dipole moments due to non-uniform distributions of positive and negative charges on the various atoms. [13]

The term van der Wall forces includes:

- Force between two permanent dipoles, called Keesom force, which occurs when two atoms in a molecule have different electro-negativity. One atom attracts electrons more than the other, becoming more negative, while the other atom becomes more positive. [12, 13]
- Force between a permanent dipole and a corresponding induced dipole, called Debye force, occurs due to change when electrons happen to be more concentrated in one place than another in a molecule, creating a temporary dipole. [12, 13]
- Force between two instantaneously induced dipoles, called London dispersion force, which occurs when one molecule with permanent dipole repels another molecules electrons, “inducting” a dipole moment in that molecule. [12, 13]

More generally, an induced dipole of any polarizable charge distribution is caused by an electric field that is external. The field may for instance originate from an ion or polar molecule in the vicinity of the charge distribution. The size of the induced dipole is equal to the product of the strength of the external field and the dipole polarizability. [12]

The van der Waal bonding is in principle present in all solids, due to its relative weakness it makes only a minor contribution to the bonding in elemental covalent and metallic solids. How attractive interaction can exist lies in the fact that distribution of the electrons within an atom is not static or rigid, but rather undergoes quantum-mechanical fluctuations. Average electric-dipole moment of the atom is zero since the center of the average distribution of positive and negative charge coincides. The instantaneous dipole moment if the atom can be nonzero due to fluctuations that give rise to a non-symmetric distribution of electrons within the atom. [12]

Van der Waal forces are relatively weak compared to normal chemical bonds, but play a fundamental role in diverse fields. All van der Waals forces are anisotropic, except those between two noble gas atoms, which mean that they depend on the relative orientation of the molecules. The induction and dispersion interactions are always attractive, irrespective of orientation, but the electrostatic interaction changes sign upon rotation of the molecules. That is, the electrostatic force can be attractive or repulsive, depending on the mutual orientation of the molecules. When molecules are in thermal motion, as they are in gas and liquid phase, the electrostatic force is averaged out to a large extent, because the molecules thermally rotate and thus provide both repulsive and attractive parts of the electrostatic force. [12]

The reason why van der Waal forces are important, are that when a gel plug is settling in a pipe, what probably happens is that the molecules in the gel plug and in the pipe turn. The reason why they turn is because the negative end of the molecule wants contact with a positive end of another molecule, and opposite. When a negative end of a molecule has got in contact with a positive end of another molecule an electric van der Waal force is taking place between these two molecules.

It is possible that the longer the gel plug stays in the pipe, the more electric van der Waal reactions would take place. This could be one of the reasons why the gel is harder to move the longer it has settled in the pipe. After the gel plug is set in motion the reason why it is easier to move then could be because when it is moving, it is not that much influenced by the electric forces between the pipe and the gel plug. This could be because when the gel plug is moving, the molecules in the gel do not have time to rotate to face the opposite charge in the pipe wall.

6.0 Application of theoretical formulas

6.1 Theoretical pressure

Fanning`s equation is used for calculating the theoretical pressure needed for moving gel plugs. This equation is valid both in laminar and turbulent flow. Fanning`s equation is written in terms of wall shear stress and diameter of pipe as:

$$\left(\frac{dp}{dx}\right) = \frac{4}{D}\tau_W \qquad (1)$$

The equation is converted into the equation for pressure drop for the whole length of the gel plug by multiplying by dx on both sides of the equal sign. The following equation would then be:

$$dp = \frac{4}{D}\tau_W \times dx \qquad (2)$$

Since the differential pressure on one side of the gel plug is atmospheric pressure and the gel has a constant length dx, dp is the same as P and dx is the same as L. This gives the equation:

$$P = \frac{4}{D}\tau_W \times L \qquad (3)$$

Where:
P = pressure for moving the gel plug [bar]
D = pipe diameter [in]
τ_W = wall shear stress [bar]
L = length of the gel plug [m]

To be able to calculate the wall shear stress the friction factor has to be known. The friction factor is related to the wall shear stress by the equation:

$$\tau_W = f\frac{1}{2}\rho U^2 \qquad (4)$$

Where:
f = friction factor
ρ = fluid density
U = flow velocity

Because of the use of Fanning`s equation the friction factor for laminar flow has to be Fanning`s friction factor. This friction factor is defined as:

$$f = \frac{16}{Re} \qquad (5)$$

Where:
Re = Reynolds number.

The equation for the Reynolds number is:

$$Re = \frac{\rho UD}{\mu} \tag{6}$$

Where:
µ = fluid viscosity

If equation 5 is put into equation 4 and further into equation 1 it makes this equation:

$$\left(\frac{dp}{dx}\right) = \frac{4}{D} \times \frac{16}{Re} \times \frac{1}{2}\rho U^2 \tag{7}$$

This is Fanning`s equation for single phase laminar flow with the factional pressure gradient at constant flow velocity and constant pipe diameter. The equation for the friction factor is in this occasion the friction factor found in equation number 5.

Equation 7 contains the term $\frac{4}{D}$. This is based on friction factor of the Fanning type. There is an alternative to this term called the Moody friction factor. In Moody`s equation the Moody friction factor "absorbs" the number 4 into the friction factor. Moody`s equation is written as:

$$\left(\frac{dp}{dx}\right)_M = \frac{1}{D} \times \frac{64}{Re} \times \frac{1}{2}\rho U^2 \tag{8}$$

For laminar flow Moody`s friction factor is:

$$f_M = \frac{64}{Re} \tag{9}$$

By comparing equation 7 and 8 it is seen that they can both be used and gives the same result. In the calculations in this master thesis only Fanning`s is going to be used.

When calculating with laminar flow the friction factor is exact and can be calculated theoretically, as a result of the well defined parabolic velocity profile. In turbulent flow the friction becomes larger. This is due to the velocity profile becoming more uniform causing a larger velocity fall-off towards the pipe wall and thus a larger shear. [14, 15]

To calculate the pressure for moving gel plugs in pipelines the viscosity, velocity, density of the fluid and the diameter and length of the gel plug must be know. Fanning`s equation for laminar flow is used because Reynolds number is so low that is has to be laminar flow. The Reynolds number has to be over 2000 for it to be other than laminar flow and it is not anywhere near of becoming this high. Underneath is seen an example of the calculations which was done prior to the field tests. [14, 15]

Example of calculation for 2 inch pipeline with 50 meters gel plug

Underneath in table 1 the properties of Temblok-50™ are seen. These properties have been used in the calculations. The viscosity of the gel is set to 150 Pa×s. This is not a confirmed number because no one knows exactly what the viscosity of Temblok-50™is. This number was selected by calculating backwards in calculations done for other gel projects with the same gel and it could be wrong because the other calculations were not tested when the project was carried out. The velocity that the gel plug is set to start moving on is 0.1 m/s. This velocity is set to be 0.1 m/s because of simplicity reasons. This is an easy and approximately correct assumption that the gel plug would start moving at this velocity.

Table 1: Properties of Temblok-50™

Fluid density ρ (kg/m^3)	1010
Fluid velocity U (m/s)	0,1
Fluid viscosity μ (Pa×s)	150

The first thing to calculation is the Reynolds number. This is used to find out if the gel is flowing with laminar of turbulent flow. The properties of the gel are calculated into equation 6:

$$Re = \frac{1010kg/m^3 \times 0{,}1m/s \times 0{,}0508m}{150Pa \times s} = 0{,}03421$$

Because the Reynolds number is less than 2000 there is a laminar flow and equation number 5, which is Fanning`s friction factor for laminar flow is used:

$$f = \frac{16}{0{,}03421} = 477{,}76$$

Further the wall shear stress has to be known. It is calculated by putting Fanning`s friction factor into equation 4:

$$\tau_W = 477{,}76 \times \frac{1}{2} \times 1010kg/m^3 \times 0{,}1^2 m/s = 2362\ Pa$$

Last the pressure for moving the gel plug is calculated by putting the shear stress into equation number 3:

$$P = \frac{4}{0{,}0508m} \times 2362Pa \times 50m \times 0{,}00001bar/Pa = 93bar$$

A complete table of all the pressures that have been calculated for different lengths of gel plugs and different diameters of pipes is seen underneath in table2. First column to the left is the lengths of the gel plugs. First row is the diameter of the pipes and the gray colored windows are the theoretical pressures in bars for moving the gel plugs.

Table 2: Theoretical pressures for moving gel plugs (bar)

Length (m)/Diameter(in)	2	4	6,1
50	93	23	10
100	186	47	20
150	279	70	30

6.2 Theoretical influence of pipe diameter

To find an answer to how much pipe diameter influences the pressures needed to move the gel plugs Fanning`s equation is used. The equation is seen in chapter 6.1, Theoretical pressure as equation number one.

By using the equation and calculating the expected pressure for each diameter of pipe in intervals of one inch and using a constant gel plug length it is possible to make a table and a graph for the theoretical influence of diameter of pipes. The table for influence of pipe diameter on theoretical pressures is seen underneath as table 3.The lengths of gel which are being used, are 50, 100 and 150 meters. It is seen in table 3 that when the diameter of the pipe is increased, the theoretical pressure will decrease. The column to the right shows that the pressure does not decrease linearly.

Table 3: Influence of pipe diameters

Diameter of pipes (in)	Theoretical pressure, gel plug of 50 meters(bar)	Theoretical pressure, gel plug of 100 meters(bar)	Theoretical pressure, gel plug of 150 meters(bar)	Decrease from previous diameter of pipe (%)
1	372,00	744,00	1116,00	
2	93,00	186,00	279,00	0,75
3	41,33	82,67	124,00	0,56
4	23,25	46,50	69,75	0,44
5	14,88	29,76	44,64	0,36
6	10,33	20,67	31,00	0,31
7	7,59	15,28	22,78	0,27
8	5,81	11,63	17,44	0,23
9	4,59	9,19	13,78	0,21
10	3,72	7,44	11,16	0,19

By drawing a graph of the influence and making a trend line it is seen that the graph follows a power trend. The graph for the 50 meter gel plug is seen as figure 3 beneath. In this figure the formula for trend line is seen as:

$$y = 371{,}95x^{-2} = \frac{371{,}95}{x^2}$$

In general this formula would be $y = Ax^{-2}$ where:
y = theoretical pressure in bar
A = theoretical pressure of one inch pipe with given gel plug length
x = size of pipe

The reason why it is possible to use this formula is that the trend line is following the line of the theoretical pressure.

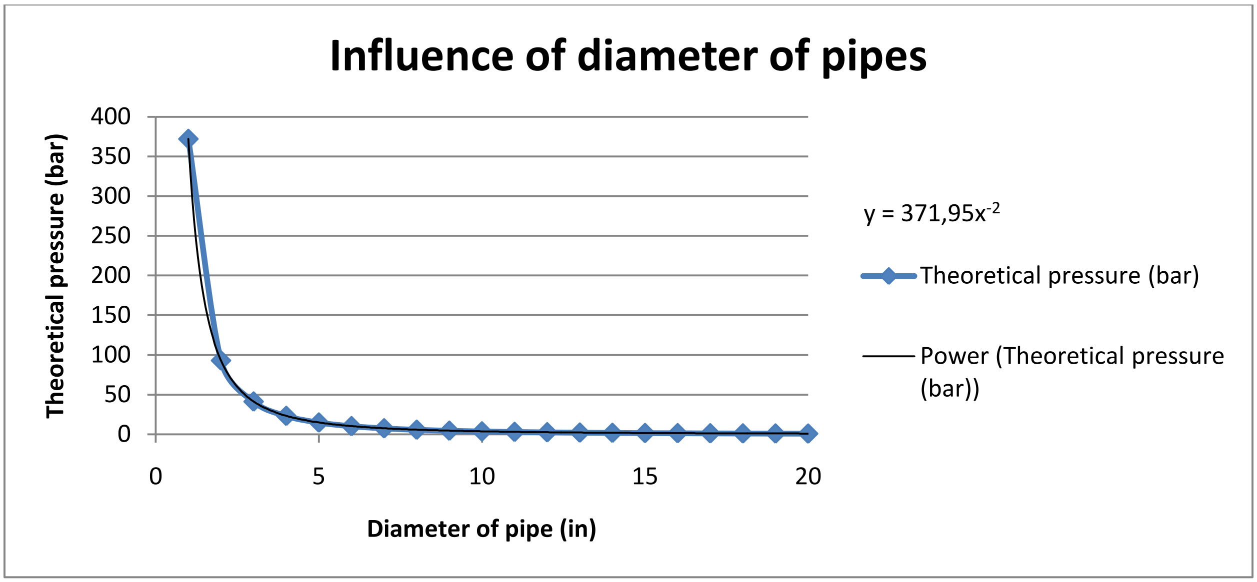

Figure 3: Influence of pipe diameters

There will be a different graph for each length of gel plug, but the trend line of the graph is going to be the same with only the difference of height. This is because the trend line is depending on the theoretical pressure of the given length of gel plug in a one inch pipe.

It is also possible to derive the formula for the trend line by using Fanning`s equation seen in chapter 6.1 as equation 1 and setting every variable as a constant except the diameter of the pipe. The equation derived is seen underneath as equation 10 and is the general equation for the trend line with the pipe diameter as the variable:

$$P = \frac{32\mu UL}{D^2} \tag{10}$$

6.3 Theoretical influence of lengths of gel plugs

For calculating the theoretical pressure depending on the length of the gel plug Fanning`s equation is used in the same matter as for calculating the influence of the pipe diameter. A table and a graph are made for the pipe diameter which was used in the tests. Table 4 seen underneath shows the influence of length of gel plugs on the theoretical pressures.

The first column to the left shows the lengths of gel plugs and the other columns show the theoretical pressures that are expected for the different pipe diameters. The first row shows the different diameter of pipes that are being used. It is seen that the theoretical pressure for moving the gel plug is increasing when the length of the gel plug is increasing.

Table 4: Theoretical pressures as a function of lengths of gel plugs

	2 inch	4 inch	6,1 inch
25 meters	47	12	5
50 meters	93	23	10
75 meters	140	35	15
100 meters	186	47	20
125 meters	233	58	25
150 meters	279	70	30
175 meters	326	81	35
200 meters	372	93	40

Figure 4 shows the graphs, trend lines and formulas made from table 4. It shows the influence of the different lengths of gel plugs in the different diameters of pipes.

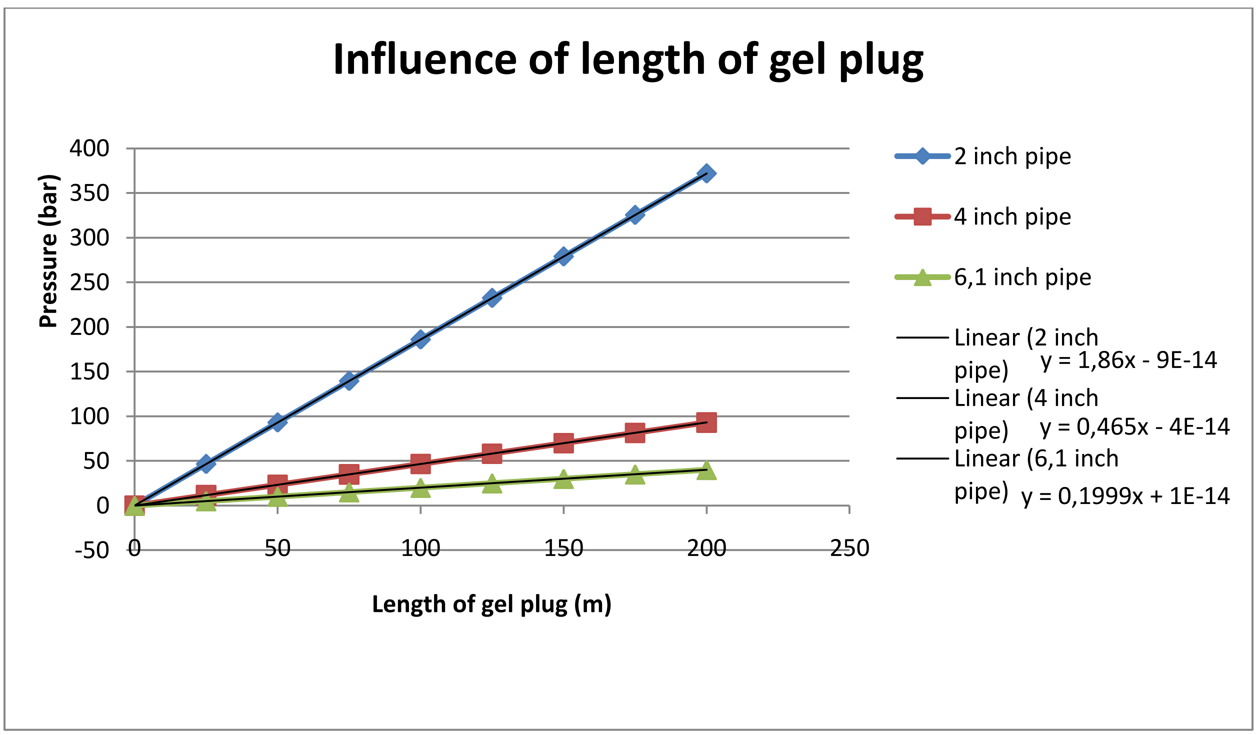

Figure 4: Influence of length of gel plugs

As seen in figure 4 the length of the gel has a linear influence on the theoretical pressure. There is a different line with different inclination for every pipe diameter. It is also seen that the trend line from the 2 inch pipe has the formula:

$y = 1{,}86x.$

In general the formula is: $y = Bx$ where:
y = theoretical pressure
B = slope of the graph which equals $B = \frac{dP}{dL}$ where dP is the difference between the pressure at two specific points on the graph and dL is the length of gel plug given in the same specific points on the graph.
x = length of gel plug

As mentioned there will be a different slope for every pipe diameter.

The influence of the lengths of gel plugs can be derived as well by using Fanning`s equation seen in chapter 6.1, Theoretical pressure, as equation 1 and setting every variable as a constant except the length of gel plug. The derived equation is seen as equation number 10 in the previous chapter.

7.0 Experimental procedure for gel tests

A test program for gathering accurate pumping and pressure data was planned. First a P&ID was drawn. P&ID is a piping and instrumentation diagram and is schematic diagram showing piping, equipment and instrument connections. It is used within process units in oil refineries, petrochemical and chemical plants, natural gas processing plants, power plants, water treatment and other similar plants. The P&ID is designed with the intention of making the gel tests as easy and efficient as possible. It is seen in the procedure in chapter 12.2, Gel pumping procedure. [16]

The aim with these tests is to figure out what kinds of pressures are needed to move gel plugs in a pipeline. It was decided to use gel plugs with lengths of 50, 100 and 150 meters. The different gel plugs were placed inside 2 and 4 inch pipelines at a test site in Risavika Harbor and a 6.1 inch pipeline at IRIS research center`s test site.

Before the tests in Risavika Harbor and at IRIS were carried out, safety margins between PSVs and calculated pressure and calculations of how much gel was needed were implemented. These calculations are seen in chapters 7.3, Safety margin between PSV and calculated pressure, and chapter 7.4, Calculation of needed gel.

7.1 Experimental procedure for gel tests in Risavika Harbor

To carry out the tests a test set-up containing the P&ID, procedure and a work schedule was designed. The test set up at Risavika Harbor contained three pumps and two loops of pipes. It also contained hoses and valves rising in size from ¼ to 4inches. The test set up was made of two main units, one pumping unit and one pipeline unit. The pumping unit is the same for every test, but the pipeline unit is changed between the 2 and 4 inch pipeline unit depending on which pipeline the test were carried out in. The two loops and the valves and connections out of the pumps are seen in figure 5 underneath.

The reason why three different types of pumps were used was because there were different purposes for each of the pumps. One pump, the Haskel ASF-60, was used to build up pressure slowly when the tests were run in the 2 inch pipeline. Another pump was used for pumping cross-linker. This was also a Haskel ASF-60 pump, but this pump had a different pumping rate compared to the first Haskel ASF-60 pump. This is why the same pump could not be used for both purposes. The last pump used was a big pump called HT-400. This pump was used to fill up the pipe with water, pumping linear gel into the pipelines and performing the tests in both pipes when it was discovered that the Haskel ASF-60 pump gave too low flow rate compared to the flow rate which was needed to perform the tests, with the exception of the 50 meter gel plug in 2 inch pipe. Picture and properties of every pump is also seen in chapter 12.2, Gel pumping procedure.

The tests are carried out by pumping linear gel and cross-linker into the pipeline unit to make the different gel plugs. Before the linear gel and cross-linker was pumped, both linear gel and cross-linker were primed as described in chapter 12.2, Gel pumping procedure.

When the gel plugs were placed to settle in the pipes they were placed ten meters into the pipes. This was done with the purpose of getting a constant pressure over the whole end of the gel plug. The pressure was given by the HT-400 pump. Placing of the plug ten meters into the pipe was also done because it would prevent gel from settling in valves and prevent a high peek on the pressure readings. This sort of peek is seen in chapter 8.1, Influence of shear stress from gel plugs with at least 12 hours settling time.

Figure 5: Test loops and connections out of pumps

Previous to pumping linear gel and cross-linker, the pipeline had to be pressure tested to check for leakages. The HT-400 pump was used for the leakage tests for both the 2 and 4 inch pipeline. Water was used to perform the leakage tests. The whole leakage test procedure is described in chapter 12.2, Gel pumping procedure.

The pumping unit consisted of one main line and one test line together with the three different pumps, tanks, flow meters, pressure gauges, valves, hoses and pipes. The main line was where the HT-400 pump was placed and two flow meters, pressure gauges and pressure recorders were connected to this line to monitor the line.

The test line had a Haskel ASF-60 pump, flow meter, pressure gauge and pressure recorder were placed on the test line as well for monitoring the line. The set up for the main line and the test line is seen in chapter 12.2, Gel pumping procedure.

The pipeline unit of 2 and 4 inches are made by mounting together pup joints of different lengths to achieve two loops of the total lengths of 350 meters for the 2 inch pipeline and 250 meters for the 4 inch pipeline.

The reason why the 2 and 4 inch pipeline tests are carried out before the tests at IRIS is that the tests are going to be carried out on Halliburton`s test site. It was desired to have experience from these tests when going to IRIS where it was more expensive to carry out the tests. The 50 meter gel plug was the first plug that was tested because the theoretical pressure for moving gel plugs are lower the shorter the gel plugs are.

It was decided to carry out the 2 inch pipeline tests first because these were the hardest to carry out regarding theoretical pressure and safety margin and it was thought to be best to be done with the hardest ones as early in the test period as possible. Safety margin is calculated as the margin between the theoretical pressure and the pressure that the test set up is able to endure. The calculations for safety factors are seen in chapter 7.3, Safety margin between PSV and calculated pressure.

The settling time for the gel plugs was varied and if possible they were repeated two or three times. After doing one gel test it was seen how much pressure was needed to move the gel plug compared to the theoretical pressure and if it was possible to do the next gel test as well. The restrictions on the test set up decided whether it was possible to carry out the new test or not.

After completing the tests in the 2 and 4 inch pipelines, the test set up was stripped down and the pumping unit and the needed equipment for the IRIS tests were moved to IRIS`s test site.

7.2 Experimental procedure for gel tests at IRIS research center

At IRIS`s test site there is a 700 meter long and 6.1 inches in diameter permanent pipeline, which is built by mounting together casings. The pumping unit was connected to this pipeline. Figure 6 shows the pumping unit and the connection between the pumping unit and the pipeline.

Figure 6: Pumping unit set up

The test line which was used during the tests in Risavika Harbor was not used at IRIS. This was because the 6.1 inch pipe was too big for the Haskel ASF-60 pump that was used in the test line set up.

The test set up will therefore be the same as seen in the P&ID in chapter 12.2, Gel pumping procedure, except for the test line which is missing.

The procedure for the tests at IRIS was the same as for the tests in Risavika Harbor and is seen in chapter 12.2. When all the tests were carried out the test set up was stripped down and data from all the tests were collected and analyzed.

7.3 Safety margin between PSV and calculated pressure

The PSV (pressure safety valve) for the 2 and 6.1 inch pipelines in the test set up is 345 bars and for the 4 inch pipeline test set up are 125 bars. The PSV is set to the highest pressures the whole test set up that every diameter of pipeline can endure. The reason that the 4 inch pipeline has a smaller PSV is that the pipe unit used in this test set up tolerates less pressure then the pipelines used in the 2 and 4 inch pipelines test set up. Safety margin is the percentage of the theoretical pressure it is possible to increase the pressure with before the test set up will fail. The formula for calculating the safety margin is:

$$Safety\ margin = \left(\frac{PSV}{Theoretical\ pressure} - 1\right) \times 100 \quad (11)$$

Underneath is an example of how the safety margin for gel plug of 50 meter length in 2 inch pipeline is calculated:

$$Safety\ margin = \left(\frac{345bar}{93bar} - 1\right) \times 100 = 270\%$$

This means that the theoretical pressure calculated can be increased with 270% before the test set up will fail.

A complete table of the safety margin for the different gel plugs is seen in table 5 underneath. As for theoretical pressure, first column to the left is the lengths of the gel plugs and first row is the pipe diameters. The gray colored windows are here the safety margin between the theoretical pressures and the PSVs measured in percentage.

Table 5: Safety margin between theoretical pressures and PSVs (%)

	2 inch	4 inch	6,1 inch
50 meters	271	438	3351
100 meters	85	169	1625
150 meters	24	79	1050

The safety margin is also calculated in bars by subtracting the theoretical pressures from the PSV pressures for every pipe diameter and every lengths of gel. The result is seen in table 6 below and the gray colored windows are the safety margins and are measured in bars.

Table 6: Safety margins between theoretical pressures and PSVs (bar)

	2 inch	4 inch	6,1 inch
50 meters	252	102	335
100 meters	159	78	325
150 meters	66	55	315

7.4 Calculation of needed gel

Because it has to be known how much gel in total, linear gel and cross-linker that is needed for the gel tests this has to be calculated. The volume needed is calculated by assuming that the pipelines are completely full of gel at the lengths of gel that is being used in the different tests. To calculate the volume that is needed this formula is used:

$$V = \pi \frac{D^2}{4} L \tag{12}$$

Volume needed for the different diameters of pipelines and lengths of gel plugs and the total needed volume is seen underneath in table 7. The rows and columns are the same as for the two previous tables, but here the gray windows are volumes of cross-linked gel in cubic meters and the two last lines are the total volume of cross-linked gel that are needed for all the tests given in both cubic meters and liters. It is calculated that because of the length of the 2 and 4 inch pipelines it is needed 3 gel plugs of every combination of length of gel and diameter of pipeline. Gel needed for the 2 and 4 inch pipeline tests was first ordered and then after these tests were done, the remains of gel were transported to the test site with the 6.1 inch pipeline and the rest of gel that was needed for these tests was ordered. These tests are going to be run with only one gel plug of every length of gel plug. This is because the pipeline is so long that it is possible to run all tests needed without any gel coming out at the other end of the pipeline.

Table 7: Volume of cross-linked gel (m^3)

	2 inch	4 inch	6,1 inch
50 meters	0,3040	1,2161	0,9427
100 meters	0,6080	2,4322	1,8855
150 meters	0,9121	3,6483	2,8282
Total (m^3):	14,7771		
Total (liter):	14777		

The volumes of linear gel needed are for simplicity calculated as the same volume needed to fill the whole pipelines with the different lengths of gel plugs. Cross-linker that is needed is calculated by multiplying the volume needed for the different lengths of gel plugs with 1%.

The mixing rate for the gel is that cross-linker is 0.75% of the volume of linear gel that is being used. When the volume of linear gel and cross-linker are calculated as said in the previous section the gel plug would be a little longer than the theoretical plug, but because it would only influence the length of the plug by a few centimeters. It is therefore negligible and uncertainty in the volume given by the different pumps would influence the lengths of gel plugs more than the adding of cross-linker.

7.5 Experimental procedure for gel tests at the University of Stavanger

The experiments at the University of Stavanger was carried out to figure out how gel plugs are moving in the pipe and if it is possible to get the fluid that pushed the gel to flow past the gel plug without moving it. Transparent pipes were used to see what happens in the pipe. Data and test log from these tests are found on the CD attached to the thesis.

Figure 7: Settling of gel plug at UiS

First the setting of the gel plug. A transparent pipe with the inner diameter of 1.57 inches was placed vertical and a rubber plug connected to a pole was placed inside the pipe. The reason for placing the rubber plug a distance into the pipe was that it would make it easier to see the effects on the gel plug and for the purpose of getting a constant pressure over the whole end of the gel plug, as mentioned in chapter 7.1, Experimental procedure for gel tests in Risavika Harbor. Linear gel and cross-linker was poured into the pipe from the highest end of the pipe. Gel plugs ranging in length from 30 centimeters to 120 centimeters were set to settle in the pipe for at least 12 hours. Figure 7 seen to the right shows setting of a gel plug in transparent pipe.

After gel plugs had been settling in the vertical pipe for at least 12 hours the whole pipe was moved and placed horizontally in the test set up. The rubber plug was then removed by pulling it out by the pole while rotating the pole. It was rotated to prevent vacuum loosening the gel plug.

The test set up consisted of a small Gilson pump, which is a piston pump that can pump pressure up to 8 MPa. A hose connected the Gilson pump and the 1.57 inch transparent pipe. The transparent pipe had a t-junction connection in the beginning of it. A pipe was placed vertically from this t-junction and it had a valve connected to the top of it. This was the only valve in the test set up. A hose going upwards was connected to the end of the transparent pipe at the end of the pipe which was in front of the gel plug. The reason for using the vertical pipe from the t-junction and the upwards going hose was to make it possible to fill the pipe with water both in front and behind the gel plug.

The height of the vertical pipe connected to the t-junction and the end of the upward going hose in the end of the transparent pipe was 35 centimeter higher than the top of the transparent pipe. The purpose of the valve was to make it possible to fill colored pink water behind the gel plugs and to provide a closed system behind the gel plugs when the valve was closed.

When the pipes in the test set up were filled up with pink colored water behind the gel plug and uncolored water in front of it, the valve was closed, making the test set up a closed system with one open end in front of the gel plug. This means that it was possible to build up pressure behind the gel plugs and have constant back pressure in front of the gel plugs.

Pink colored water was used behind the gel plug and uncolored water in front of the gel plugs because this made it easier to see how the fluid behind the gel plug behaved when flow and pressure influenced the gel plugs. Because the gel plug has a lighter color than the pink colored water it is easy to see how the gel plug moves and if there is any influence on the gel plug by the water pushing it. It will also make it possible to see if the pink colored water is able to move past the gel plug without moving the gel plug. Figure 8 underneath shows the whole test set up which was used during gel tests at the University of Stavanger.

Figure 8: Test set up at UiS

A camera was set up to provide pictures of what was happened in the pipe and a pressure gauge was mounted to provide pressure readings. The tests were carried out after the pipe was filled up with water at both ends of the gel plugs and the valve on top of the vertical pipe connected to the t-junction was closed.

When all of this was done, the pressure recorder and the camera were started before the pump was started. The pump is set to provide a pink colored water flow of 10, 50 or 100 ml/min. Pictures were taken and pressure was recorded when the tests were carried out.

When one test was finished the gel plug was flushed out of the pipe and the transparent pipe was disconnected from the upward going hose and the t-junction. It was cleaned by flushing water at high velocity through it while it was rotated. The pipe was then placed vertically again and a new gel plug was made using the same procedure as for the previous one. After all the gel tests were carried out the whole test set up was stripped down and data from all the tests were collected and analyzed.

8.0 Results of gel tests

In this chapter the results of large scaled gel tests carried out in Risavika Harbor and IRIS will be interpreted. There will also be an interpretation of results from small scaled tests carried out during the large scaled gel tests and at the University of Stavanger.

There are many variables that have to be considered when interpreting the data from the gel tests. These variables are such as pipe diameter, length of gel plug, temperature, shear stress, cracks, settling time, first and second time the gel plug is set, flow of water pushing the gel plug, remains of gel in the pipeline and uncertainty of the data collected. Other parameters which were observed during the gel tests will also be discussed in this chapter.

With so many variables it is not easy to interpret them all at the same time. It is therefore a good idea to neglect some of the parameters. Some of the parameters are not as good documented as others are and are therefore easy to leave out. The first that is done is to say that the pressures needed to move the gel plugs in the pipelines is only depending on the shear stress.

8.1 Influence of shear stress from gel plugs with at least 12 hours settling time

The reason for starting with only the shear stress is that when comparing shear stress it is possible to compare the different gel plugs with each other independent of lengths of gel plugs. The formula being used for the comparing is Fanning`s equation, it is seen as equation 1 in chapter 6.1, Theoretical pressure. Fanning`s equation has to be rewritten for the purpose of using it in this comparison, and a rewriting of equation number 3 in chapter 6.1 gives the equation:

$$\tau_W = \frac{P \times D}{4L} \tag{13}$$

By combining equations 4, 5 and 6 in chapter 6.1, Theoretical pressure, the equation for theoretical pressure is seen as:

$$\tau_W = \frac{16}{\frac{\rho U D}{\mu}} \times \frac{1}{2}\rho U^2 \rightarrow \frac{8\mu U}{D} \tag{14}$$

It is seen from this that if the velocity of the gel plugs is constant, then there will be a different shear stress for every diameter of pipe. The theoretical calculations for shear stress for moving the gel plugs are found in chapter 6.1, Theoretical pressure.

The tests that were carried out in Risavika Harbor and at IRIS had pipelines with diameters of 2, 4 and 6.1 inches. The comparison between the different shear stress are going to be a comparison between different gel plugs that have been settling in the pipes for over 12 hours and are going to be moved for the first time. Every test is carried out with a HT-400 pump. Specifications for the HT-400 pump are found in chapter 12.2 Gel pumping procedure.

It is seen in chapter 12.1, Data from gel tests in Risavika Harbor and IRIS research center that in many tests a peek in the pressure right after the pump is set in motion will occur. The peek is going approximately straight up and then straight down again. An example of such a peek is seen underneath in figure 9. This peek happens when the gel plug starts to move. The peek cloud be made either because when the pump has a high flow it will sort of punch the gel plug and it will take a couple of seconds after this punch before the gel plug starts to move. Or it could be made due to the pressure wave momentarily pushing up the velocity of the gel. This peek in pressure is much higher than the pressure needed for moving the gel. When determining the pressure needed to move the gel plug this peek must be taken into consideration.

When determining what kind of pressures needed for moving the gel plugs a little notch on every peek is used. This notch is on the side of the peek where the pressure is going down again. When the notch is not easy to see, data pressure recordings which are seen on the CD following this thesis are used. The notch is what is interpreted as the pressure needed for moving the gel. A correct gradual build up of pressure over a short time is also going to produce a peek in the beginning of the tests when the gel plugs are set in motion, but this peek will be as shown in figure 10 much more like a lump and not just strait up and down again.

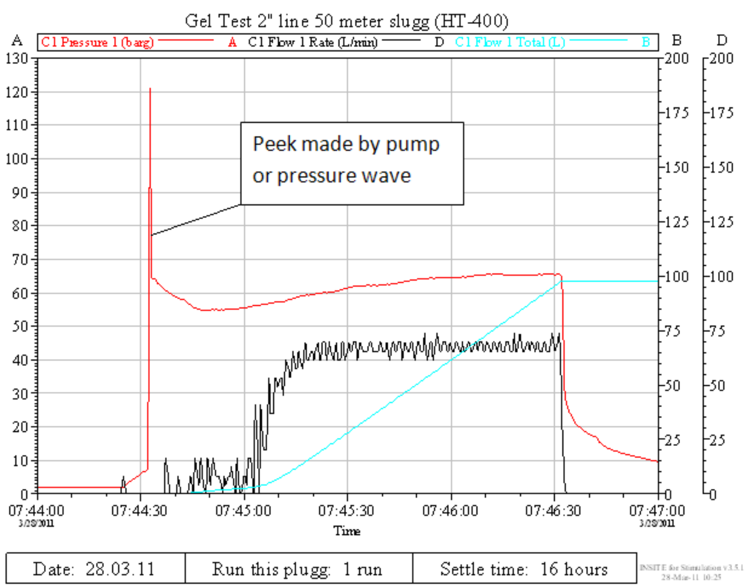

Figure 9: Peek made by pump or pressure wave

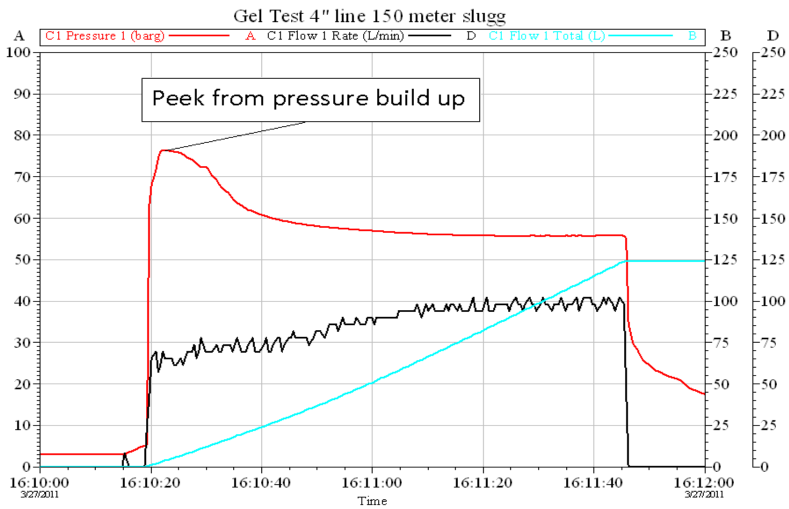

Figure 10: Peek from pressure build up

A table for the interpreted pressures needed to start moving the gel plugs and the theoretical pressures calculated for the pressures needed to start moving the gel plugs is made by using the data collected after the gel plugs have been settling for at least 12 hours and are being pumped by the HT-400 pump. These data are chosen because these are the most stabile data being least influenced by variables which have been mentioned in this chapter and were considered constant in this comparison. The collected data from the tests and the theoretical pressures found in chapter 6.1 is seen in table 8 underneath.

Table 8: Comparing pressure results from gel tests with more than 12 hours of settling time with theoretical pressures

Diameter (in)	2	4	6,1
50 meter plug			
Theoretical pressure (bar)	93	23	10
Result from test (bar)	64	38	10
100 meter plug			
Theoretical pressure (bar)	186	47	20
Result from test (bar)	149	53	20
150 meter plug			
Theoretical pressure (bar)	279	70	30
Result from test (bar)	200	77	37

The first comparing of the data collected in table 8 is going to be used in equation 11, found in this chapter. By using shear stress it will be possible to compare the different lengths of gel plugs with each other to find out if there is a connection between the length of the gel plugs and the pressure needed to move them. The theoretical shear stress for the different diameters of pipes and lengths of gel plugs is seen in the gray windows underneath in table 9 and is measured in bars.

Table 9: Theoretical shear stress (bar)

	2 inch	4inch	6,1 inch
50 meters	0,02362	0,01181	0,00775
100 meters	0,02362	0,01181	0,00775
150 meters	0,02362	0,01181	0,00775

It is seen from table 9 that in theory the same shear stress will appear for every length of gel plugs, but there are different shear stresses for every diameters of pipe. The reason for this is because shear stress is depending on diameter of pipe as seen in equation 12 in this chapter.

The shear stresses are calculated from the pressures measured in the tests by using equation 11 in this chapter and is seen in table 10 underneath.

Table 10: Shear stress collected from tests with settling time of at least 12 hours (bar)

	2 inch	4inch	6,1 inch
50 meters	0,01626	0,01930	0,00775
100 meters	0,01892	0,01346	0,00775
150 meters	0,01693	0,01304	0,00955

8.1.1 The 2 inch pipe with gel plugs with settling time of at least 12 hours

It is seen that for the 2 inch pipe every result of the shear stresses from the tests is lower than the theoretical shear stress for this diameter of pipe. Even the highest result collected from the test is much lower than the theoretical shear stress.

Uncertainty is also an issue to be considered. Because of the length of the different gel plugs, a miss in interpreting the result by one bar in the 50 meter test will have a bigger consequence for the result than a miss by one bar in the 150 meter test.

There are two results which are almost the same and one a little higher than the others. The one result that is higher than the others are not so high that it would be considered as a bad result. By calculating the average of the results an average of 0.01737 bars is found. This is much less than the 0.02362 bars in average calculated from the theoretical formula.

The percentage difference in the average of shear stress calculated from the test results and the theoretical shear stress is calculated to be:

$$\frac{0{,}01737bar - 0{,}02362bar}{0{,}02362bar} \times 100 = -26{,}46\%$$

It is from the results of the tests a 26.46% lower shear stress than the theoretical shear stress. This indicates that there are other variables influencing the gel plugs than only the shear stress or wrong use of shear stress in the formula. This will be discussed later.

8.1.2 The 4 inch pipe with gel plugs with settling time of at least 12 hours

The 4 inch pipe has two results that are approximately the same. These are for the 100 and 150 meter gel plugs. For the 50 meter gel plug there is a higher result than the others. By looking at tables 9 and 10 it is seen that all three results are higher than the theoretical shear stress. From this the average of all the test results are calculated to be 0.01527 bars.

The percentage difference of shear stress from the 4 inch pipe results and the theoretical shear stress are calculated:

$$\frac{0{,}01527bar - 0{,}01181bar}{0{,}01181bar} \times 100 = 29{,}27\%$$

This shows that the test results give a 29.27% higher shear stress than the theoretical shear stress.

8.1.3 The 6.1 inch pipe with gel plugs with settling time of at least 12 hours

As seen in table 10 the shear stress from test results for the 50 and 100 meter gel plugs are the same as the theoretical shear stress. Shear stress from the 150 meter gel plug is higher than the other two. This test had a very high peek caused by the pump. The average of shear stress in the 6.1 pipe is 0.00835 bars and it is lower than the theoretical shear stress.

The percentage difference of shear stress and the theoretical shear stress:

$$\frac{0{,}00663bar - 0{,}00775bar}{0{,}00775bar} \times 100 = -14{,}44\%$$

It is shown from the results of the test results a 14.44% lower shear stress than the theoretical shear stress.

8.1.4 Shear stress from gel plugs with at least 12 hours settling time multiplied by diameter of pipe

The percentage deviation between the theoretical shear stress and the shear stress calculated from the test results are difficult to compare with each other because of influenced of diameter of pipe. To be able to do this comparison the influence of diameter of pipe has to be neglecting. This is done by multiplying equation 14 on each side of the equal sign with D. This makes the equation:

$$\tau_W D = 8\mu U \tag{15}$$

By using equation 15 the table for shear stress, but without the influence of diameter of the pipe is made. The table is seen bellow as table 11 and the denomination of the gray squares is bar × m. The table has the same design at earlier tables.

Table 11: Theoretical shear stresses multiplied with diameters of pipes

	2 inch	4inch	6,1 inch
50 meters	0,00120	0,00120	0,00120
100 meters	0,00120	0,00120	0,00120
150 meters	0,00120	0,00120	0,00120

It is seen that the theoretical shear stress multiplied by the diameter of the pipe neglects the influence of diameter of pipe on shear stress and makes it possible to compare the different pipe sizes with each other.

Table 12 beneath is calculated by using equation 16, seen beneath, and calculating back from the pressure measured in the tests. Equation 16 is seen as:

$$\tau_W \times D = \frac{P \times D^2}{4L} \tag{16}$$

Table 12: Shear stresses multiplied by diameters of pipes calculated from test results with settling time of at least 12 hours

	2 inch	4inch	6,1 inch
50 meters	0,00083	0,00196	0,00120
100 meters	0,00096	0,00137	0,00120
150 meters	0,00086	0,00132	0,00148

By neglecting the diameter of the pipe a percentage deviation from the theoretical gives a more precise view of the deviation from the theoretical shear stress multiplies by diameter of pipe. By using the values of the different categories in table 12 the average of the shear stress in both pipe size and length of gel can be calculated. These averages for the different diameters of pipes and the average of different lengths of gel plugs and average of all the tests are seen underneath in table 13.

Table 13: Average of shear stress multiplied by diameter of pipe calculated from result of gel tests

Category	**Average**
50 meters	0,00133
100 meters	0,00118
150 meters	0,00122
2 inch	0,00088
4inch	0,00155
6,1 inch	0,00129
Total average	0,00124

It is noted that the average of shear stress multiplied by diameter of pipe for the length of gel plug at 50 meter is bigger than the theoretical shear stress multiplied by diameter of pipe. The 100 and 150 meter are almost the same as the theoretical shear stress multiplied by the diameter of the pipe. It is also noted that the average of shear stress for the 2 inch pipe is lower than the theoretical shear stress multiplied by diameter of pipe and for 4 and 6.1 inch pipe is higher. The influence of length of gel plug and diameter of pipe will be looked closer into in chapter 8.3 and 8.4. It is also seen in table 13 that the average of shear stress multiplied by diameter of the pipe for every test result is almost the same as the average of the theoretical shear stress multiplied by diameter of the pipe.

8.2 Influence of shear stress from gel plugs with 2 hours settling time

Until now it has only been interpreted data from gel plugs which has been settling for over 12 hours. The data seen in chapter 12.1, Data from gel tests in Risavika Harbor and at IRIS research center, give clear indications that settling time has an impact on the pressure needed to move the gel plugs. This issue will now be looked more into, starting with the influence of shear stress for gel plugs which have been settling in the pipe for 2 hours. Most of these plugs have already been moved once after a first time settling period of over 12 hours.

The data that have been collected for the 2 hours settling time is seen in table 14 underneath.

Table 14: Comparing pressure results from gel tests with 2 hours of settling time with theoretical pressures

Diameter (in)	2	4	6,1
50 meter plug			
Theoretical pressure (bar)	93	23	10
Result from test (bar)	55	16	5
100 meter plug			
Theoretical pressure (bar)	186	47	20
Result from test (bar)	79	33	7
150 meter plug			
Theoretical pressure (bar)	279	70	30
Result from test (bar)	146	56	20

As for the data interpreted in chapter 8.1, Influence of shear stress after at least 12 hours settling time, the same approach is used for the interpretation of the data for 2 hours settling time. The first comparison of data is done by using the data collected in table 14 and equation 13 in chapter 8.1. This equation will be used to compare the different lengths of gel plugs with each other by using shear stress as done in chapter 8.1. The theoretical shear stress for the different diameters of pipes and lengths of gel plugs is seen in table 9 in chapter 8.1.

Shear stress is calculated from the pressures measured in the tests by using equation 13 in chapter 8.1, Influence of shear stress after at least 12 hours settling time, and is seen in table 15 underneath. The calculation is done in the same way as in chapter 8.1 and shear stress is measured in bars.

Table 15: Shear stresses calculated from tests with settling time at 2 hours (bar)

	2 inch	4inch	6,1 inch
50 meters	0,01397	0,00813	0,00387
100 meters	0,01003	0,00838	0,00271
150 meters	0,01236	0,00948	0,00516

8.2.1 The 2 inch pipe with gel plugs with settling time of 2 hours

It is seen that every result in the 2 inch pipe after 2 hours of settling time is both lower than the theoretical results and the results of the pressures after at least 12 hours settling time. There is more distribution between the results after two hours settling time than there was after at least 12 hours settling time, but there are still no results that are far from the others.

The average of the results from the 2 inch pipe gives a value of 0.01212 bars. This is less than the average of 0.01737 bars from the at least 12 hours settling time tests, and also less than the theoretical average of 2 inch pipe which is at 0.02362 bars.

The percentage difference of the shear stress from the test results and the theoretical shear stress is calculated:

$$\frac{0{,}01212bar - 0{,}02362bar}{0{,}02362bar} \times 100 = -48{,}69\%$$

It is shown from the results of the tests a 48.69% lower shear stress than the theoretical shear stress. This is also lower than the results given by the at least 12 hours settling time tests. This indicates that a longer settling time would influence the pressure by then needing higher pressures to move the gel plugs and also indicated a change in conditions from an initially set gel to a moved-set-moved again situation. This will be interpreted in chapter 8.5, Influence of settling time.

8.2.2 The 4 inch pipe with gel plugs with settling time of 2 hours

The results from the 4 inch pipe are not that far from each other. By comparing table 9, 10 and 15 it is seen that the results after 2 hours of settling time is lower than both the theoretical shear stress and the shear stress after at least 12 hours settling time that was higher than the theoretical shear stress.

The average of shear stress from the results after 2 hours of settling time is 0.00886. As expected this is a lower average than for the at least 12 hours of settling time average, but this time in opposite of the average for the at least 12 hours settling time the average for 2 hours settling time is lower than the theoretical average.

The percentage difference of shear stress from the 4 inch pipe results and the theoretical shear stress is calculated to be:

$$\frac{0{,}00886bar - 0{,}01181bar}{0{,}01181bar} \times 100 = -25{,}85\%$$

This shows that the test results give a 25.85% lower shear stress than the theoretical shear stress.

8.2.3 The 6.1 inch pipe with gel plugs with settling time of 2 hours

It is seen in table 15 that these results have approximately the same distribution as for the 2 inch pipe results. The average of shear stresses in the 6.1 inch pipe is 0.00392 bars and is lower than the theoretical shear stress. This average is as for the two other diameters of pipe lower than the at least 12 hours settling time average. This is also as for the 2 inch pipe lower than the theoretical shear stresses.

The percentage difference from average of shear stress from test results and theoretical shear stress is calculated to be:

$$\frac{0{,}00392bar - 0{,}00775bar}{0{,}00775bar} \times 100 = -49{,}44\%$$

This shows that the test results give a 49.44% lower shear stress than the theoretical shear stress.

8.2.4 Shear stress from gel plugs with at least 2 hours settling time multiplied by diameter of pipe

There is a clearly deviation between the theoretical shear stresses and the shear stresses calculated from the results. This is the same as it was for the at least 12 hours of settling time results. The results show the same tendency with the 2 and 6.1 inch pipe results being lower than the results from the 4 inches in diameter pipe.

As for the results in shear stress calculated from the test results after at least 12 hours of settling time the results in shear stresses found after 2 hours settling time is influenced by the diameter of the pipe. Equation 12 in chapter 8.1.4, Shear stress from gel plugs with at least 12 hours settling time multiplied by diameter of pipe, is used to find theoretical shear stresses multiplied by diameter of pipes. The results of these calculations are the same as used in chapter 8.1.4 and is found in table 11.

It is seen in table 11 that the theoretical shear stress multiplied by the diameter of the pipes neglects all the variables except shear stress. This makes it possible to compare the different pipe sizes with each other.

Table 16 beneath is made by using equation 15 found in 8.1.4, Shear stress from gel plugs with at least 12 hours settling time multiplied by diameter of pipe, and calculated back from the pressure measured in the tests that is seen in table 15 in chapter 8.2, Influence of shear stress with gel plugs with 2 hours settling time.

Table 16: Shear stress multiplied by diameter of pipes calculated from test results after 2 hours of settling time

	2 inch	4inch	6,1 inch
50 meters	0,00071	0,00083	0,00060
100 meters	0,00051	0,00085	0,00042
150 meters	0,00063	0,00096	0,00080

Table 16 shows that all the results are below the theoretical shear stress multiplied by diameter of the pipes. The results are evenly distributed from 0.00042 to 0.00096. And none of the results has a high divergence from the rest of the results.

By using the values of the different categories in table 16 the average of the shear stress in both pipe size and length of gel can be calculated. These averages for the different diameters of pipes and the average of different lengths of gel plugs and average of all the tests are seen underneath in table 17.

Table 17: Average of shear stress multiplied with diameter calculated from results of gel tests after 2 hours settling time

Category	Average
50 meters	0,00071
100 meters	0,00059
150 meters	0,00080
2 inch	0,00062
4inch	0,00088
6,1 inch	0,00061
Total average	0,00070

It can be noted that every average of shear stress multiplied by diameter of pipes is below the theoretical shear stress multiplied by diameter of pipes. By comparing table 17 with table 13 in chapter 8.1.4, it is seen that the 50 and 100 meters gel plugs have the same difference between the results with 100 meters gel plug approximately 0.0001 lower than the 50 meters gel plug. The 150 meters gel plug is in the results after 2 hours settling time approximately 0.0001 higher than the 50 meters gel plug, while it is approximately 0.0001 lower than the 50 meter gel plug after settling time of at least 12 hours.

In the 2, 4 and 6.1 inch pipe results there is no consistency between the results after 2 hours and at least 12 hours of settling time. For the 2 inch pipe there is an increase of 0.00026, the 4 inch pipe an increase of 0.00067 and for the 6.1 inch pipe an increase of 0.00068.

Because there is a clear difference between the theoretical data and the results of the different gel tests that has been used so far it is natural to draw in more of the variables mentioned in chapter 8.0, Results of gel tests.

The next variable to be considered are the diameter of pipe, length of gel plug and settling time and interpretation of the influence these variables have on the pressure needed to start moving the gel plugs.

8.3 Influence of pipe diameter

The influence of pipe size is compared with Fanning`s equation and his interpretation of the influence. Fanning`s equation is the same equation that were used in chapter 8.1, Influence of shear stress from gel plugs with at least 12 hours settling time and chapter 8.2, Influence of shear stress from gel plugs with 2 hours settling time. It is seen as equation 1 in chapter 6.1, Theoretical pressure. The influence of pipe diameter is calculated by comparing the 50 meters gel plug with more than 12 hours of settling time in the 2 inch pipe with 50 meters gel plugs with more than 12 hours of settling time in the 4 and 6.1 inch pipe. Then the same comparison is done with both the 100 and 150 meter gel plug before doing it all over again with data from gel plugs that have been settling for 2 hours.

The data used in this chapter is the same data used in chapter 8.1, Influence of shear stress with gel plugs with at least 12 hours settling time, and in chapter 8.2, Influence of shear stress with gel plugs with 2 hours settling time. The data from the gel plugs with at least 12 hours of settling time is seen in table 8 in chapter 8.1 and the data from gel plugs with 2 hours of settling time is seen in table 14 in chapter 8.2.

From the data collected in table 8 and 14, three figures with graphs are made to see if the theoretical influence of pipe diameter versus pressure follows the same trend as seen in chapter 6.2, Theoretical influence of diameter of pipes. These graphs are seen underneath as figure 11, 12 and 13.

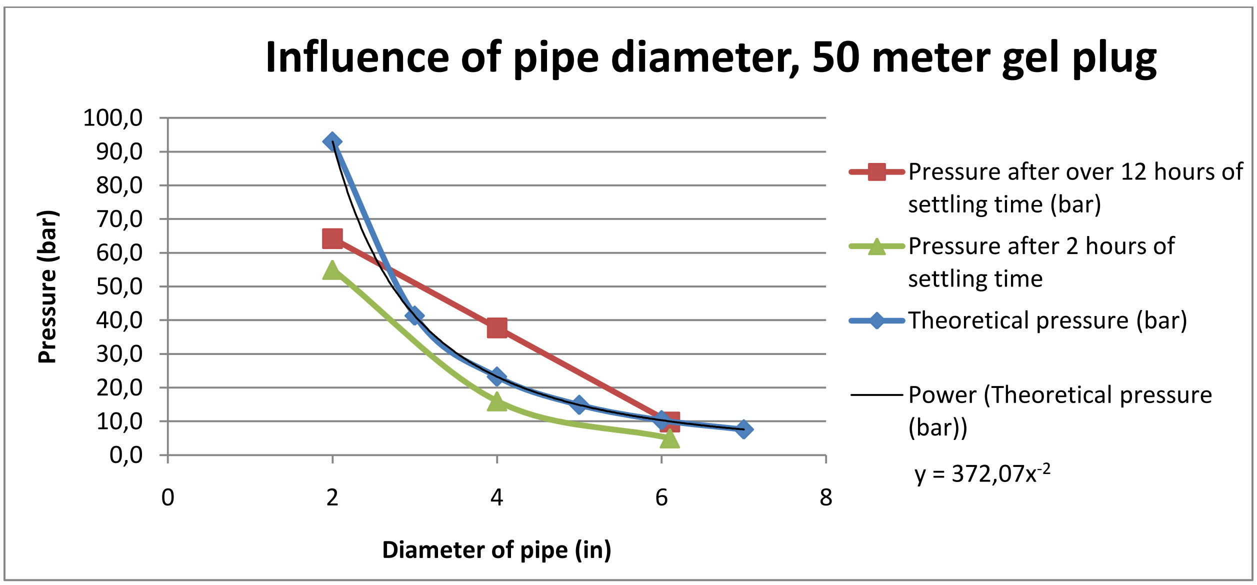

Figure 11: Influence of pipe diameter, 50 meter gel plug

8.3.1 Influence of pipe diameter, 50 meter gel plug

The graph shows that the pressure after more than 12 hours of settling time follows a straight line. The line for pressure after 2 hours of settling time follows the same trend as the theoretical pressure, but the pressure for 2 inch pipe is lower than the rest when compared with the trend.

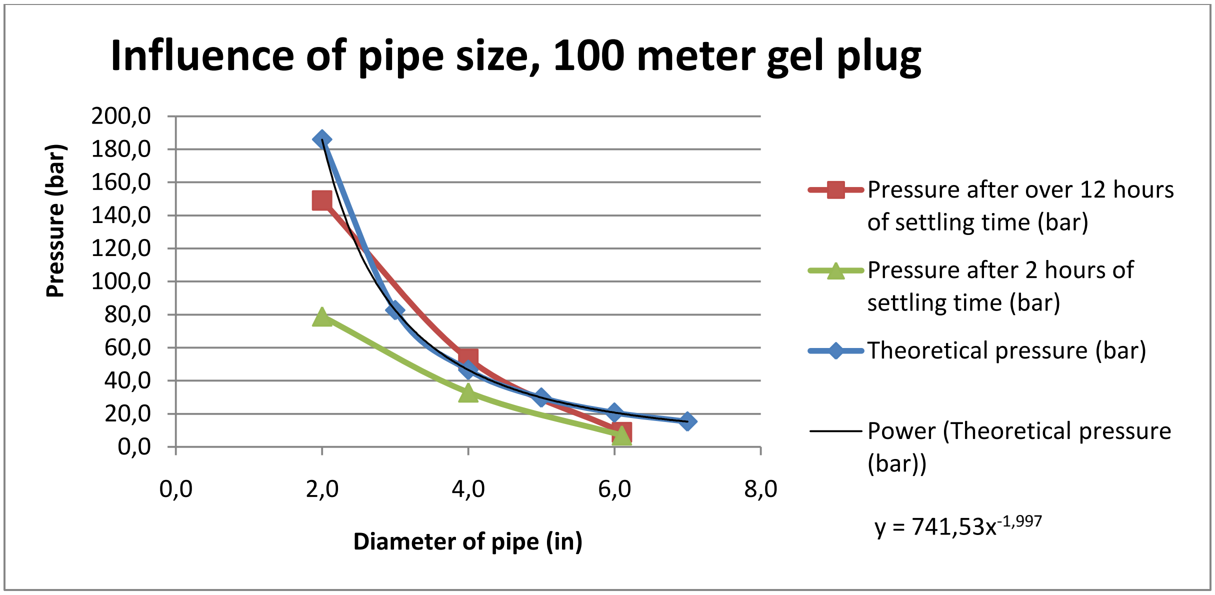

Figure 12: Influence of pipe diameter, 100 meter gel plug

8.3.2 Influence of pipe size, 100 meter gel plug

The 2 inches in diameter gel plug follows the same trend as for the 50 meter gel slug in figure 11. The graph showing pressure from the over 12 hours of settling time shows a tendency to become more like the theoretical pressure than in the 50 meters gel plug graph.

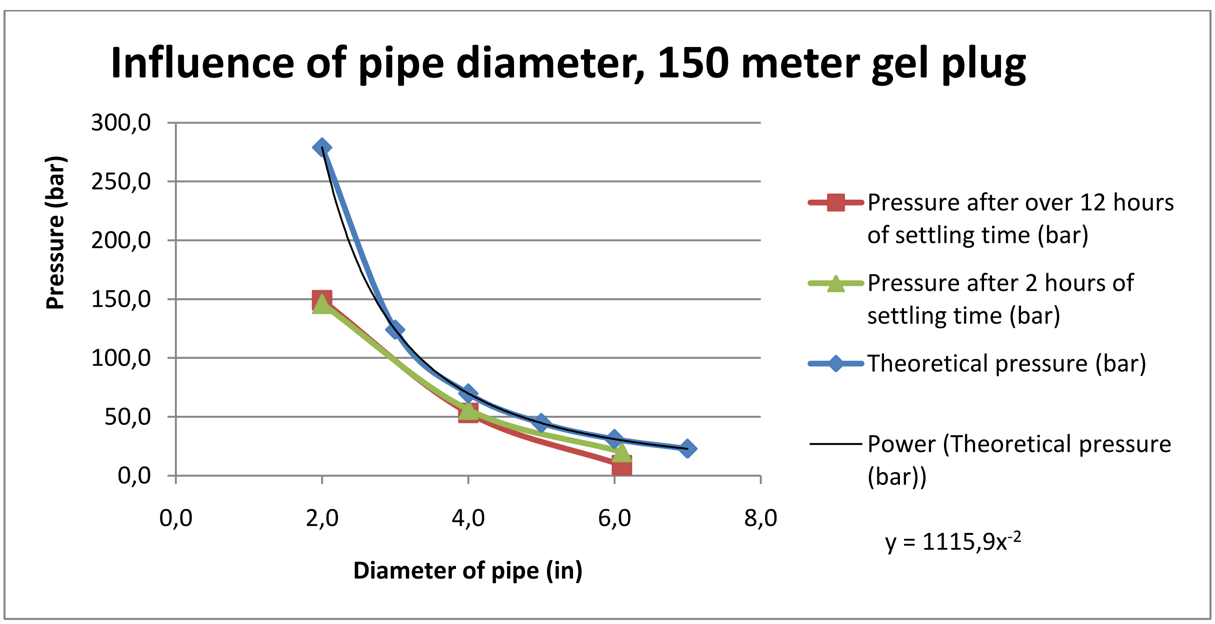

Figure 13: Influence of pipe diameter, 150 meter gel plug

8.3.3 Influence of pipe size, 150 meter gel plug

All three graphs show the same tendency as the previous two comparisons. The graphs almost follows the trend line, but the point for 2 inch pipe is lower compared to the theoretical pressure than the points for 4 and 6.1 inch pipe.

8.4 Influence of length of gel plugs

The influence of the length of gel plug is also compared by using Fanning`s equation and his interpretation of the influence. The influence of length of gel plug is calculated by comparing 50, 100 and 150 meters gel plugs with settling time more than 12 hours in the 2 inch pipe with the theoretical pressure for different lengths of gel in a 2 inch pipe. The same is then done with the 4 and 6.1 inch pipe, before the whole process is repeated for gel plugs with 2 hours of settling time.

The data being used are also here the same data which were used in the previous subchapters and is seen in table 8 in chapter 8.1, Influence of shear stress with gel plugs with at least 12 hours settling time, and in table 14 in chapter 8.2, Influence of shear stress with gel plugs with 2 hours settling time.

From the data collected in table 8 and 14 three figures with graphs are made to see if the theoretical pressure follows the same trend for length of gel as in chapter 6.3, Theoretical influence of lengths of gel plugs. These graphs are seen underneath as figure 14, 15 and 16.

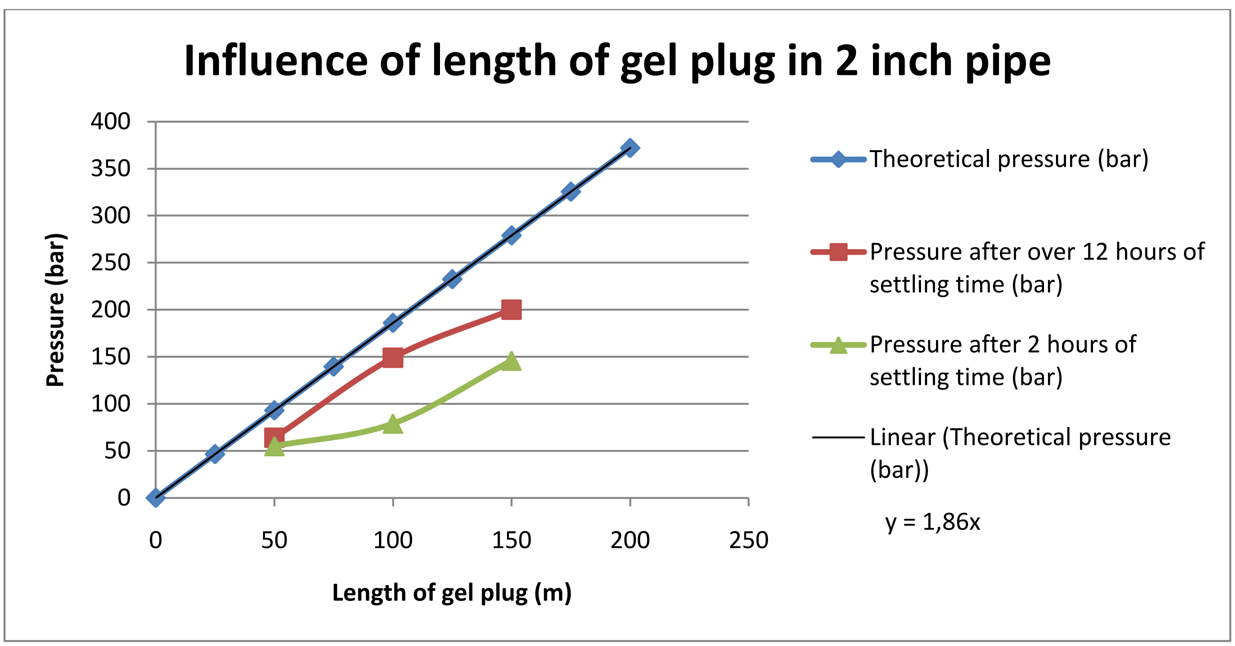

Figure 14: Influence of length of gel plug in 2 inch pipe

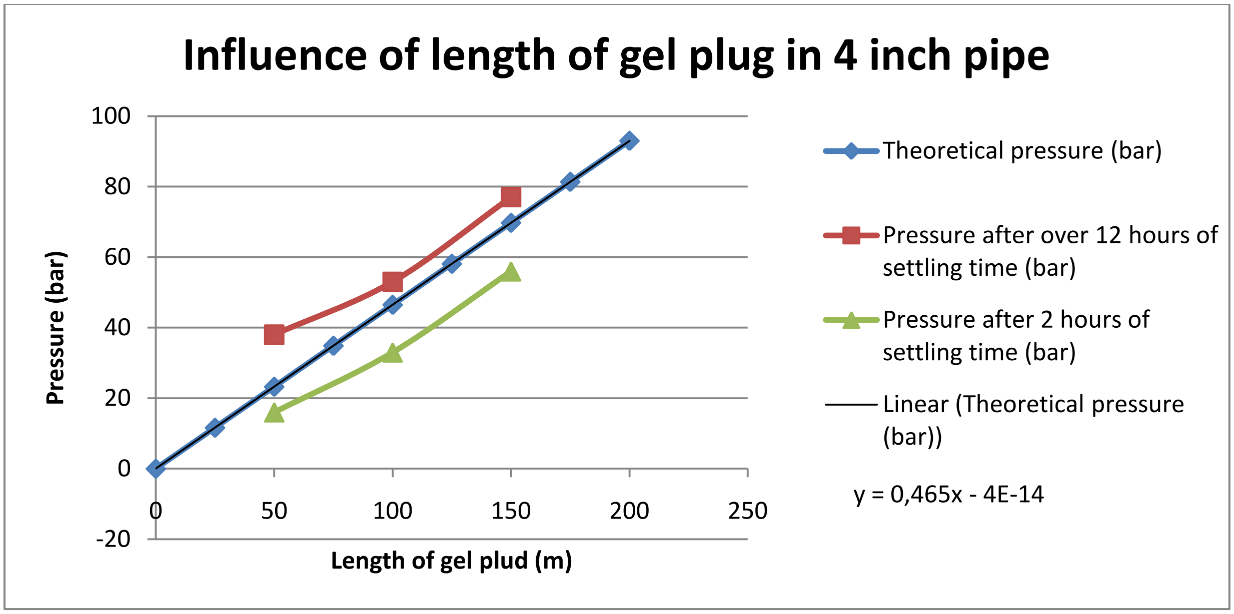

Figure 15: Influence of length of gel plug in 4 inch pipe

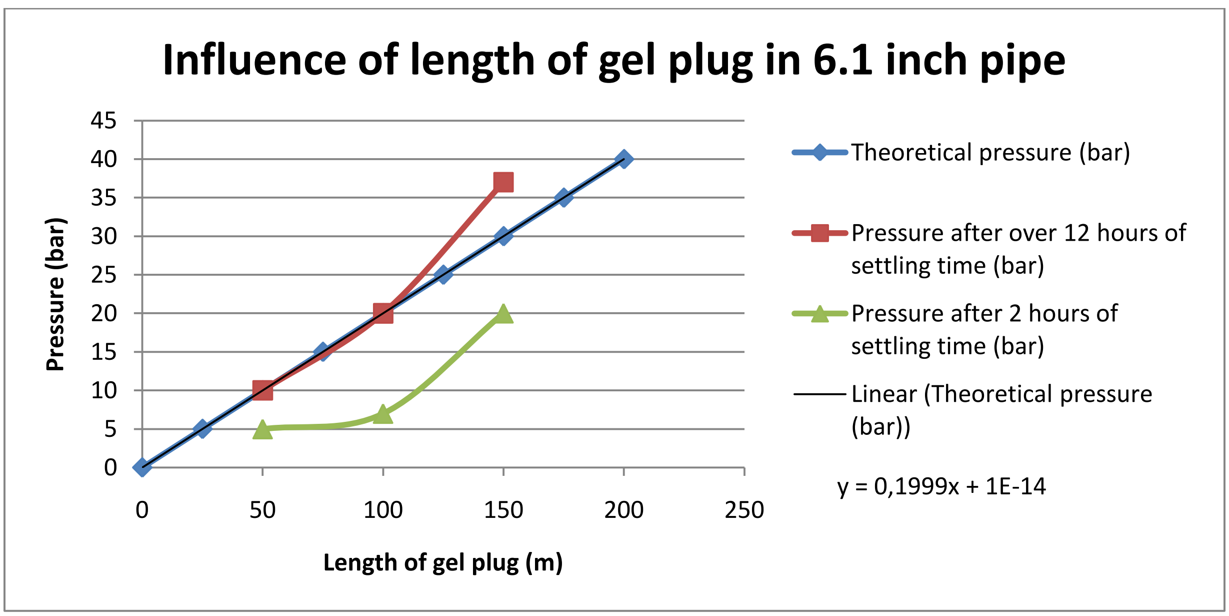

Figure 16: Influence of length of gel plug in 6.1 inch pipe

As seen in the figures above the theoretical pressure follows a straight line, but none of the lines made by the results from the tests follows a straight line. It is seen from the data used in this chapter that settling time has an influence on the pressure needed to move the gel plugs. This is analyzed in the next chapter.

8.5 Influence of settling time

After looking at the data from the test results seen in chapter 12.1, Data from gel tests in Risavika Harbor and at IRIS research center, there is a clear indication that settling time has an influence on pressure needed to move the gel plugs. There is no known formula for settling times influence on pressure needed to move gel plugs.

To find out about the connection between settling time and pressure needed for moving gel plugs, the pressures from chapter 12.1, Data from gel tests in Risavika Harbor and at IRIS research center, are interpreted to find the pressure which occurs when gel plugs start to move. The data were collected and put into tables. They are first sorted after pipe diameter, then after length of gel plugs and pumps that were used during the tests.

The reason that the tables are sorted after pipe diameter is that in theory there is a linear connection between length of gel plugs and a power connection between pipe diameters. By sorting after pipe diameter it will be easier to find a trend in the settling time.

The data is further sorted after settling times, with the gel plug with least setting time first and the gel plug with the most setting time last. If there is more than one run with the same settling time the one with the least amount of pressure needed to move the gel plug comes first in the table and the one with most pressure needed to move the gel plug comes last. The previous test runs are also included to figure out if moving the gel inflicts the settling process.

The table for 2 inch pipe with settling time, pressure needed to move the gel plugs and previous test runs are seen underneath as table 18.

Table 18: 2 inch pipe with settling times, pressures needed to move the gel plugs and previous test runs

2 inch pipe, 50 meter gel plug, Haskel pump		
Settling time (hours)	Pressure needed to move the gel plug (bar)	Previous test runs
2	64	3
2	70	1
2	71	2
16	95	0
2 inch pipe, 50 meter gel plug, HT-400 pump		
Settling time (hours)	Pressure needed to move the gel plug (bar)	Previous test runs
2	55	1
3	58	2
16	64	0
2 inch pipe, 100 meter gel plug, HT-400 pump		
Settling time (hours)	Pressure needed to move the gel plug (bar)	Previous test runs
2	74	1
2	79	1
2	120	0
16	149	0
2 inch pipe, 150 meter gel plug, HT-400 pump		
Settling time (hours)	Pressure needed to move the gel plug (bar)	Previous test runs
2	135	0
2	144	1
2	150	0
16	200	0

It is seen in the table above that there is little difference between pressures when gel plugs have been settling for the same amount of time if it is the second, third or fourth time the gel is settling. When the gel plug is settling for the first time there is a difference between the influence in the 150 meters gel plug and the 100 meters gel plug. In the 150 meters gel case there is no difference between settling for the first time and second time if it settles for the same amount of time, but for the 100 meters gel plug case it is much higher after settling for the first time. The reason for this depends on what has happened in the pipe before the test was run. Influence on the gel plug will be interpreted later

Next is the table for the 4 inch pipe. It is seen underneath as table 19.

Table 19: 4 inch pipe with settling times, pressures needed to move the gel plugs and previous test runs

4 inch pipe, 50 meter gel plug, HT-400 pump		
Settling time (hours)	Pressure needed to move the gel plug (bar)	Previous test runs
2	6	3
2	10	2
2	16	1
16	38	0
4 inch pipe, 100 meter gel plug, HT-400 pump		
Settling time (hours)	Pressure needed to move the gel plug (bar)	Previous test runs
2	24	2
2	32	0
2	34	1
16	53	0
4 inch pipe, 150 meter gel plug, HT-400 pump		
Settling time (hours)	Pressure needed to move the gel plug (bar)	Previous test runs
2	55	0
16	44	1
17	68	1
29	77	0

It is seen in the table that the 50 meters gel plug gets lower pressure for moving the gel plug every time it is moved, despite of the settling time being the same. In the 150 meters gel plug case it is seen that the 16 hours of settling time needs lower pressure to start moving than 2 hours of settling time. The 2 hours settling time was settling for the first time, but the 17 hours of settling time was much higher than the 16 hours of settling time. The 16 hours of settling time is the only result which does not coincide with the rest of the results and is therefore left out in the rest of the interpretation.

Then it is the table for 6.1 inch pipe, which is seen underneath as table 20.

Table 20: 6.1 inch pipe with settling times, pressures needed to move the gel plugs and previous test runs

6.1 inch pipe, 50 meter gel plug, HT-400 pump		
Settling time (hours)	Pressure needed to move the gel plug (bar)	Previous test runs
2	5	1
17	10	0
6.1 inch pipe, 100 meter gel plug, HT-400 pump		
Settling time (hours)	Pressure needed to move the gel plug (bar)	Previous test runs
1	6	2
2	7	1
3	2	3
15	20	0
6.1 inch pipe, 150 meter gel plug, HT-400 pump		
Settling time (hours)	Pressure needed to move the gel plug (bar)	Previous test runs
2	20	2
2	22	1
19	37	0

Because of the same reasons as for the 150 meter gel plug in the 4 inch pipe, the 3 hours of settling time for the 100 meter gel plug in the 6.1 inch pipe is left out. The rest of the results are used further in the interpretation of the influence of settling time.

The next step in the interpretation is to make figures with graphs of settling times versus pressures needed to move gel plugs. To make these figures the average tables are made so that only one value of pressure is included for every settling time. The average is calculated from the data in the tables above and is seen below in table 21, 22 and 23. The table is sorted in the same way as the previous tables after pipe diameters, length of gel plugs and pumps which were used. The first table and figure made are the table and figure made by the data from the 2 inch pipeline tests. It is seen in table 21 and figure 17 underneath.

Table 21: Settling time and average pressure needed to move the gel plug for 2 inch pipe

2 inch pipe, 50 meter gel plug, Haskel pump	
Settling time (hours)	Average pressure needed to move the gel plug (bar)
2	68
16	95
2 inch pipe, 50 meter gel plug, HT-400 pump	
Settling time (hours)	Average pressure needed to move the gel plug (bar)
2	55
3	58
16	64
2 inch pipe, 100 meter gel plug, HT-400 pump	
Settling time (hours)	Average pressure needed to move the gel plug (bar)
2	91
16	149
2 inch pipe, 150 meter gel plug, HT-400 pump	
Settling time (hours)	Average pressure needed to move the gel plug (bar)
2	143
16	200

In the different categories of length and pumps there are two different settling times in three of the categories and three different settling times in one category. This is the 50 meter gel plug pumped by the HT-400 pump. A figure with settling time and pressures needed to move the gel plugs was made. Linear trend lines with their equations are drawn into the figure, one trend line for every category and graph. This can be seen underneath as figure 17.

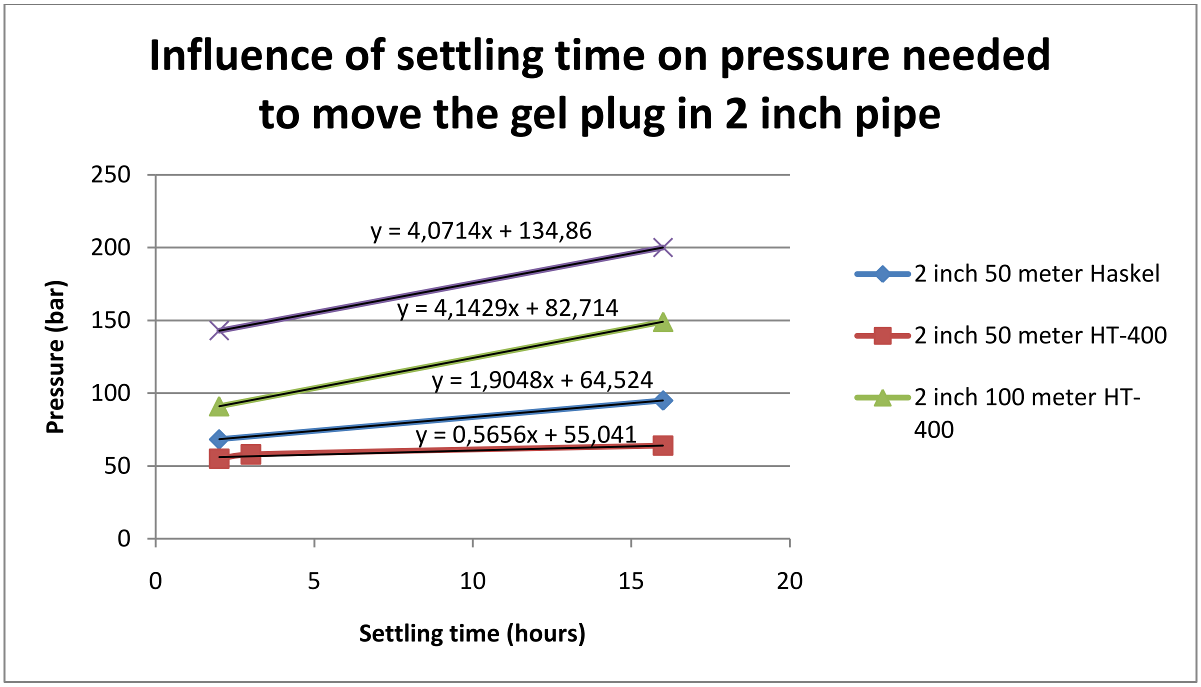

Figure 17: Influence of settling time on pressure needed to move the gel plug in 2 inch pipe

The influence of settling time on pressure needed to move the gel plug is calculated by calculating the average of the different quotient seen in the figure. The different quotient is the number written in front of the x in the equation. For the 2 inch pipe the average different quotient is calculated to be 2.67. It is seen in figure 17 that there is a wide distribution between the values of the different quotient.

The data from the 4 inch pipeline tests are next to be interpreted. These data are interpreted using the same methods as in the interpretation of the 2 inch pipeline tests and is put into table 22 and figure 18 shown below.

Table 22: Settling time and average pressure needed to move the gel plug for 4 inch pipe

4 inch pipe, 50 meter gel plug, HT-400 pump	
Settling time (hours)	Average pressure needed to move the gel plug (bar)
2	11
16	38
4 inch pipe, 100 meter gel plug, HT-400 pump	
Settling time (hours)	Average pressure needed to move the gel plug (bar)
2	30
16	53
4 inch pipe, 150 meter gel plug, HT-400 pump	
Settling time (hours)	Average pressure needed to move the gel plug (bar)
2	55
17	68
29	77

As for the 2 inch pipe there are two categories with 2 different settling times and one category with one settling time. The 150 meters gel plug which is the one with three different settling times has a wide range in settling time, stretching from 2 hours to 29 hours with 17 hours in between. The graph made from these results will give a good indication of if the settling time has a linear trend. The graphs made from table 22 are shown below.

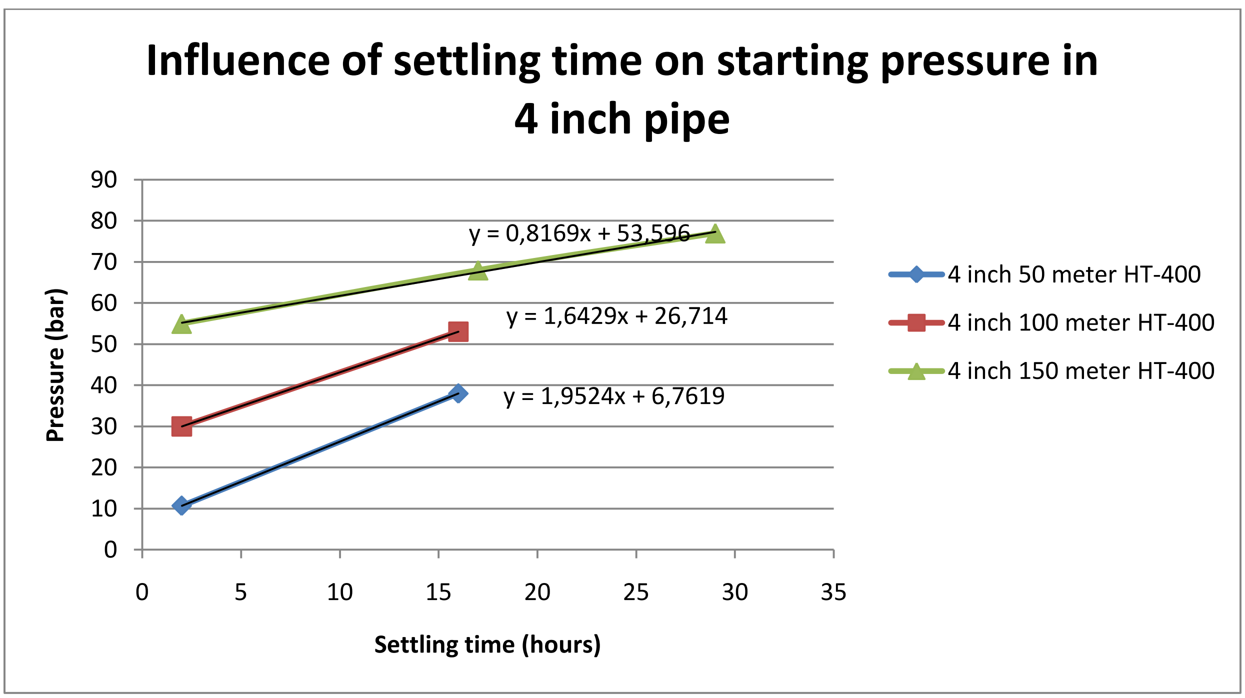

Figure 18: Influence of settling time on starting pressure in 4 inch pipe

Figure 18 show that the different quotients have a smaller distribution for the 4 inch pipe than for the 2 inch pipe. The graph made from the 150 meters gel plug shows that it is a correct approximation that settling time has a linear trend. The average different quotient is calculated to be 1.47. This is a lower value than the average different quotient for the 2 inch pipe.

The data from the last results to be interpreted is the data from the 6.1 inch pipeline tests. These are as for the 2 and 4 inch pipeline put into an average table and a figure is made in the same way as the two previous figures were made.

Table 23: Settling time and average pressure needed to move the gel plug for 6.1 inch pipe

6.1 inch pipe, 50 meter gel plug, HT-400 pump	
Settling time (hours)	Average pressure needed to move the gel plug (bar)
2	5
17	10
6.1 inch pipe, 100 meter gel plug, HT-400 pump	
Settling time (hours)	Average pressure needed to move the gel plug (bar)
1	6
2	7
15	20
6.1 inch pipe, 150 meter gel plug, HT-400 pump	
Settling time (hours)	Average pressure needed to move the gel plug (bar)
2	21
19	37

As for the 2 and 4 inch pipe the figure with trend line and its equation is made.

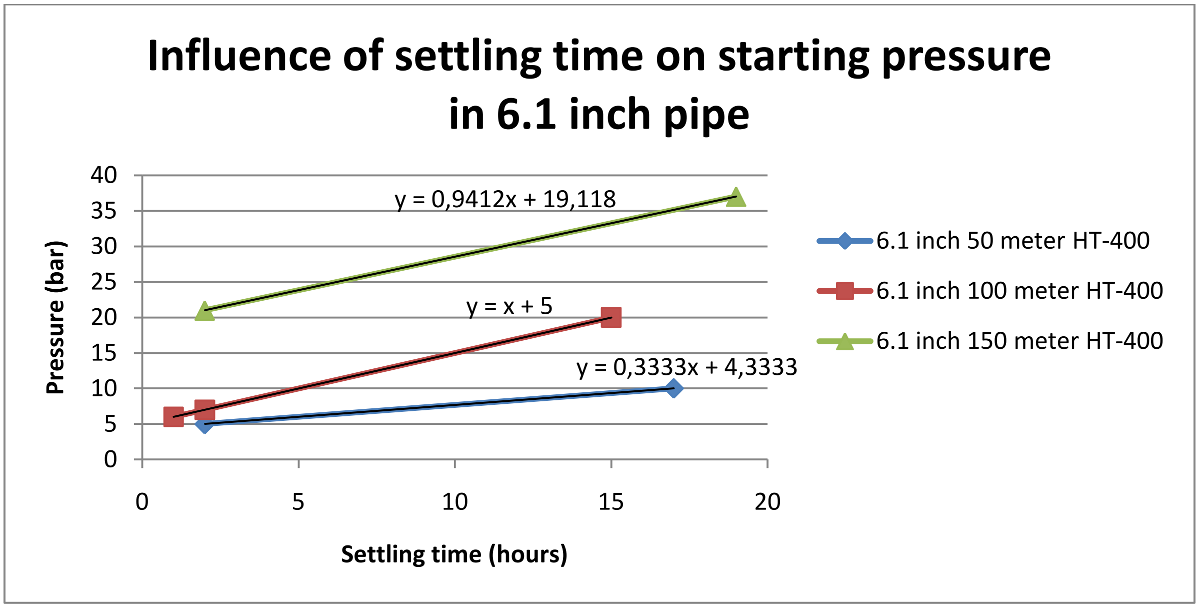

Figure 19: Influence of settling time on starting pressure in 6.1 inch pipe

Figure 19 shows that there is approximately the same distribution of different quotient for the 6.1 inch pipeline tests as for the 4 inch pipeline tests. The average different quotient is calculated in the same way as for 2 and 4 inch pipes and is calculated to be 0.76.

By comparing the average influence of settling time on pressure it is shown that the influence is getting lower when the pipe diameter is getting bigger. To find a connection between the influence that settling time has on pressure needed to move gel plugs and pipe diameter figure 20 below is made. The figure shows the connection between pipe diameter and the different quotient which is used to measure the influence of settling time on pressure.

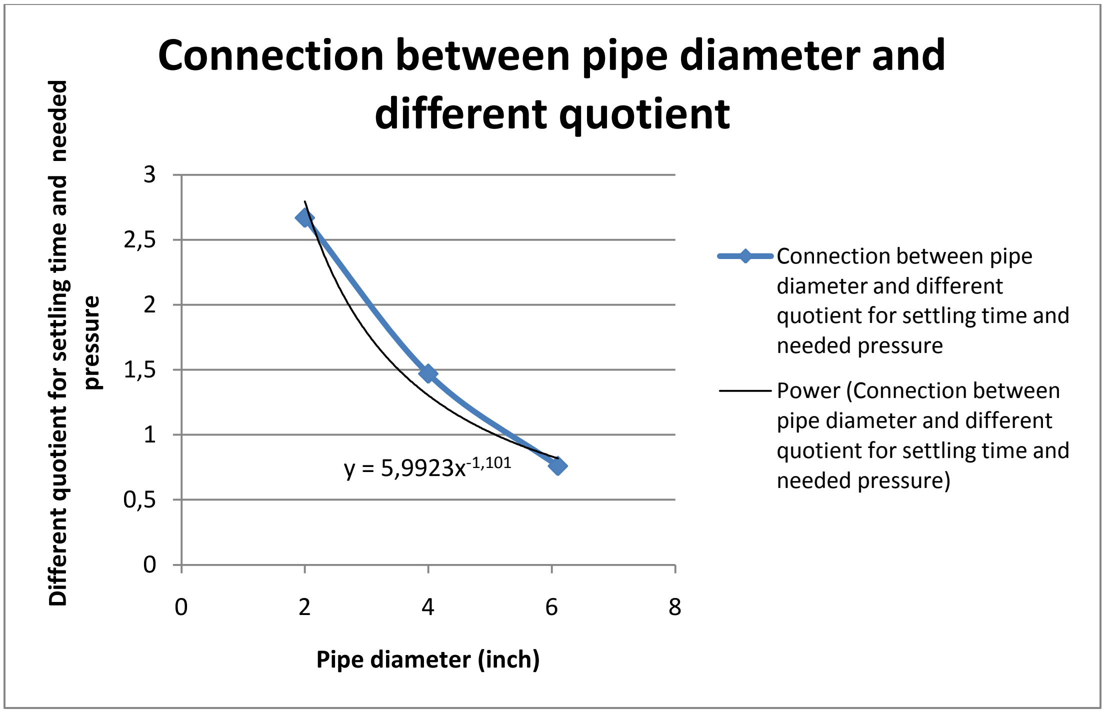

Figure 20: Connection between pipe diameter and different quotient

This figure shows that there is not a linear connection between pipe diameter and the difference quotient as assumed. To find a formula for the influence of settling time on pressure needed to move the gel plug more tests will have to be carried out because at this stage it is only possible to assume which kind of trend the graph follows. It could be exponential-, logarithmic, polynomial-, or power-equations connected to the connection between pipe diameter and difference quotient for settling time and pressure needed to move the gel plug.

A power trend line with its equation is put into the figure to find the connection between the pipe diameter and the difference quotient for settling time and needed pressure. Power line is chosen because this is the theoretical connection between pipe diameter and pressure as shown in chapter 6.2 Theoretical influence of pipe diameter.

The power line in figure 20 has the equation: $y = 5{,}9923x^{-1{,}101}$.
Where:
y = $\frac{dp}{dt}$ = difference quotient for settling time and needed pressure
x = d = pipe diameter (inch)

The equation above is approximately the same as the equation: $\frac{dp}{dt} = \frac{6}{d^{1{,}1}}$

A general equation for the different linear trend lines shown in figure 17, 18 and 19 is: $y = ax + b$.
Where:

y = P = pressure needed to move the gel plug (bar)
a = $\frac{dp}{dt}$ = difference quotient for settling time and needed pressure
x = t = settling time (hours)
b = point of intersection between graph and y-axis

The equation will now be : $P = \frac{dp}{dt}t + b$

By putting $\frac{dp}{dt} = \frac{6}{d^{1,1}}$ into $P = \frac{dp}{dt}t + b$ the equation for influence of settling time on pressure needed to move the gel plug is shown as:

$$P = \frac{6}{d^{1,1}}t + b \qquad (11)$$

If b is known then this equation can probably be used with the influence of other variables to find the pressure needed to move gel plugs.

8.6 Influence of settling time for gel plugs that have been moved

After looking at the influence of settling time on pressure needed to move the gel plug it is then natural to look at the influence of settling time on the gel plug if it settles for the first, second or third time. By using the data shown in tables 18, 19 and 20 in the previous chapter, an interpretation on if moving the gel plug has influence on settling time for the gel plugs is done.

First the data with the same settling time for a new plug and a plug which has already been moved will be interpreted. There are three different gel plugs which have the same settling time for new gel plugs and gel plugs which have already been moved. The data is collected in table 24 below.

Table 24: Gel plugs with the same settling time for new gel plugs and gel plugs that have been moved

Settling time (hours)	Pressure needed to move the gel plug (bar)	Run number
2 inch pipe, 100 meters gel plug, HT-400 pump		
2	120	1
2	79	2
2 inch pipe, 150 meters gel plug, HT-400 pump		
2	135	1
2	150	1
2	144	2
4 inch pipe, 100 meters gel plug, HT-400 pump		
2	32	1
2	34	2

The table shows that in the 2 inch pipe 100 meters gel plug case a higher pressure is needed to move the gel plug after first settling compared to second settling. In the two other cases, the 2 inch pipe 150 meter gel plug and 4 inch pipe 100 meter gel plugs, there is no significant difference between the pressure needed to move the gel plug after the first and second settling. The reason why the pressure is higher in the 2 inch pipe 100 meters gel plug case could be because of temperature. The new gel plug was set to settle in the middle of the day and it was one of the warmest days during the gel tests runs. It is a possibility that temperature has an influence on the pressure needed to move the gel plugs. This is discussed in chapter 8.8, Temperature influence.

Next it is natural to look at gel plugs that have been moved several times with the same settling time. The data which is used is also in this case collected from tables 18, 19 and 20 in the previous chapter. There are four different cases where gel plugs have been moved after they have been settling with same settling time. The different cases are collected below in table 25.

Table 25: Gel plugs moved after settling with same settling time

Settling time (hours)	Pressure needed to move the gel plug (bar)	Run number
2 inch pipe, 50 meter gel plug, Haskel pump		
2	70	2
2	71	3
2	64	4
4 inch pipe, 50 meter gel plug, HT-400 pump		
2	16	2
2	10	3
2	6	4
4 inch pipe, 100 meter gel plug, HT-400 pump		
2	34	2
2	24	3
6.1 inch pipe, 150 meter gel plug, HT-400 pump		
2	22	2
2	20	3

The table shows approximately the same pressure for second and third run for the 2 inch pipe 50 meters gel plug case. With 70 bars of pressure needed to move the gel plug in the second run and 71 bars in the third. In the fourth run for the 2 inch 50 meters gel plug case only 64 bars of pressure was needed for moving the gel plug. During this test the pump was stopped for 10 seconds and this could be the reason behind the lower pressure reading.

In the 4 inch pipe 50 meters gel plug case there is clearly a decrease in pressure needed to move the gel plug. This gel plug was the first one that was run in the 4 inch pipe. After the gel tests when the 4 inch pipe was stripped down the inside of the pup joint, which was mounted together to build the pipeline, had a thin layer of remains of gel stuck to its walls. The decrease in pressure needed to move the gel plug could be caused by the pipe wall tearing the gel plug apart, making it shorter for every test that was run. This could also be the reason why the 4 inch 100 meter gel plug has a decrease in pressure. In the 6.1 inch pipe 150 meters gel plug case it is the same pressure at the second and third run.

To figure out more about the resettling and behavior of the gel and the influence of water, small tests were run in sample bottles simultaneously with the tests in the 2, 4 and 6.1 inch pipes. An interpretation of these tests is found in next chapter.

8.7 Resettling of gel and mixing gel with water

To find out how gel behaves three different small tests were carried out. One of the questions that came up during the full scale tests was if the gel was ripped apart during the test, and what would happen if it was ripped apart. Would it go back to its original form or would it stay broken. To find the answer to this a gel plug was placed inside a one liter sample bottle. The gel plug was left in the bottle to settle and after it had settled the bottle was shaken until the whole plug was torn into small pieces.

After leaving the bottle for five hours the gel had repaired itself back to its original form, except for approximately one centimeter at the top part of the gel that still had some unrepaired gel in it. The reason for this layer is that it had less force pushing from above and it will therefore need more time for the gel to repair itself compared to gel further down in the bottle. A gel plug in a bottle would therefore start self healing in the bottom of the bottle and work its way upwards to the top.

After leaving the gel plug in the sample bottle for a total time of more than 12 hours the whole gel had settled to one plug again and gone back to its original form. This shows that this gel is shear healing and will re-cross link as said in chapter 5.1, Temblok-50™. This also means that this gel is thixotropic because it heals itself back to its original form. More about thixotropy is found in chapter 5.5, Thixotrophy. The gel was also left for weeks in the sample bottles. It was then seen that the gel was getting harder and more stuck to the sides of the sample bottle the longer it stayed in the bottle without being inflicted by stress.

Another aspect that came up was if the gel would mix with water after it had settled. This question again led to two different questions. Will gel and water mix if the settled gel plug is in steady state? And what would happen if the gel is torn apart and there is water in the surrounding environment? Would gel and water then mix or stay separate?

To find the answer to these questions two tests were carried out. Two different gel plugs where placed in two different one liter sample bottles, and left to settle for more than 12 hours. Both gel plugs were at approximately 7 deciliters. After they had settled approximately one deciliter of water was poured into both of the sample bottles. The water was poured carefully, making sure not to break up the gel.

One of the bottles was then left without inflicting any stress on the gel by shaking the sample bottle. The sample bottle was now containing a gel plug at the bottom and water above it inside the bottle. As seen in figure 21 on the next pace. After leaving it for several days nothing had happened to the gel plug.

Water was still lying at the top of the gel plug. It is natural that the water would lie at the top of the gel because water has a higher density than gel and will therefore float on top of the gel. The gel plug was then moved carefully so the gel would not break apart. It was possible and easy to move the gel plug, but it was impossible to get the water to the other side of the bottle by moving it slowly. Even when the bottle was turned upside down the water would not float to the top of the sample bottle past the gel plug.

Figure 21: Sample bottle with water lying on top of gel

The other sample bottle was shaken until the whole gel plug was torn apart and then left for more than 12 hours. The water and the gel plug had then been mixed together and re-cross linked into one new gel plug. This new gel plug was lighter in color and softer than the previous gel plug. A gel plug will only mix with water when it is inflicted by stress and by this ripped into pieces.

The reason why Temblok-50™ will mix with water is because of Temblok-50™s gel structure. Temblok-50™ is water based and will therefore mix with water forming a more and more soft gel as more water is added into the gel. When a big enough percentage of water compared to cross linker is added, there will be so much water in the gel that the cross linker is not capable of reacting with all the water and cross link into a gel plug. It will then become a thick viscous fluid. As more and more water is added, the gel will gradually form a thinner viscous fluid, until the whole gel is completely dissolved in water. [3]

These tests show that there is an influence on the gel plugs from the fluid which pushes the gel plugs. This influence from water pushing the gel plug depends on how consistent the end of the gel plug is. The water also influence the pipe wall to gel interface when water pushes gel plugs. More about this is seen in chapter 8.9, Influence and behavior of gel plugs ends.

8.8 Temperature influence

The temperature influence on pressure needed to move gel plugs is an influence which should have been measured more accurately. The reason why it was not measured accurate enough was a misguidance. From test results run after it had been below freezing conditions one night showed that less pressure was needed to move the gel plug when it had been settling in a pipeline with freezing conditions around the pipeline. The test results are seen in chapter 12.1, Data from gel tests in Risavika Harbor and at IRIS research center.

These results show that a gel plug in a 4 inch pipe and with the length of 100 meters only needs 9 bars pressure for moving it after it has been inflicted by freezing condition during settling. The gel plug had been settling in the pipe for 20 hours before the test was carried out. One test had been run with the gel plug before it was set to settle for 20 hours. This test was run after 2 hours of settling time and the pressure needed to move the gel plug was 32 bars. This shows that the gel plug was as it was suppose to be, and that temperature had an influence on the result. Another gel plug of same length, which had been settling for 16 hours in the same pipe, needed 53 bars of pressure for moving.

Two tests were run that same day after the pipelines had been inflicted by freezing conditions. The other one was a gel plug in the 2 inch pipe with the length of 100 meters and settling time of 20 hours. This gel plug needed 15 bars pressure to move. It was then set to settle for 29 hours. Then it needed 170 bars of pressure to start moving. This shows that also this plug behaved as it was supposed.

The test after 29 hours of settling time is not included in the interpretation of settling time because the gel started coming out at the end of the line after just a few seconds when the test was run. If this test is included in the graph for influence of settling time on pressure needed to move the gel plug it would have shown that the graph was still a straight line with approximately the same equation for the trend line. The results from gel tests with infliction of freezing conditions are shown in table 26 below.

Table 26: Gel plugs with freezing conditions involved

2 inch pipe, 100 meters gel plug			
Settling time (hours)	Pressure needed to move the gel plug (bar)	Run number	Comment
20	15	1	*Freezing conditions involved*
29	170	2	
4 inch pipe, 100 meters gel plug			
Settling time (hours)	Pressure needed to move the gel plug (bar)	Run number	Comment
2	32	1	
20	9	2	*Freezing conditions involved*

Table 26 shows that the freezing conditions have influence on the pressure needed to move the gel plug either it has been moved once or not. Both gel plug tests shows that after being inflicted by freezing conditions the pressure needed for moving the gel plug is much lower than the pressure needed for moving the gel plug when it has not been inflicted by freezing conditions. This is also seen by comparing the data in table 26 with data from table 18 and 19 in chapter 8.5.

It is not known why the pressure needed to move the gel plugs are lower when the gel plugs have been influenced by freezing conditions. There are three different scenarios that could be the reason why the pressure is lower. The first scenario is that when freezing conditions occur the cross-linking or shear healing with the re-cross-linking process as described in chapter 5.1, Temblok-50™ does not work as it should. It is known from experience that low temperatures inhibits the cross linking.

The second scenario is that the freezing conditions inflicts the gel plug and makes crystals out of the gel structure and by this makes it easier to move. Ice crystals could also be made in the water between the gel plug and the pipe wall making the pipe wall icy and more slippery and smooth.

The third scenario is that the freezing conditions influence the van der Waal effect. It can influence the van der Waal effect by interfering with the molecules ability to turn and because of this the molecules positive end would not be able to react with another molecules negative end. This is described more thoroughly in chapter 5.6, Electric van der Waal forces.

It cannot be determined if one or several of the scenarios occurs when gel plugs are set in pipelines which have been exposed to freezing conditions. The 2 inch pipe test shown in table 26 shows that high pressure was needed to move the gel plug after it had been settling for 29 hours without freezing conditions involved. From this it can be determined that gel plugs are not destroyed by being exposed to freezing conditions this condition.

It is natural to think that if influence of freezing conditions leads to low pressure needed to move gel plugs, the influence of warm conditions would lead to scenarios where high pressure is needed to move gel plugs. For answering if this is true, more data with only temperature varying have to be collected.

8.9 Influence and behavior of gel plugs ends

The influence and behavior of the ends of the gel plugs is an influence which is impossible to see through steel pipes. Small scaled tests were therefore carried out at the University of Stavanger using transparent pipes. The experimental procedure for these tests is seen in chapter 7.5, Experimental procedure for gel tests at the University of Stavanger.

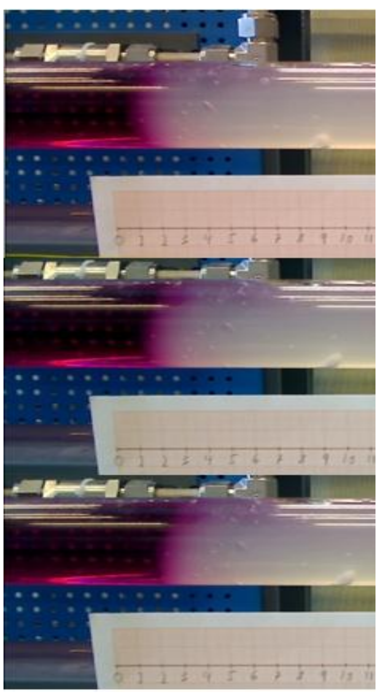

Figure 22: Behavior of end of gel plugs nearest pump

In these tests it was decided to make the end of the gel plugs which was closest to the pump as straight as possible. This end is the one which receives the pressure given by the pump and the effects on it would be easiest to see if the gel plug had a straight end. In real situations the end of the gel plug would only be straight if a pig is used in the end of the gel plug. When linear gel is stopped pumping and water is pumped afterwards, the water and linear gel will mix because of turbulence in the flow making the end of the gel uneven.

The first which is looked into is when the pump is started and pressure is building up behind the gel plug. How will the end of the gel plug behave? To figure this out a camera was connected to a computer and set to take pictures of the end of the gel plug while the pump was running. The way the end of the gel plug, which was closest to the pump, behaved is seen in figure 22 to the left.

The figure shows clearly that the top of the gel is pushed forwards when the gel plug receives pressure from the pump. The reason for this is that gel has a higher density than water so water will flow on top of the gel, as shown in figure 21 in chapter 8.7, Resettling of gel and mixing gel with water.

With the top of the gel plug receiving more pressure than the rest of the gel the question if it is possible to get water to move on the top of the gel through the pipe without moving the gel plug comes up. Water moving on top of the gel plug could be the reason behind the pressure being very low in the gel tests carried out in Risavika Harbor with the Haskel pump and a gel plug in the 2 inch pipe and with length of 100 meters. Another test was carried out at the University of Stavanger to figure this out. The interpretation of this test is shown in chapter 8.10, Behavior of gel plugs in pipes.

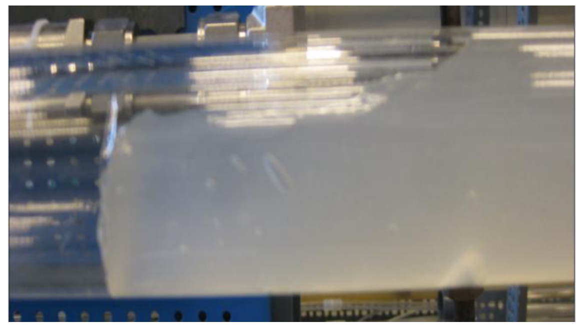

Figure 23: Crack between gel plugs and pipe wall

When a gel plug is left to settle in a pipeline with water at each end of it, it will slowly drift downwards in the ends of the gel plug. This is, as mentioned before, because of the viscosity of the gel. When the gel is drifting downwards it will open up a crack between the gel plug and the pipe wall and this will be filled with water. This crack is very small because the water between the gel plug and the pump pushes the gel plug and because the gel "sticks" to the pipe wall making it impossible for water behind the gel to expand the crack more. Figure 23 above to the right shows such a crack. In the figure there is air behind the gel plug because this will show the crack better.

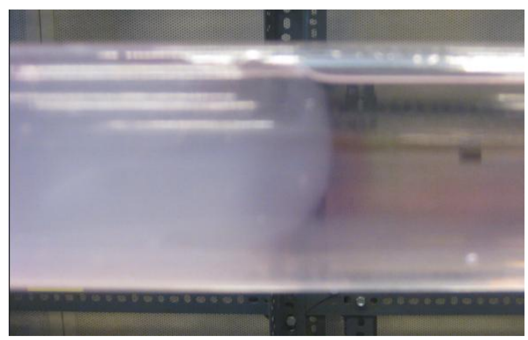

Figure 24: Front end of gel plugs

When it comes to how the other end of the gel plugs which has no infliction from the pump. The behavior of this end is influenced by what is in the pipe in front of it. In these tests the only thing which was lying in front of the gel plugs in the pipes were remains of gel from previous test runs. The influence of these remains on the gel plugs are discussed in chapter 8.10, Behavior of the gel plugs in pipes.

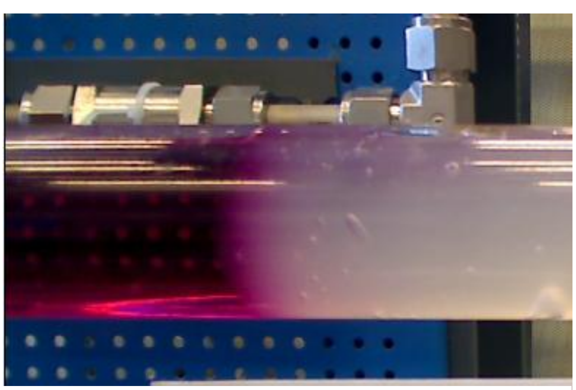

Figure 25: Influence of water on end of gel plug that has not been moved

If there is no remains of gel in front end of the gel plug in the pipe it will have a parabolic form as shown in figure 24 above.

Next the influence of water at the end of the gel plugs is going to be looked into. This influence is different if the gel plug has been influenced by stress by being moved or not, as described in chapter 8.7, Resettling of gel and mixing gel with water. To see how much this influences the end of the gel plug two different tests were carried out. First a gel plug was set to settle in a transparent vertical pipe to get a straight end on the gel plug. Then the transparent vertical pipe was mounted horizontally into the test set up and water was filled up at both ends of the gel plug, pink colored water at the end of the plug which was nearest to the pump and clear water at the other end. The gel plug was then left in the pipe for 24 hours without having inflicted any stress on the gel plug. As seen in figure 25 above there is not much influence from the water on the gel plug.

The influence of water on a gel plug which had been moved was then tested. As for the previous test a gel plug was set to settle in a transparent vertical pipe and then mounted in horizontal position in the test set up. The gel plug was first moved once and then set to settle in the pipe for 23 hours. Figure 26 seen below shows what happens after the gel plug has been settling in the pipe.

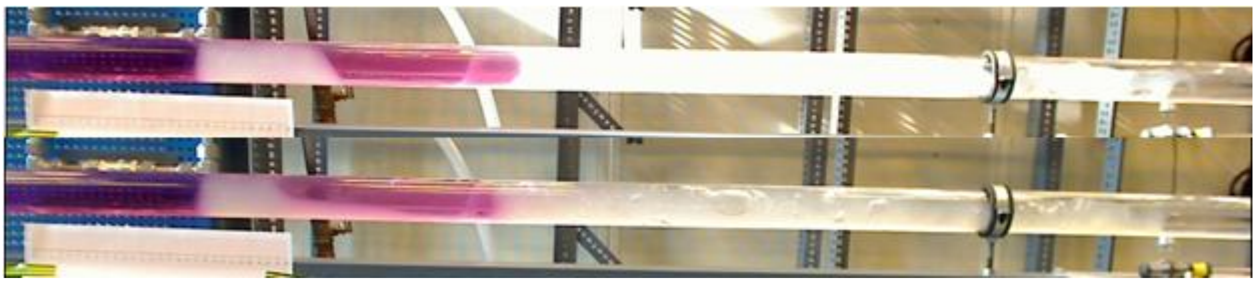

Figure 26: Gel plug which has first been moved and then been settling for 23 hours

Figure 26 shows that a gel plug which has been moved once and then left to settle for 23 hours will in the gel plug end nearest to the pump, shown to the left in the figure, have a little less slope because of the water tends to float on top of the gel.

In the front end of the gel plug the same thing has happened, but here the gel has also mixed with the water. The pink area in the middle of the gel plug, which will be discussed in the next chapter, shows clearly the effect of water having a lower viscosity than gel. Gel is more on the bottom of the pipe here than it was when it started settling. This has clearly made the end of the gel plug nearest the pump weaker because it is now shorter than before the settling began. Because of this effect gel plugs will need more pressure to be moved because it gets more stuck to the pipe wall when it is settles. It would also need less pressure for moving the gel plugs because of water making the end of the gel plug smaller.

Because the gel plug is split and one part of the gel plug is shorter it will be easier for water to flow over the short gel plug when the pump starts up again. This brings us back to how the whole gel plug behaves in the pipe. This will be interpreted in the next chapter.

8.10 Behavior of gel plugs in pipes

To be discussed now is how gel plugs behave in pipelines. Issues like if water can be run through or around gel plugs without any movement in the gel plug, will be interpreted. It will also be discussed what happens to remains of gel in the pipeline and if a gel plug can be split into two gel plugs.

First the issue regarding the possibility to run water through or around gel plugs without moving the gel plug will be analyzed. This question came up when the 100 meters gel plug in the 2 inch pipe which was pumped by the Haskel ASF-60 pump showed that a lower pressure was needed to move the gel plug than the previous test. The previous test was carried out in the same pipe with the same pump, but the gel plug was only 50 meters long. In theory gel plugs will need more pressure before they start to move the bigger they are.

After moving the gel plug of 100 meters length with the HT-400 pump which showed that a higher pressure was needed to move the gel plug it was clear that the Haskel ASF-60 pump was too small. The problem with the Haskel ASF-60 pump was that it did not pump enough volume of water to move the gel plug.

To figure out if it was possible to get water past the gel plug without moving the gel plugs a small scaled test was carried out at the University of Stavanger. A 1.22 meters long gel plug was placed in a 1.57 inch pipe. It was set to settle in the same way as described for the previous tests at the University of Stavanger. The description is found in chapter 7.5, Experimental procedure for gel tests at the University of Stavanger.

This time the Gilson pump was set to run at a flow rate of 10ml/min. The pump was run for 10 minutes. The result from this test is shown in figure 27 below.

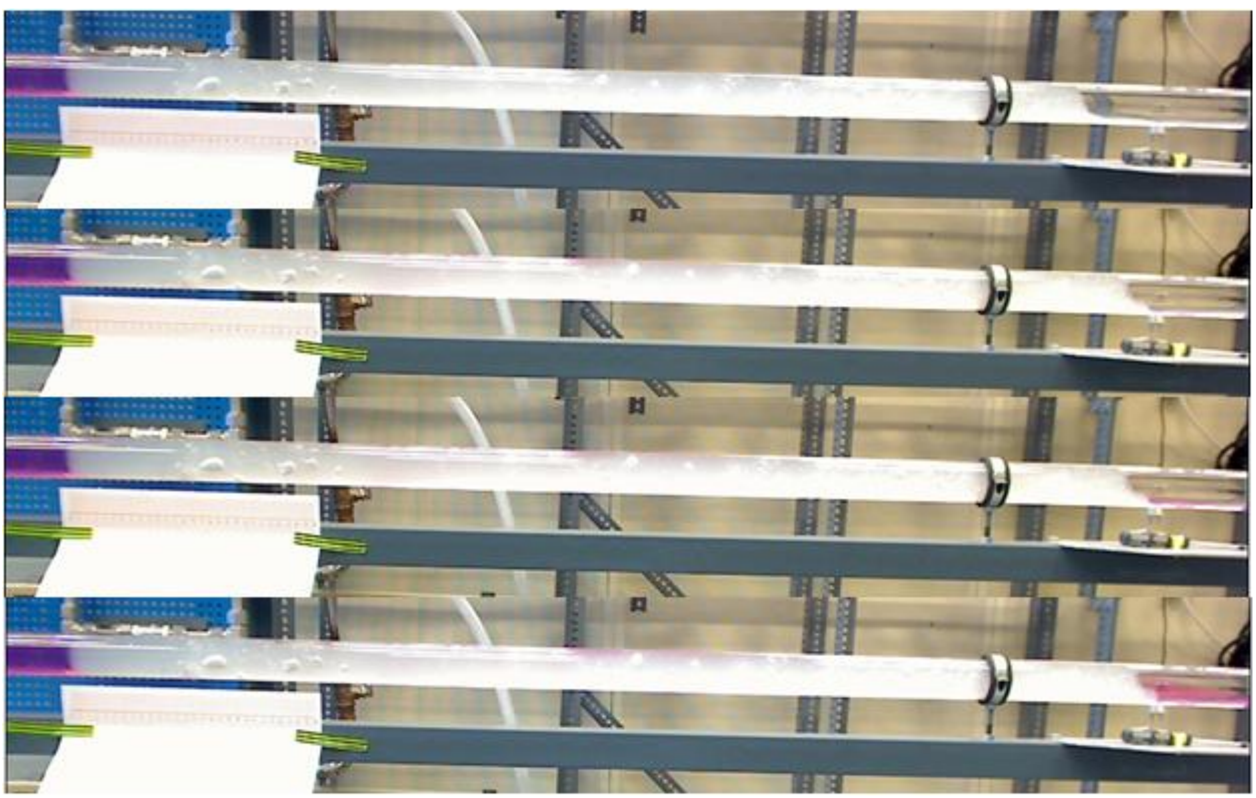

Figure 27: Pumping water past gel plug witout moving the gel plug

Figure 27 shows that it is possible to pump water past gel plugs without moving them. The picture of the first pipe in the figure is taken before the test was started. At this time there is pink colored water behind the gel plug and clear water in front of it.

The second picture shows that water has started to flow on top of the gel, indicated by a little pink area on top in the middle of the gel plug. It is also seen that the gel plug has become longer. In the third picture there is both pink colored water on top of the gel plug and in front of it. The fourth picture shows clearly pink colored water in front of the gel plug. By comparing the first and the fourth picture it is seen that the gel plug has not moved. This means that with low flow rate on the water behind the gel plugs it is possible to get water past the gel plugs without moving them.

After the pump had been running for a while the flow rate of the pump was increased from 10 ml/min to 50 ml/min. The gel plug then started to move as a whole plug. This shows that gel plugs will move if the flow given by the pump is high enough. The reason why it moved now, is that when the flow from the pump is higher, it will "punch" the end of the gel plug. This results in the end of the plug being pushed forward and upwards tightening the crack which is between the gel plug and the pipe wall in top of the pipe. The crack which needs to be tightened is seen in figure 23 in the previous chapter.

From the observations done in this test it is clear that the flow rate of fluid which pushes the gel plugs has an influence on the pressure needed to move gel plugs. This influence will be looked more into in chapter 8.11, Influence from flow rate of water pushing the gel plugs.

The next issue to be looked into is what happens to remains of gel in the pipe. A gel plug was set in the same way as the previous gel plugs at the University of Stavanger. When this gel plug had set linear gel and cross-linker were spilled on the pipe wall in front of the gel plug making small gel lumps which was sticking to the pipe wall even when the pipe was mounted vertically. Before the test was launched the solid gel plug was 70 cm long with 60 cm of pipe with remains of gel in it in front of the gel plug. After the transparent pipe was mounted horizontally in the test set up the Gilson pump was started with a flow rate of 100 ml/min. The outcome of the test is seen underneath in figure 28.

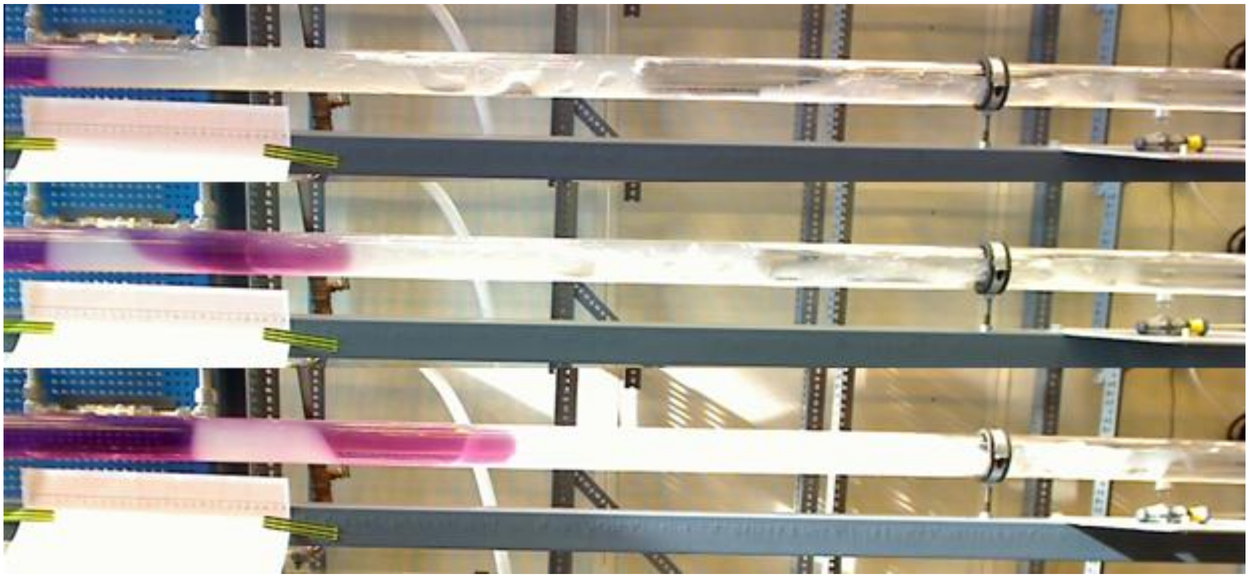

Figure 28: Gel plug run with remains of gel in front

As seen in figure 28, the remains of gel on the pipe wall will in smooth pipes be transported forward by the gel plug, making it a part of itself. This will inflict the pressure needed to move the gel plugs because the gel plugs will be longer in total length when more gel is included in it. With a small amount of remains in the pipe this will only give a small increase in the pressure.

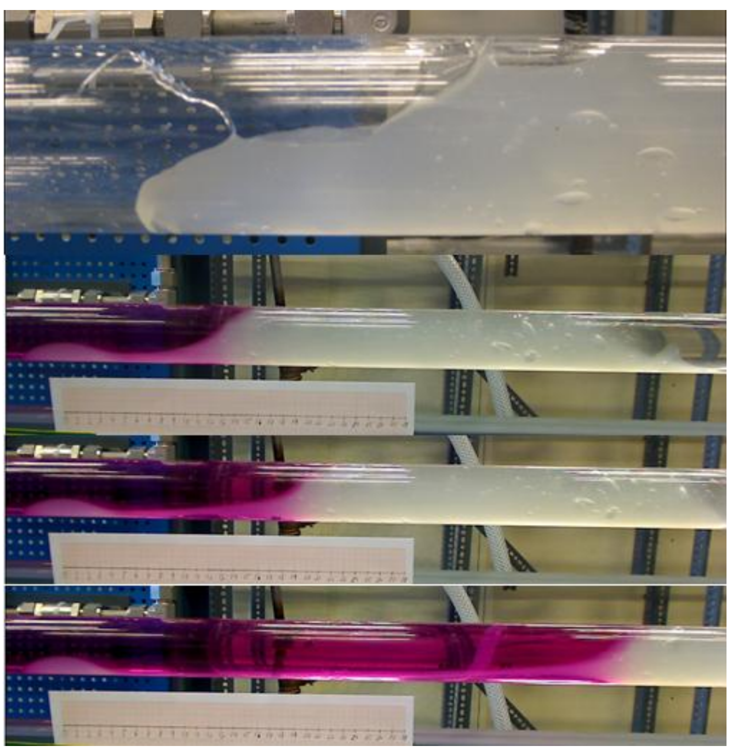

Figure 29: Dividing of gel plug caused by inclined end of gel plug

There were two effects that occurred during this test. The first is the effect of remains of gel being pushed by the gel plug and included in the whole gel plug. The second is the effect which divided this gel plug into two gel plugs when the test was carried out. This also happened in other gel tests which were run in the transparent pipe at the University of Stavanger. In most of the tests which were carried out, the gel plugs did not split into two different gel plugs, but those which did had either a plug end which was not vertical straight or air bubbles close to the end of the gel plug. To see the effect connected to gel plugs splitting into two gel plugs, figures 29 and 31 which are shown below were made. The gel plugs are made in the same way as the previous gel plugs made for tests at the University of Stavanger.

Figure 29 above first shows a picture of how the end of the gel plug was before water was filled up at both ends of the gel plug.

The second picture was taken after water was filled up at both ends of the gel plug. This shows that the pressure given by filling up the pipe with water was enough to move and begin to split the gel plug.

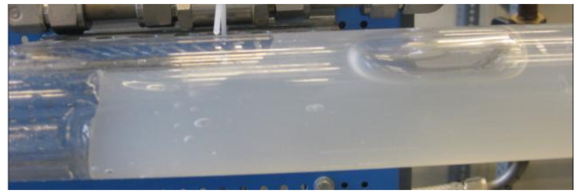

Figure 30: End of gel plug with air bubble

The third and fourth picture shows that the gel plug is not completely divided into two different plugs. A string which is getting thinner as the biggest part of the gel plug moves making it a little bit shorter as the gel plug is moves forward. This is done by dragging gel from the biggest part of the gel plug to make the string between them. It is also seen in figure 29 that the top of the gel plug is pushed more forward as written in chapter 8.9, Influence and behavior of the ends of the gel plugs.

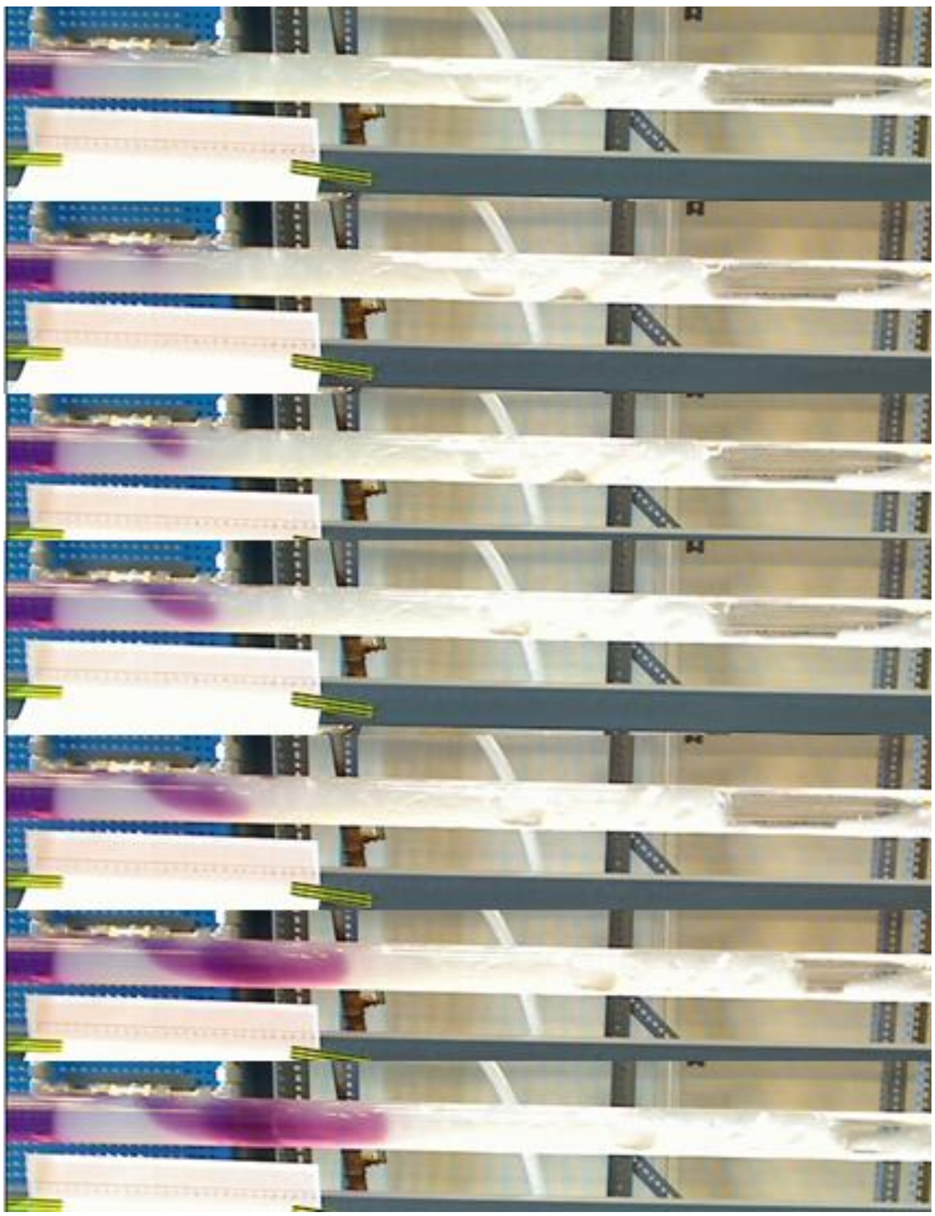

Figure 31: Splitting of gel plug caused by air bubble

There is one other way which gel plugs are split into two different gel plugs which occurred during the gel tests at the University of Stavanger. What happened during this test is shown to the left in figure 31. The gel plug for this test was made in the same way as the previous once. Figure 30 seen above shows the end of the gel plug before the pipe was filled with water at both ends of the gel plug. The figure shows an air bubble which has occurred near the end of the gel plug at the end nearest to the Gilson pump.

The first picture shown in figure 31 is taken before the test was initiated. The air bubble which was seen in figure 30 is now smaller, and not that easy to spot.

When the Gilson pump had started to pump water in behind the gel plug, the air bubble flew out of the pipe following the top of the gel plug. It flew along the top side of the gel from its original position a few centimeters from the back end of the gel plug and out of the pipe in front of the gel plug. In just a couple of seconds it flew out of the pipe in front of the gel. This means it flew from the left to the right in the figure following a path between the top of the gel and the pipe wall.

In the second picture which is after the test was initiated it is seen how the pink colored water is moving on top of the gel plug. The third and fourth picture shows how the water is "drilling" downwards in the gel plug. The two last pictures show how the biggest part of the gel plug has started to move without any movement in the first little part of the gel plug. This is the same effect which was seen in figure 27, Pumping water past gel plug witout moving the gel plug.

After this test was carried out the gel plug was set to settle in the pipe for two hours. The results from the test after the pump was started up again is seen in figure 32 to the left.

Figure 32: Moving of gel plug which has been split and settled for 2 hours

By comparing the first picture in figure 32 and the last picture on figure 31 it is seen that the influence of water on the gel plug which has already been moved has started influencing the little gel plug. This is the same influence as the one shown in figure26, Gel plug which has first been moved and then been settling for 23 hours in chapter 8.9.

Figure 32 shows that when the gel plug had been settling for 2 hours and the pump was started up again, with flow rate of 100 ml/min, both gel plugs started to move simultaneously instead of the biggest part of the gel plug only starting to move as the previous test. The reason for this is probably that in spite of the water influencing the gel plug and making it weaker, as seen in the previous chapter, the influence of settling time makes the gel plug “stick” more to the pipe wall than the water manages to weaken it. When the pump then is started, the small gel plug probably “sticks” more to the pipe wall than before because there is no air bubble there now. This leads to a case where the water pushing the gel plug also pushes the crack on top of the gel plug upwards and by this moves the small gel plug. The small gel plug then pushes the water between the two gel plugs which again pushes the big gel plug in front of it. This again leads to the moving of both gel plugs simultaneously.

These two tests with the gel plug splitting in two needed approximately the same pressure for moving the gel plugs. This is in spite of the gel plug having 45 hours of settling time before the first test and only 2 hours of settling time before the second test. It could be a coincident that both tests need approximately the same pressure because when both gel plugs are pushed simultaneously this is almost the same as pushing one giant gel plug consisting of both gel plugs and the water in between them.

As seen from the tests carried out at the University of Stavanger there are many coincidences involved in the behavior of gel plugs. These coincidences and the influences of other variables will be discussed in the next chapter.

8.11 Influence of flow rate of water pushing gel plugs

The last variable to be looked at is the influence of flow of water pushing gel plugs. During the gel tests this variable was kept as constant as possible. From the first run of 100 meters gel plug in the 6.1 inch pipe seen in chapter 12.1.12, The 6.1 inch pipe with 100 meters gel plugs pumped by HT-400 pump it is shown that a higher flow rate will create a higher pressure. The test which was run with this plug started with a flow of 130 liters per minute. This flow was believed to be a too low flow for pushing the gel plug and the effect of water bypassing the gel plug, which was later proved as shown in the previous chapter, was believed to occur. The flow of water given by the pump was therefore increased twice. It was first increased to 280 liters per minute and then to 330 liters per minute. The effects on the pressure by increasing the flow is seen underneath in figure 33.

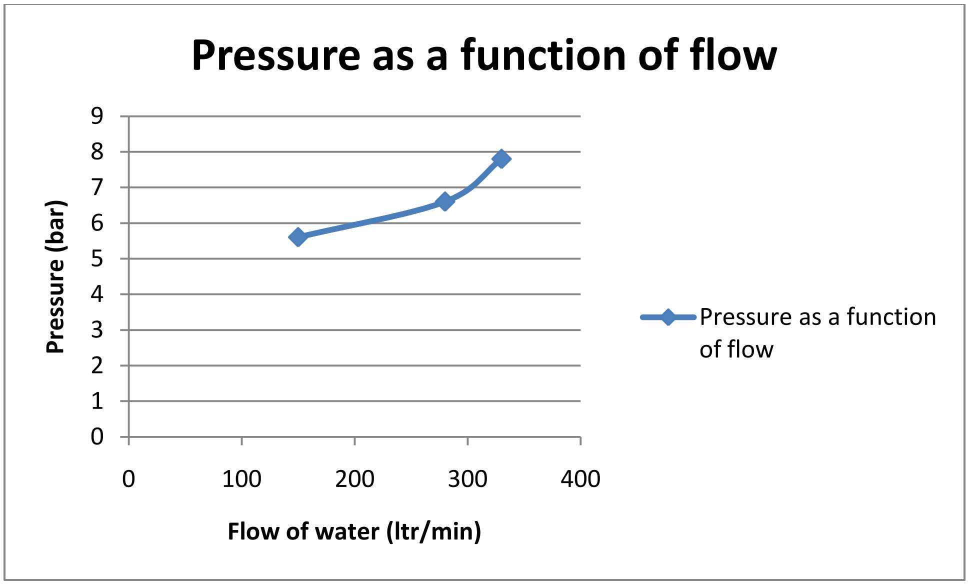

Figure 33: Pressure as a function of flow

Figure 33 shows an increase in pressure when the flow of water pushing the gel plug is increased. The graph in the figure has a higher difference quotient as the flow is getting higher. This is believed to occur because of more gel is getting pushed as the velocity of the water pushing increases. It will when the flow is increased be less water bypassing the gel plug. Because of this more gel will be pushed by the water and this again leads to an increased pressure needed to move the gel plug.

There were two gel plugs of 50 meters length in the 2 inch pipe in which tests were carried out. Different pumps were used with different flow rate in each of the tests. Both the Haskel ASF-60 and the HT-400 pumps were used and both gel plugs were moved after 16 and 2 hours of settling time. A comparison between flow and pressure given by these tests shows that the pressure needed for moving the gel plugs was lower when the flow was getting higher. This is the opposite of what happened in figure 33. The comparison between these two tests is therefore not included in this interpretation because other variables are not kept constant between the two tests. Gel tests where only flow is varied in small scale tests, could be a good approach to find an answer to how the flow of water is influences the pressure needed to move the gel plug.

9.0 Discussion

This chapter contains discussions regarding the results which were found in the interpretations in chapter 8.0, Results of gel tests.

9.1 Discussion of the influence of shear stress from gel plugs with at least 12 hours settling time

In this discussion the results from the 2, 4 and 6.1 inch pipe with settling time of more than 12 hours will be discussed. The 2 inch pipe is the first to be looked at.

From the results in chapter 8.1, Influence of shear stress from gel plugs with at least 12 hours settling time it is seen that for the 2 inch pipe every result of the shear stresses from the tests are lower than the theoretical shear stress for this diameter of pipe. Even the highest result collected from the test is much lower than the theoretical shear stress. It is of course possible that the uncertainty in the interpretation of the result has influenced the results. The peek made by the pump as shown in figure 9 in chapter 8.1 makes it difficult to interpret when the gel plugs starts to move. Every test in the 2 inch pipe has some kind of peek caused by the pump which has been neglected from the pressure recorded in table 10 in chapter 8.1.

Next is the 4 inch pipe with settling time of more than 12 hours. By looking at tables 9 and 10 in chapter 8.1, Influence of shear stress from gel plugs with at least 12 hours settling time it is seen that all three results are higher than the theoretical shear stress. There are two results that are approximately the same. These are for the 100 and 150 meter gel plugs. The 50 meter gel plug has a higher result than the other two gel plugs. As for the 2 inch pipe uncertainty has an influence. It would be easy to look at the result from the 50 meter gel plug as a bad result and reject this, but there is no reason for rejection of this test result because uncertainty is not included in the interpretation.

In the interpretation for the 6.1 inch pipe table 10 in 8.1 shows that the shear stress from test results for the 50 and 100 meter gel plugs are the same as the theoretical shear stress. Shear stress from the 150 meter gel plug is higher than the other two. The two shear stresses which are the same as the theoretical result could be so by chance or it could be that the 6.1 inch pipe is more accurate regarding pressure and diameter than the other two pipe diameters. A starting point of the gel is hard to determine so this could be a good interpretation.

There is clearly a deviation between the theoretical shear stress and the shear stresses calculated from the test results. The result that differs from the other results in the different pipe sizes is not of the same length of gel plug in any of the different pipe sizes.

It is shown in figure 34 below that if the theoretical shear stress and the results from the different shear stresses are put in the same figure there is no accordance between the theoretical shear stress and the shear stress given by the results from the gel tests.

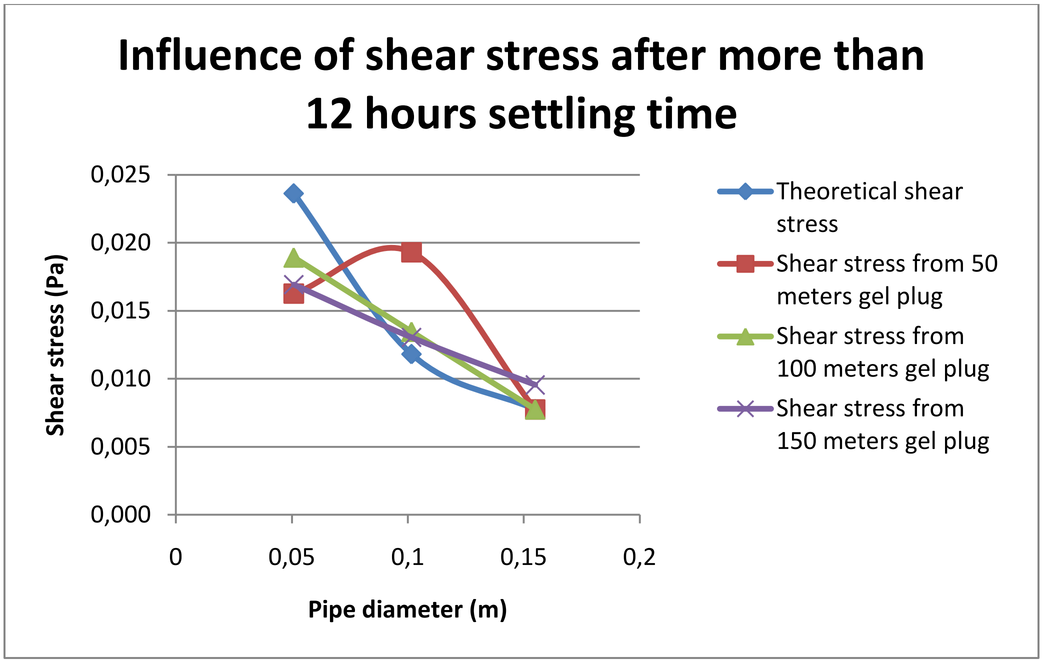

Figure 34: Influence of shear stress after more than 12 hours settling time

Theoretical shear stress is a function of viscosity, pipe diameter and velocity, but there are more variables which need to be included. Experience from the test results is that the expression for theoretical shear stress lacks the variables of settling time, temperature and flow rate of water pushing the gel plug. These variables influence the shear stress, but not directly. Settling time influences the shear stress because more settling time is making the gel plug "stick" more to the pipe wall and by this helping the shear stress with holding the gel plug back. More about settling time and the other variables will be discussed later in this chapter.

9.2 Discussion of the influence of shear stress from gel plugs with 2 hours settling time

As expected the results of shear stress after 2 hours of settling time had a lower shear stress then the results after more than 12 hours of settling time. The theoretical shear stress is still the same because in the formula for shear stress settling time is not included. This means that settling time has an influence on the pressure needed to push gel plugs and an indirectly influence on shear stress.

The results of the shear stress from the 2 hours settling time show the same tendency as the 2 and 6.1 inch pipe results by being lower compared to the theoretical shear stress than the results from the 4 inch pipe is. This clearly indicates that the theoretical formula for shear stress is wrong. Maybe it should be as the shear stress from the 100 and 150 meters gel plugs in figure 34 indicates, more linear.

9.3 Discussion of the influence of pipe diameter

As the graphs in the figures in chapter 8.3, Influence of pipe diameter indicate the use of power trend line for calculating the theoretical pressure found in chapter 6.2, Theoretical influence of diameter of pipes, may not be the right trend line to use if looked at the results from the tests. It is possible there is another connection between diameter of pipe and pressure, but it can also be a power line connection as the theoretical pressure indicates. The results are so close to the accurate trend that the influence of pipe diameter is set to be the same as the theoretical influence from Fanning`s equation seen in chapter 6.1, Theoretical pressure.

9.4 Discussion of influence of length of gel plugs

As seen in the figures in chapter 8.4, Influence of length of gel plugs, the influence of length follows a straight line, but none of the lines made by the results from the tests follows a straight line. This can be because of uncertainty in the data collected or it can be because of other influences. There is no clear indications that the influence of length of gel is different than the influence which is found from Fanning`s equation, this influence is therefore set to be the correct one to use in the calculation of pressure needed to move a gel plug.

9.5 Discussion of influence of settling time

From earlier in this chapter it was seen that settling time has an influence on the pressure needed to move the gel plug. As said, more settling time makes the gel plug “stick” more to the pipe wall. This could be because of the van der Waal forces. Settling time is therefore important when it comes to figuring out which pressure is needed to move gel plugs.

It is seen in the tables in chapter 8.5, Influence of settling time that there is little difference between pressure when the gel plug has been settling for the same amount of time if it is the second, third or fourth time. When gel plugs were settling for the first time and second time there was a difference between the influences if settling time in two different cases. In one case there was no difference between settling for the first time and second time if the gel plug settled for the same amount of time. But in the other case the gel plug needed much higher pressure before it started to move after settling for the first time compared to the second time. There can be many reasons for this. It depends on what has happened in the pipe before the test was run and if there is a big influence by temperature

9.6 Discussion of temperature influence

The influence of temperature can be neglected if the pipeline lies on the sea bed because of the constant temperature of 4°C there. If the temperature surrounding the, pipe which the gel plug is set in, is inflicted by temperatures under zero degrees Celsius there will be a reaction of some kind causing the pressure needed to push the gel to sink. Which of the reactions mentioned in chapter 8.8, Temperature influence that occurs, is unknown and should be tested more thoroughly. Temperatures influence on the pressure needed to push gel plugs have not been measured enough in the tests. There are clear indications that temperature has a bigger role in the pressure needed than presumed.

9.7 Gel behavior in the pipe and flow rate of water pushing gel plugs

These influences are much easier to be sure of because they were seen during the tests. To figure out these influences transparent pipes were used.

It was seen in the tests that the influences of the behavior of gel plugs in pipes are random. Most of the gel plug will be uninflected by the flow rate of water pushing the gel plug if gel plugs are run with a high enough speed. In the end of the gel plug it could be influenced by the water pushing the gel plug. If the gel plugs have not been moved and it is a good gel plug, it will not be influenced by the water pushing on the gel plug in the end of it.

Gel plugs can also be divided into two plugs depending on the making of the plugs. If there are air pockets in the gel, especially at the top of the gel, these could influence the behavior of the gel plug, even split it in two. This depends on if the water which pushes the gel plug, finds a path along the pipe wall to the air pocket or not.

There is always a crack between the top of the gel plug and the pipe wall and this crack has to be pushed together by the flow of water given by the pump or else the end of the gel plug will be inflicted. If the velocity of the water pushing the gel plug is too low, this will allow the water to pass on top of the gel plug without moving the gel plug. The water can also “drill” itself into the gel plug if air pockets or bends are found. This could be one of the reasons gel plugs divide into two or more gel plugs. The crack at the end could also be pushed upwards sealing the pipe and making the water move the whole gel plug.

The pressure needed to move the gel plug is also influenced by the history of the pipe and what the pipe has contained or what fluids have been run in the pipe before the gel test is carried out. If another gel plug has been run before the test is carried out, this plug could have left remains of gel in the pipe. A gel plug would absorb big bits of gel, but also leave bits of itself to the pipe wall. The inclination of the end of the gel plug would also influence the pressure needed to move gel plugs.

As seen it is not easy to find out if the gel plugs are influenced by something which happens inside the pipe without a transparent pipe. There are many unknown factors about influence on the behavior of the gel plugs in pipes. For starters it is easy just to say that the gel plug would not divide into more than one gel plug, but a dividing and then settling of the plug could make the gel plug harder to move than a whole plug being moved and then settled again. To neglect most of these influences and provide the lowest possible pressure which is needed to move gel plugs, the flow rate of water given by the pump has to be influencing the gel plug in the right way. It has to be so high that it will not find a path true the gap between the pipe wall and the top of the gel plug and still as low as possible. The flow also has to be low because the pressure gets higher as the flow gets higher. This makes it hard to figure out the influences and the ideal velocity of the water pushing the gel plug is unknown.

10.0 Conclusion

The gel tests show that many variables influence the pressure needed to move gel plugs. The variables which were interpreted were pipe diameter, length of gel plug, temperature, shear stress, cracks, settling time, first and second time the gel plug is set, flow of water pushing the gel plug, remains of gel in the pipeline and uncertainty of the data collected.

From these variables it was found that all of them had some kind of influence on the pressure needed to push gel plugs. The variables of first and second time gel plugs are set and remains of gel in the pipeline could be neglected when the pressure needed to start moving gel plugs are calculated. If it is the first or the second time gel plugs are set has almost no influence on the pressure needed to move gel plugs.

Remains of gel in the pipeline have a bigger influence on gel plugs when they are already set in motion. The reason for this is because gel plugs will collide with the remains of gel in the pipe and push them in front of itself, absorbing them and making them a part it. When the gel plug is stopped, the absorbed remains will cross-link with the rest of the gel plug making the whole gel plug bigger. The pushing of the remains in front of the gel plug will influence the pressure needed to push the gel plug because the total length of the gel plug will then be longer. Remains of gel along the pipe walls will also influence the shear stress in the pipe because these remains will help gel plugs flow easier in the pipe when gel plugs are already set in motion.

The variables which need to be included, when pressure needed to move gel plugs is calculated, are pipe diameter, length of gel plug, temperature, shear stress, settling time and flow of water pushing the gel plug.

Cracks have an influence only then the flow rate of the water pushing the pump is too low. If the flow rate given by the pump is too low a crack between the top of the gel plug nearest the pump and the pipe wall, which always occurs, will be the beginning of a path which the water in the flow rate can use to flow past the gel plug on top of it. When the flow rate of water given by the pump is high enough, it will “punch” the end of the gel plug so hard that it will be pushed upwards and seal the crack in top of the gel plug, making it possible to neglect the influence of this crack.

The theoretical equation used to calculate pressure needed to move gel plugs are a rewriting of Fanning`s equation and is shown below:

$$P = \frac{4}{D}\tau_W \times L$$

It can be concluded that Fanning`s theoretical equation does not contain of enough variables to calculate the correct pressure needed to move gel plugs. This equation contains the variables; pipe diameters, length of gel plug and shear stress. Experience from the test results is that this equation lacks the variables of settling time, temperature and flow rate of water pushing the gel plug.

The theoretical equation for shear stress is seen in the equation as τ_W and the formula for τ_W is $\frac{8\mu U}{D}$. This means that the equation for shear stress contains viscosity and velocity of the gel plug and pipe diameter and none of the other variables. If a new equation for calculating the pressure needed to move gel plugs are going to be made these three variables are probably needed in it. The new expression for shear stress which will be a part of this new equation is unknown. What is known is that in this new equation temperature, flow rate of water pushing the gel plug and settling time has to be included in addition to the three variables which are already used in the old equation.

Settling time influences shear stress because the gel plug “sticks” more to the pipe wall when it settles. This will make it harder to move and gives in a way the wall more shear stress because the gel plugs “work” together with the shear stress of the pipe wall and provides more shear stress which the pump has to overcome to push gel plugs forward.

The influence of temperature on the pressure needed to move gel plugs was not measured accurately enough. What can be concluded from the gel tests is that when a pipe with a gel plug inside is exposed to temperatures below zero degrees Celsius, the pressure needed to move gel plugs will be much lower than if the pipe has not been exposed. It can also be concluded that gel plugs will not be destroyed by being moved in or influenced by the pipe being exposed to temperatures below zero degrees Celsius.

When gel plugs are set in pipelines lying on the sea bed in deep water, the temperature can be neglected because the temperature will always be four degrees Celsius at the sea bed in deep water. Gel is known from theory to be very inflicted by temperature. It is therefore important to know the influence this variable has on the pressure needed to move gel plugs when they are not set at the sea bed in deep water.

Flow rate of water given by the pump is not directly influencing the shear stress, but it influences the shear stress indirectly. Too low flow rate will make the water, which is supposed to push the gel plug, flow into the crack between the top of the gel plug and the pipe wall. This crack is made because gel has a higher density then water and therefore water tends to flow on top of the gel. If the flow rate given by the pump is too low, then water will flow past the gel plug on top of it. Water can then either flow all the way across on top if the gel or it can “drill” itself downwards in the gel plugs if there are air bubbles or bends in the pipe. From the observations done during the gel tests it is clear that the flow rate of water pushing gel plugs has an influence on the pressure needed to move gel plugs.

The tests carried out in transparent pipes showed that there are many coincidences involved in the behavior of gel plugs. It was discovered that the top of the gel plug is the first part of it to be pushed forwards by pressure coming from the water which is pushed by the pump. The whole gel plug therefore starts to move first in the top of the gel plug and last in the bottom of it.

The shape of the end of the gel plugs and if there are bubbles in it influence the pressure needed to move the gel plug. If the end of the gel plug is inclined the flow rate needed to push the end of the gel plug upwards has to be bigger than if the end of the gel plug is vertical. Because the shape of end of the gel plug is not easy to predict, it is hard to figure out if the water is going to flow on top of the gel or push it forwards. If there are air bubbles on top of the gel plug near the end of it the air bubbles will influence the pressure needed to move gel plugs because the air bubbles will help water to flow on top of the gel plug. Both air bubbles and the inclination of the end of the gel plug can cause the gel plug to split into two gel plugs.

The conclusion from this is that the gel tests have given much information about how gel behaves in pipes and different pressures needed to move different lengths of gel plug in pipes of different sizes. A complete equation for calculating the pressure needed to move gel plugs cannot be calculated from these results because the behavior of the end of the gel plug and the influence of temperature is not well enough documented.

To figure out the behavior of the end of the gel plugs an approach could be to make gel plugs in small scale tests in approximately the same way as they are made in real life situations. Then vary the flow rate to see how the end of the gel plugs is shaped and behaves. Then take the average of how much of gel which is left in the pipe and at which flow rate the water flows over or pushes the gel plugs.

To solve the problem with temperature influencing the pressure, the small scaled tests could either be run in a room with constant temperature of four degrees Celsius and neglecting the temperature in the new equation. This will make the equation only useful when gel is set in pipelines on the sea bed in deep water. Another way of solving the problem regarding temperature, would be to run similar small scale tests imitating real life situations and only varying the temperature in the room. The use of pigs in these tests could make it possible to neglect the influence of the behavior of the end of gel plugs.

As seen from this conclusion there are still many things to be tested before an equation which calculates the pressure needed for moving gel plugs, can be constructed, but these gel tests are a step in the right direction.

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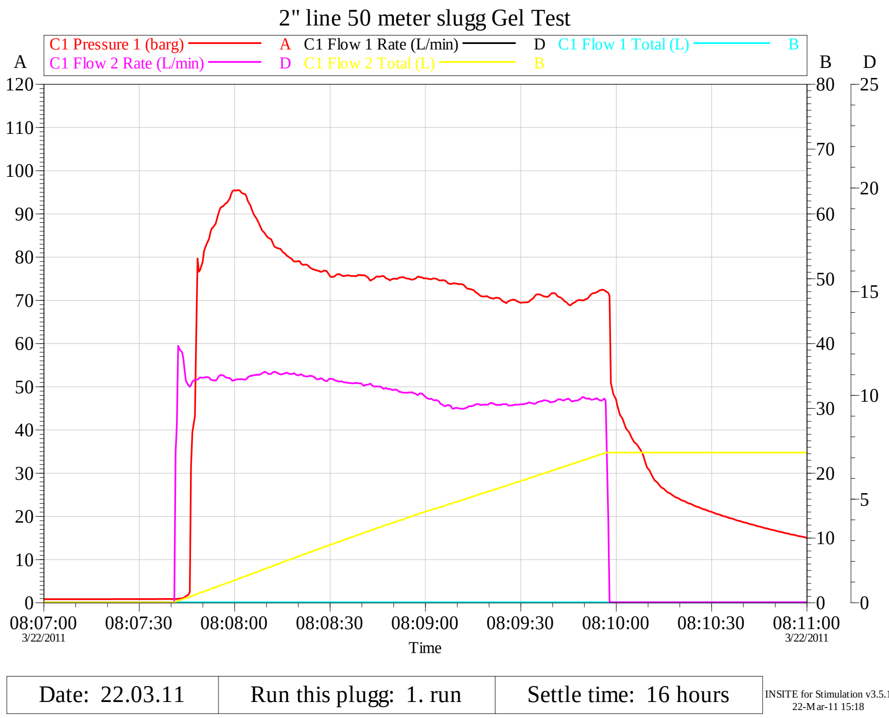
12.0 Appendix

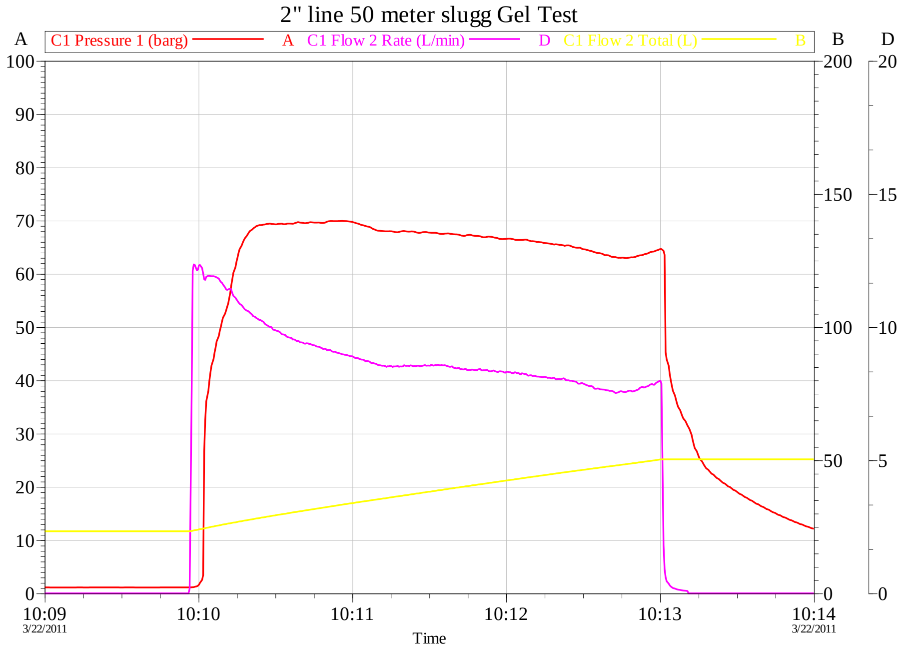
His chapter contains extensive information collected or used during the gel tests in Risavika Harbor and at IRIS research center.

12.1 Data from gel tests in Risavika Harbor and at IRIS research center

This chapter contains graphs made from the data collected during the gel tests in the 2, 4 and 6.1 inch pipelines with 50, 100 and 150 meters gel plugs carried out in Risavika Harbor and at IRIS research center.

12.1.1 The 2 inch pipe with 50 meters gel plugs pumped by Haskel ASF-60 pump





Date: 22.03.11	Run this plugg: 2. run	Settle time: 2 hours

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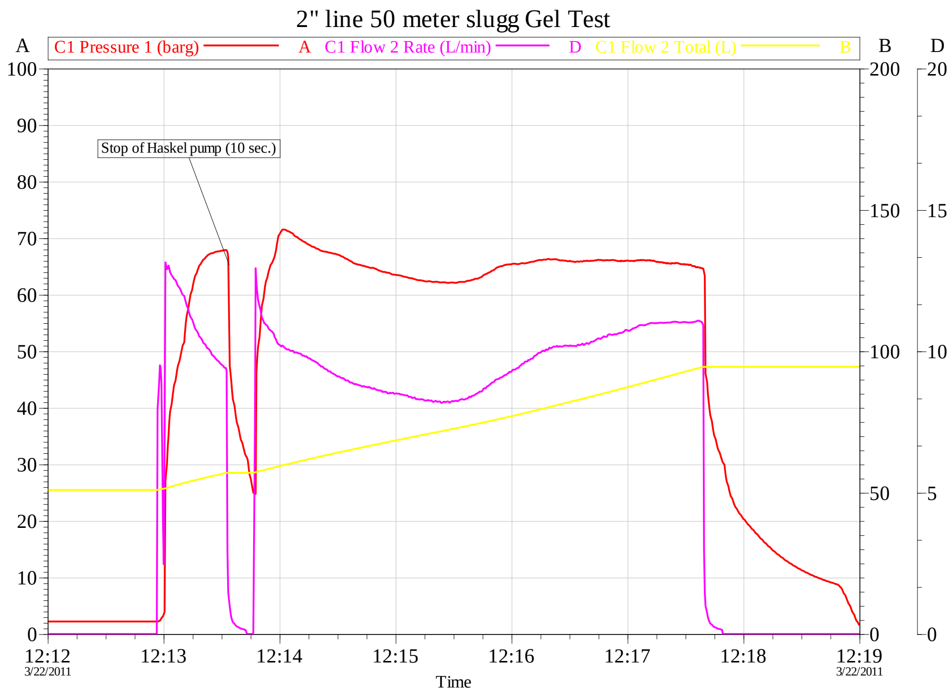
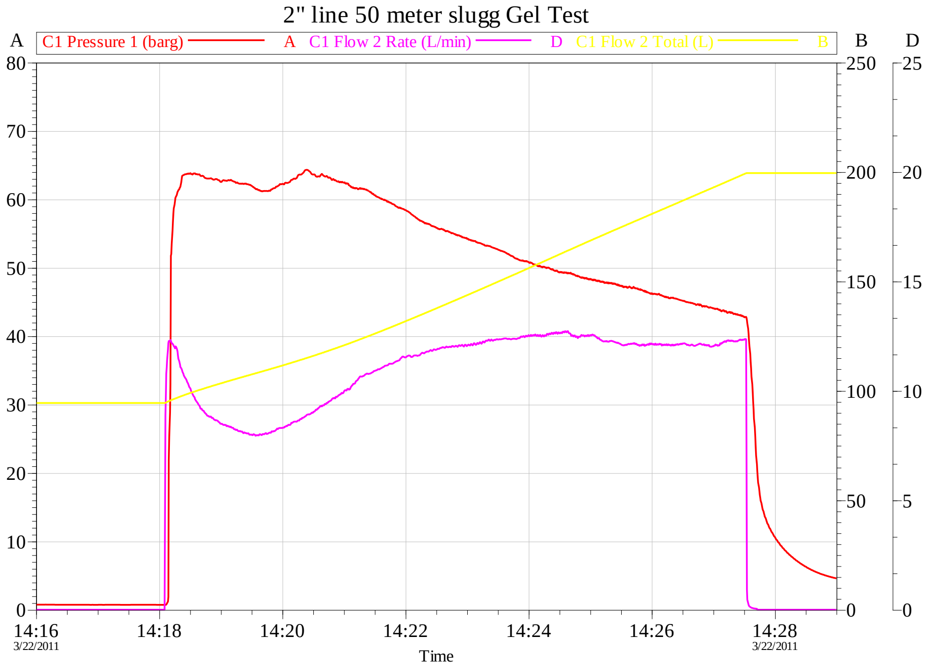
22-Mar-11 10:36



Date: 22.03.11	Run this plugg: 3. run	Settle time: 2 hours

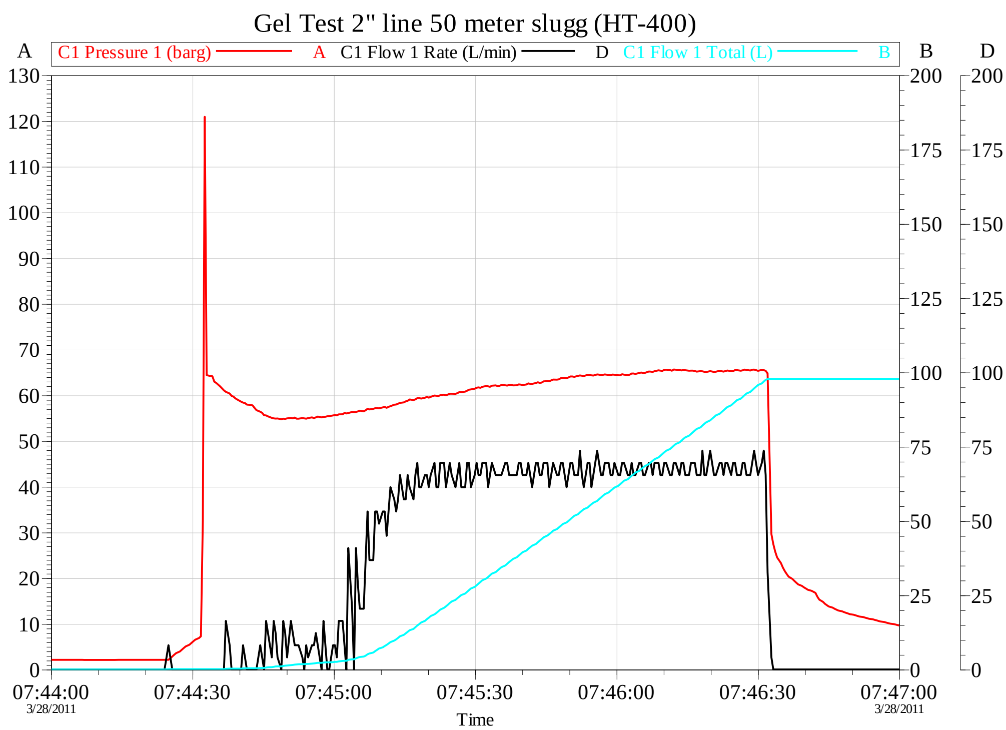
INSITE for Stimulation v3.5.1
22-Mar-11 12:28



Date: 22.03.11	Run this plugg: 4. run	Settle time: 2 hours

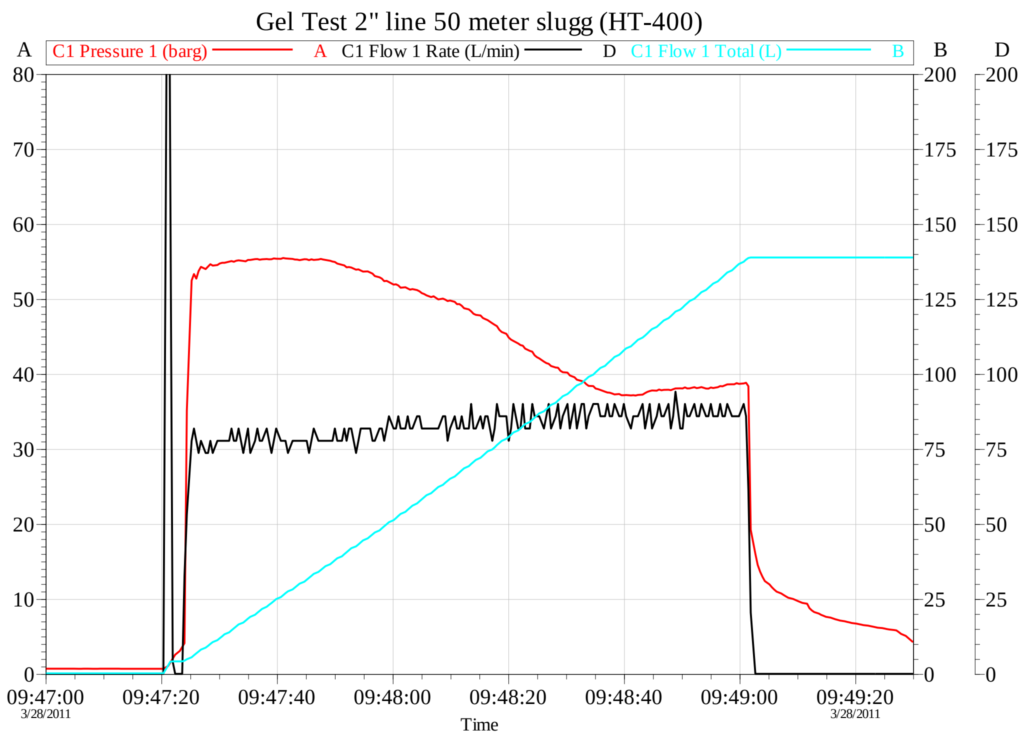
INSITE for Stimulation v3.5.1
22-Mar-11 14:33

12.1.2 The 2 inch pipe with 50 meters gel plugs pumped by HT-400 pump



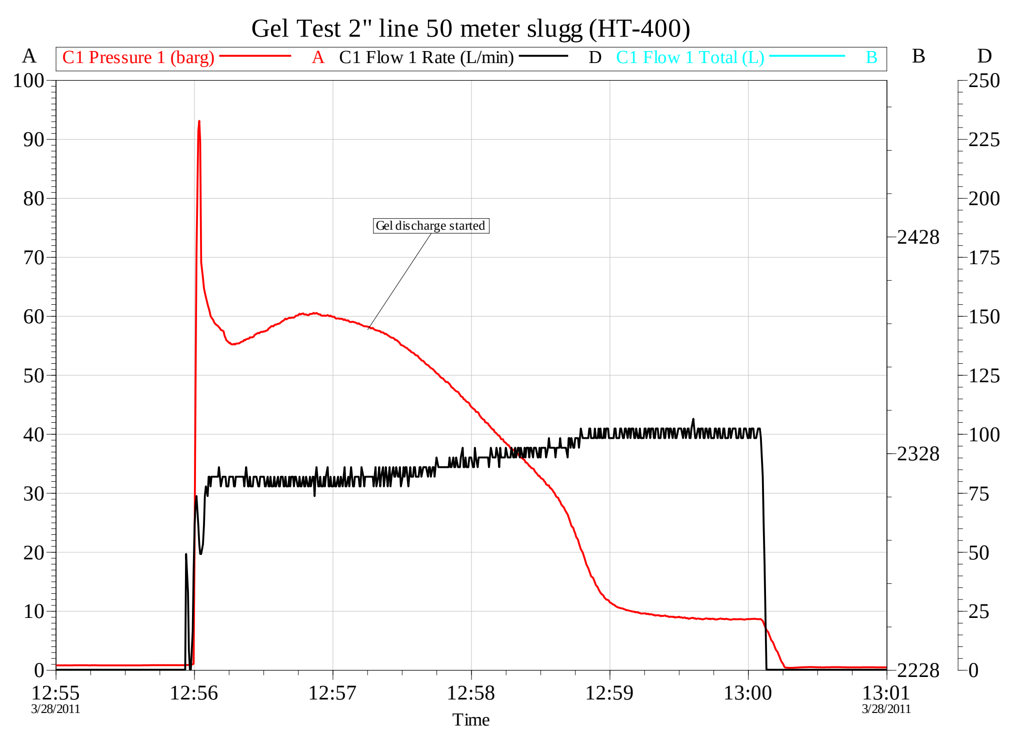
Date: 28.03.11	Run this plugg: 1 run	Settle time: 16 hours

INSITE for Stimulation v3.5.1
28-Mar-11 10:25



Date: 28.03.11	Run this plugg: 2 run	Settle time: 2 hours

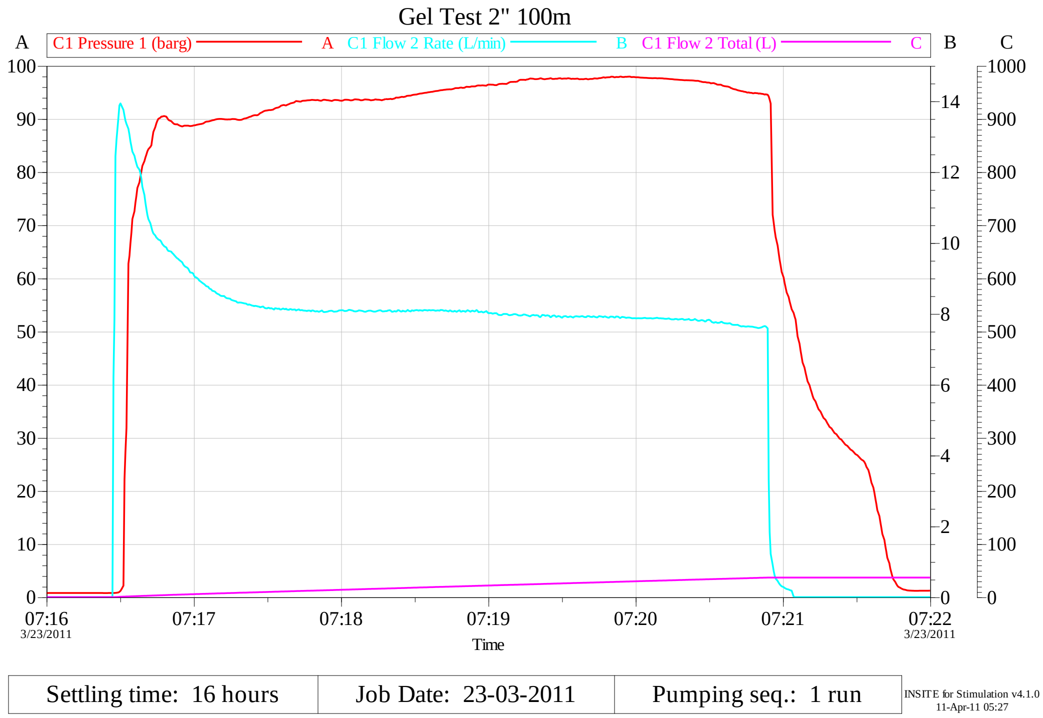
INSITE for Stimulation v3.5.1
28-Mar-11 13:12

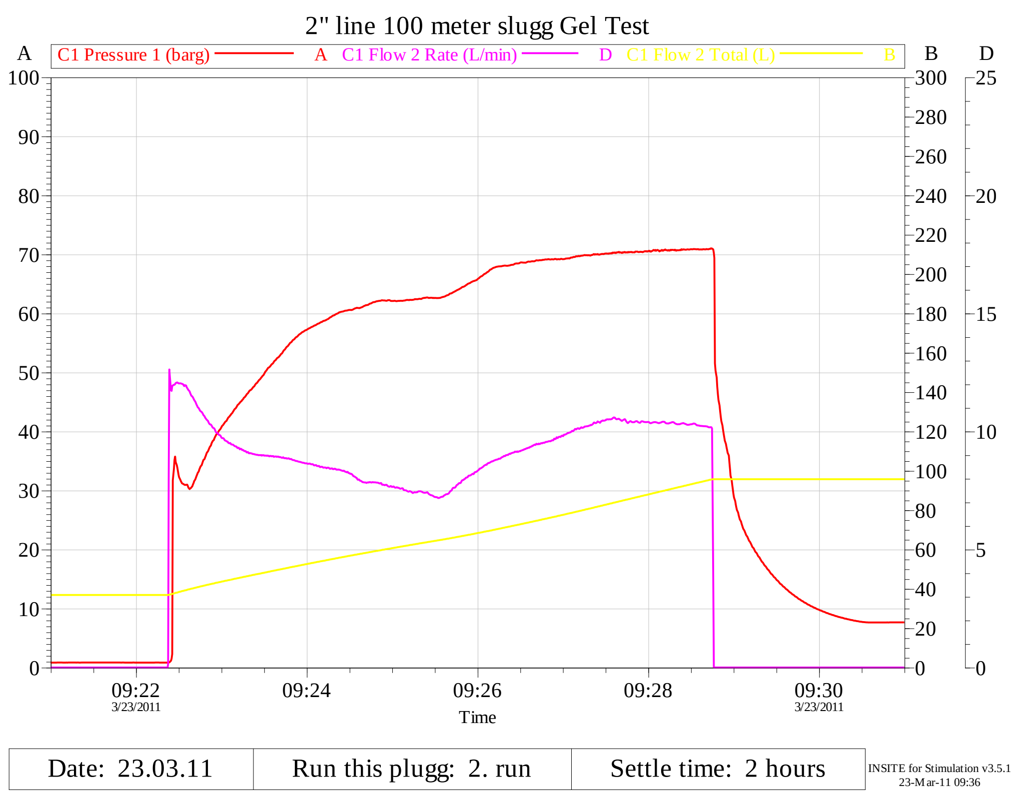


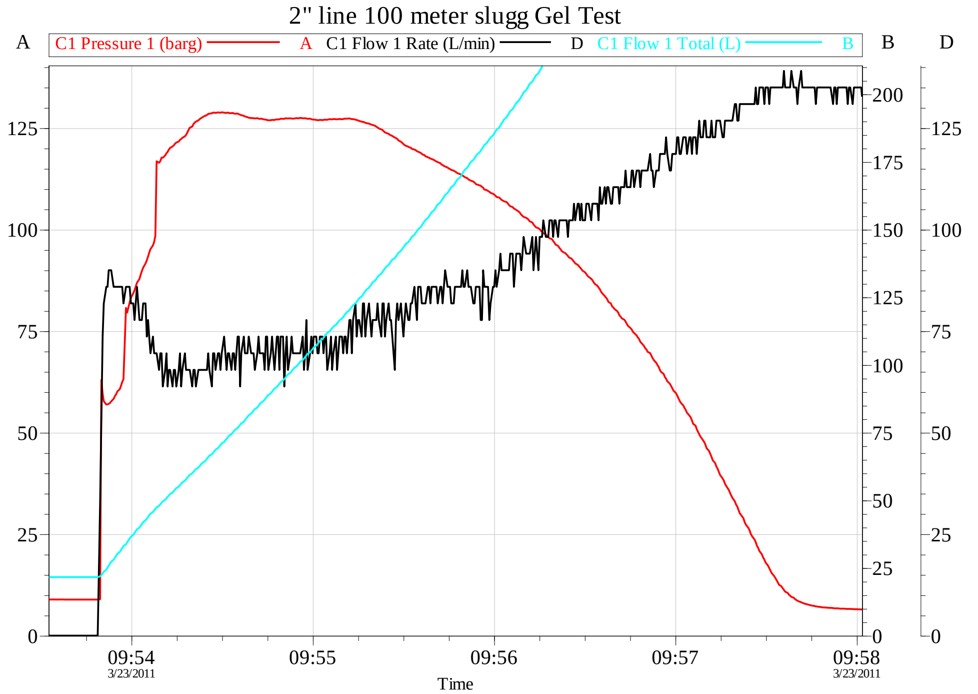
Date: 28.03.11	Run this plugg: 3 run	Settle time: 3 hours

INSITE for Stimulation v3.5.1
28-Mar-11 14:25

12.1.3 The 2 inch pipe with 100 meters gel plugs pumped by Haskel ASF-60 pump



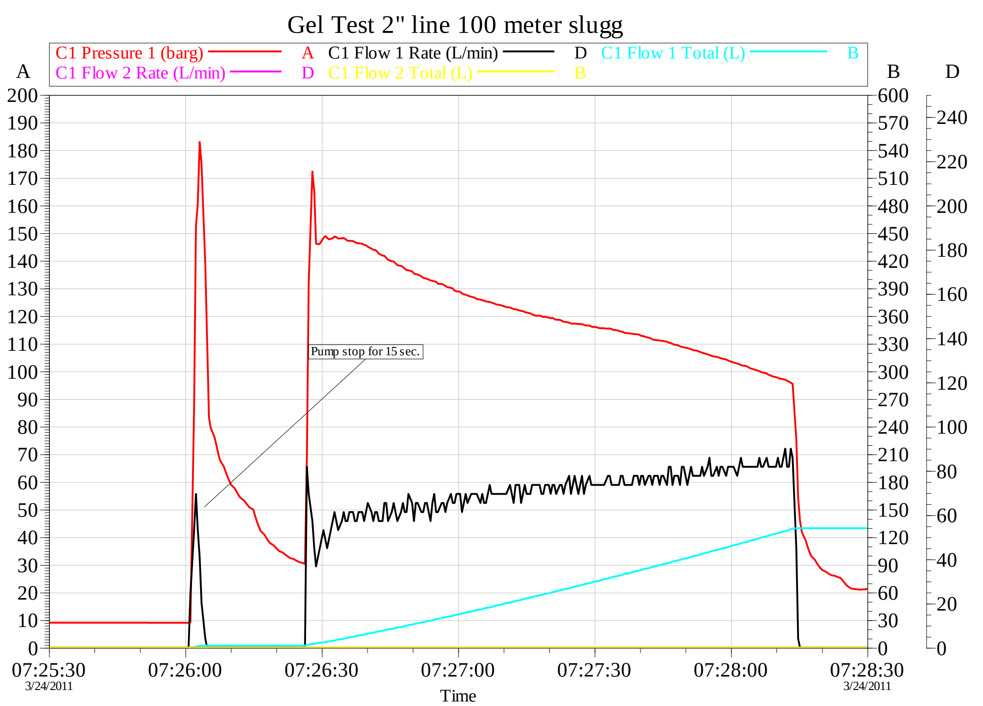




Date: 23.03.11	Run this plugg: 3. run (HT)	Settle time: 2 hours

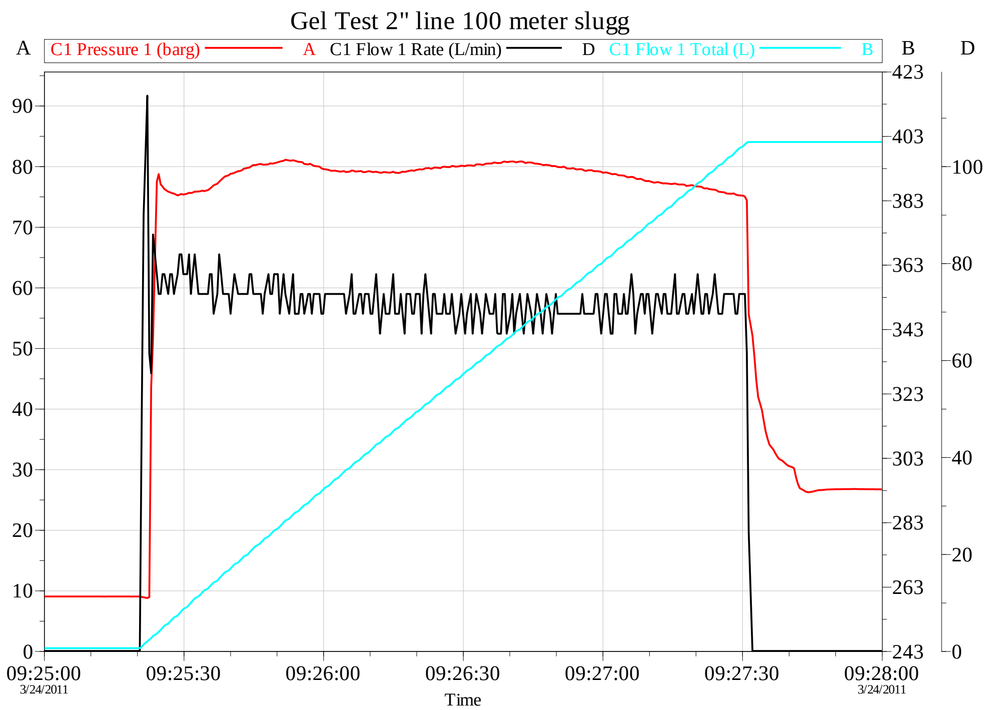
INSITE for Stimulation v3.5.1
23-Mar-11 11:35

12.1.4 The 2 inch pipe with 100 meters gel plugs pumped by HT-400 pump



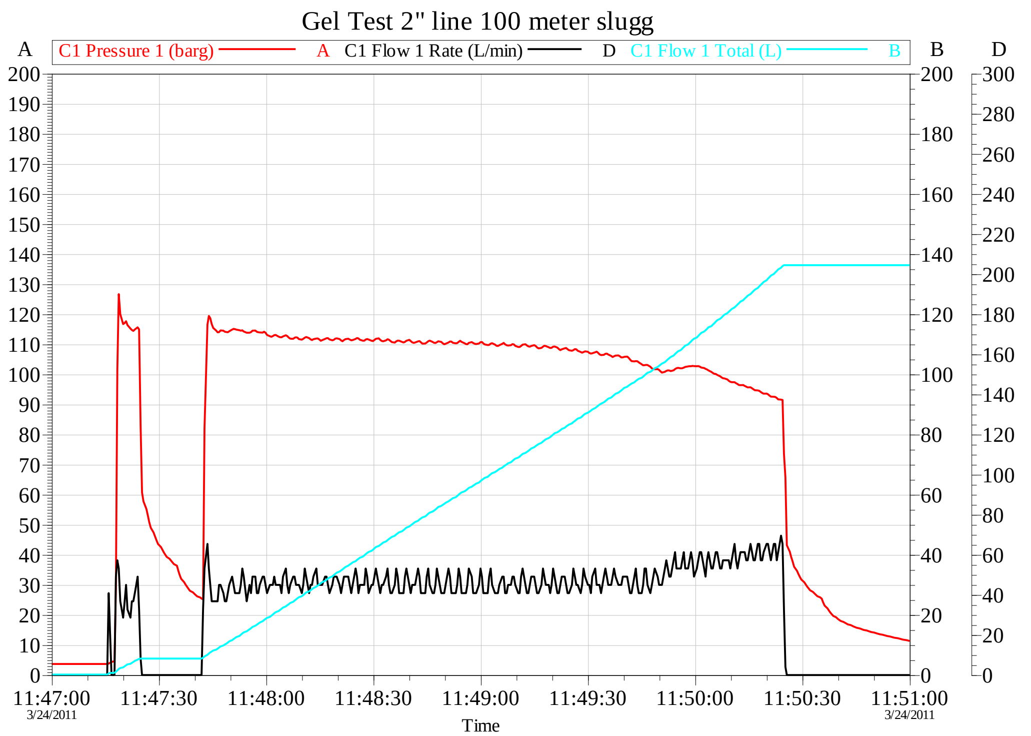
Date: 24.03.11	Run this plugg: 1. run	Settle time: 16 hours

INSITE for Stimulation v3.5.1
24-Mar-11 08:02



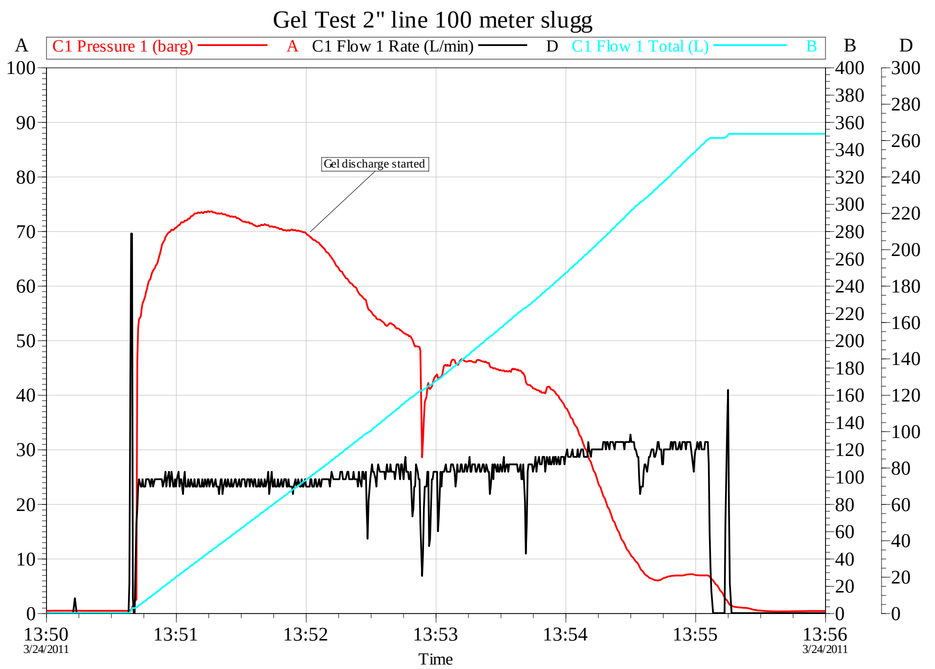
Date: 24.03.11	Run this plugg: 2. run	Settle time: 2 hours

INSITE for Stimulation v3.5.1
24-Mar-11 10:12



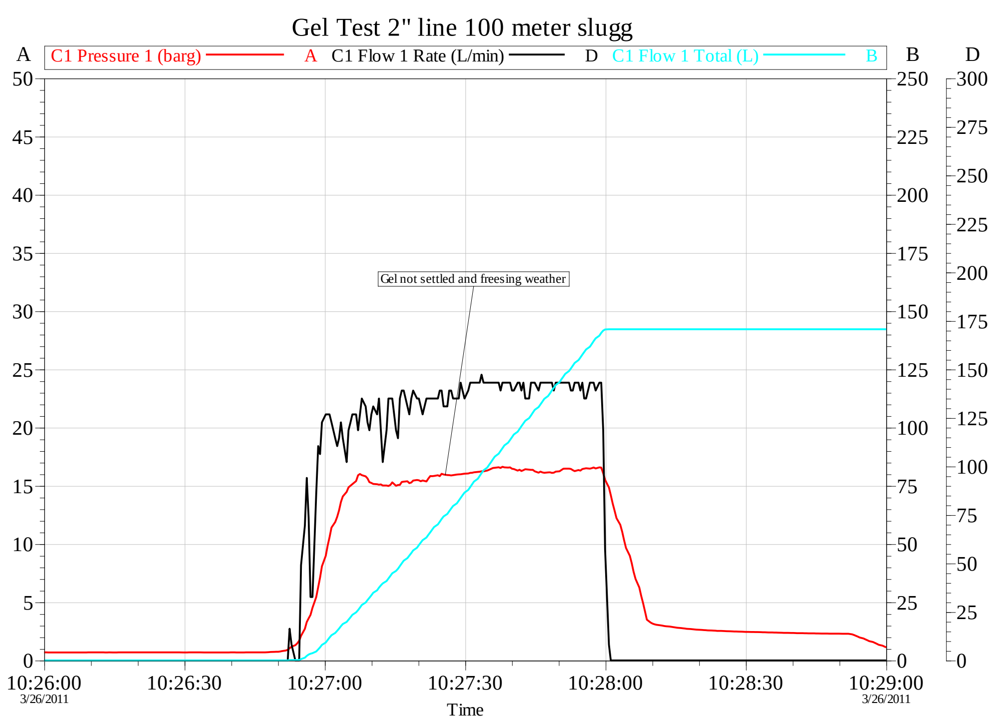
Date: 24.03.11	Run this plugg: 1. run (new slugg)	Settle time: 2 hours

INSITE for Stimulation v3.5.1
24-Mar-11 12:44

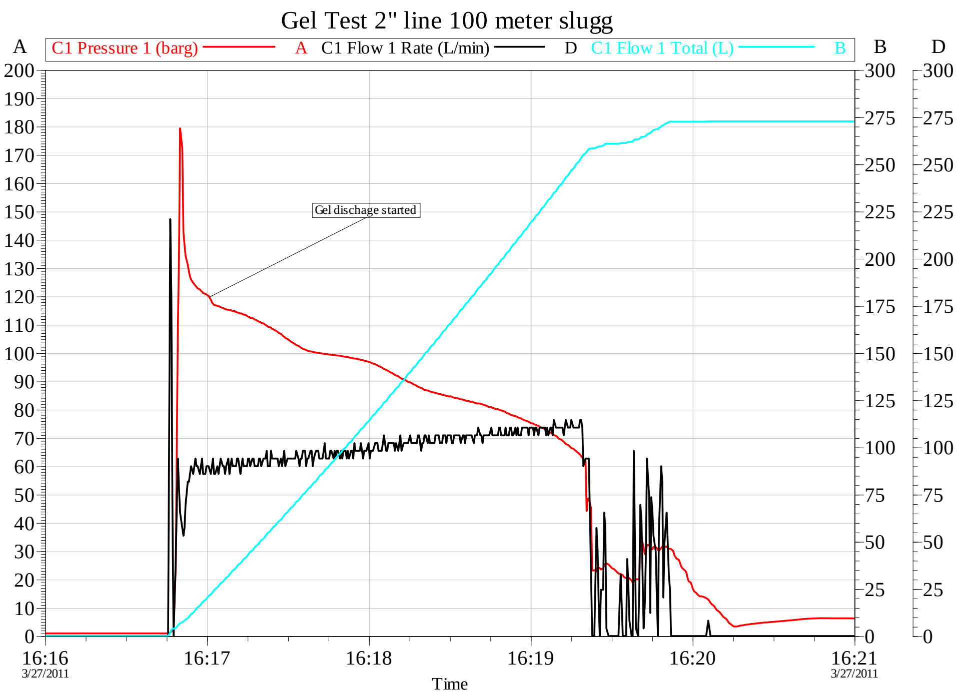


Date: 24.03.11	Run this plugg: 2. run (New slugg)	Settle time: 2 hours

12.1.5 The 2 inch pipe with 100 meters gel plugs pumped by HT-400 pump. With freezing conditions involved



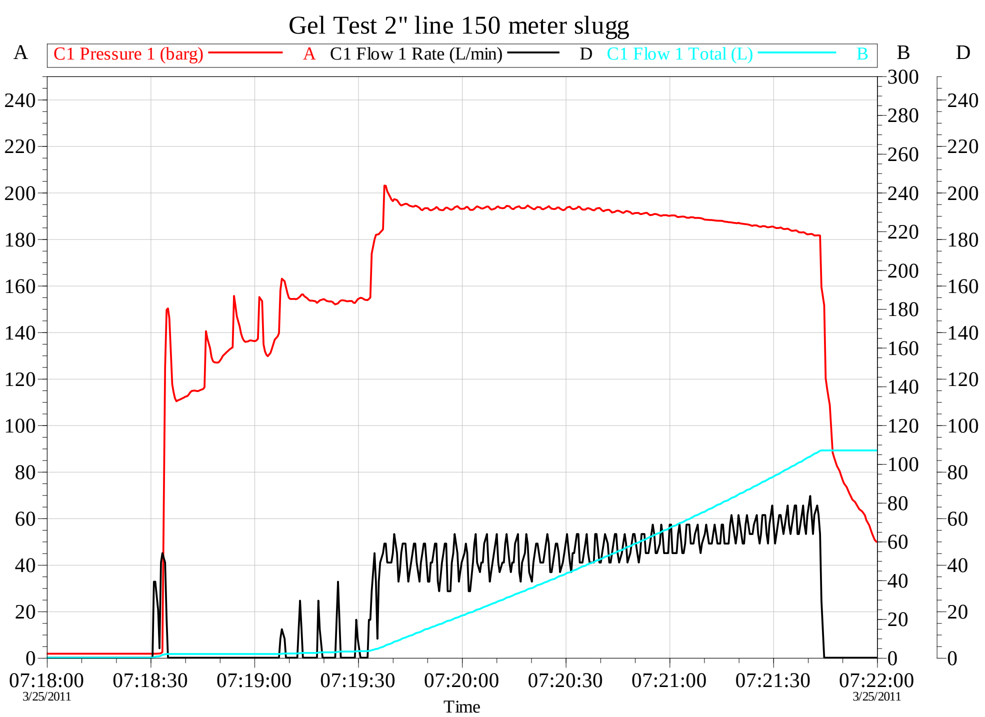
Date: 26.03.11	Run this plugg: 1 run	Settle time: 20 hours



Date: 27.03.11	Run this plugg: 2 run	Settle time: 29 hours

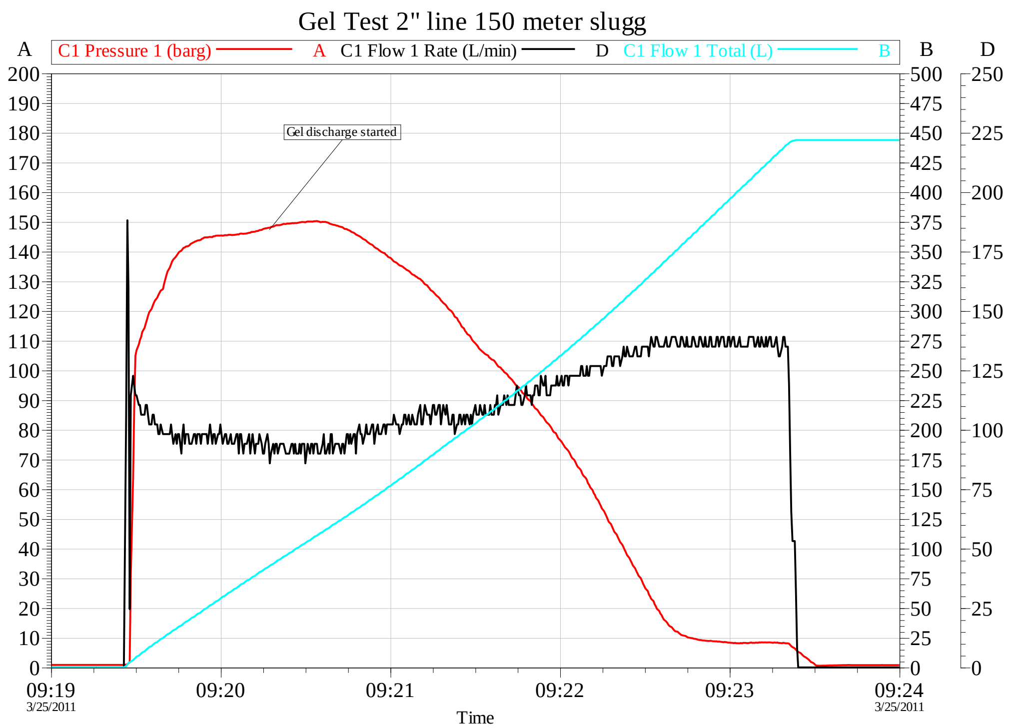
INSITE for Stimulation v3.5.1
28-Mar-11 10:01

12.1.6 The 2 inch pipe with 150 meters gel plugs pumped by HT-400 pump



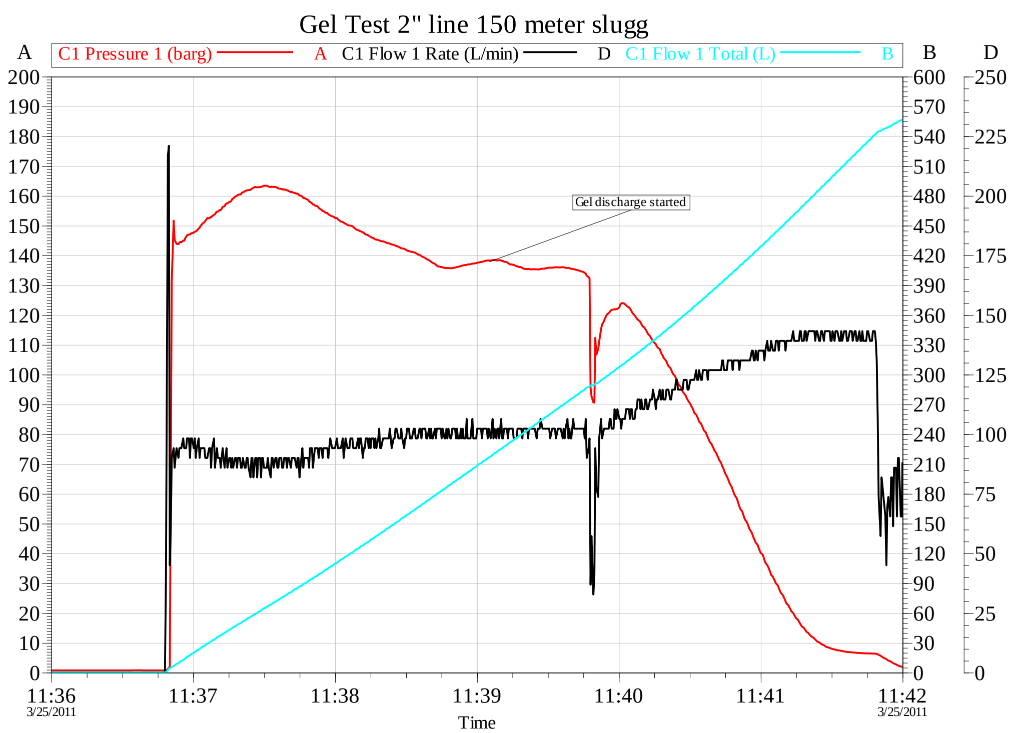
Date: 25.03.11	Run this plugg: 1. run	Settle time: 16 hours

INSITE for Stimulation v3.5.1
25-Mar-11 07:48



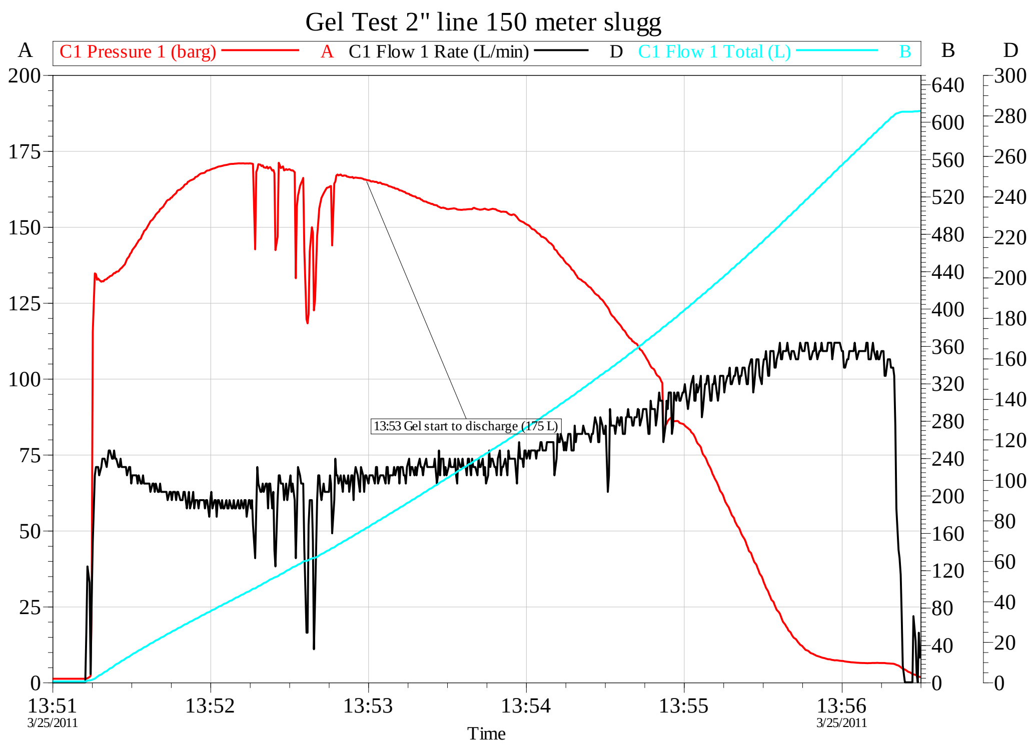
Date: 25.03.11	Run this plugg: 2. run	Settle time: 2 hours

INSITE for Stimulation v3.5.1
25-Mar-11 10:04



Date: 25.03.11	Run this plugg: 1 run (New slugg)	Settle time: 2 hours

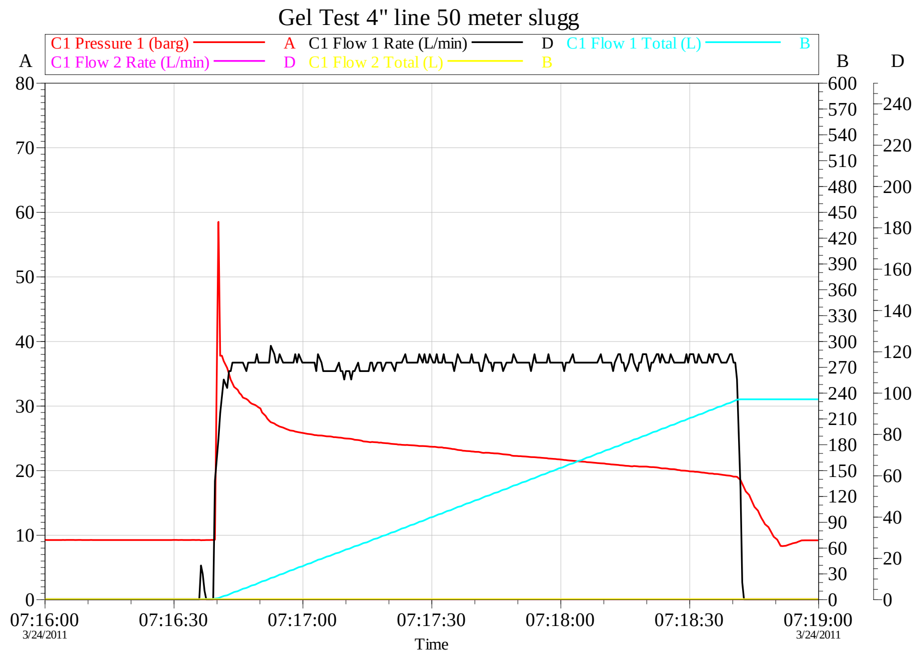
INSITE for Stimulation v3.5.1
25-Mar-11 11:57



Date: 25.03.11	Run this plugg: 1 run (New slugg)	Settle time: 2 hours

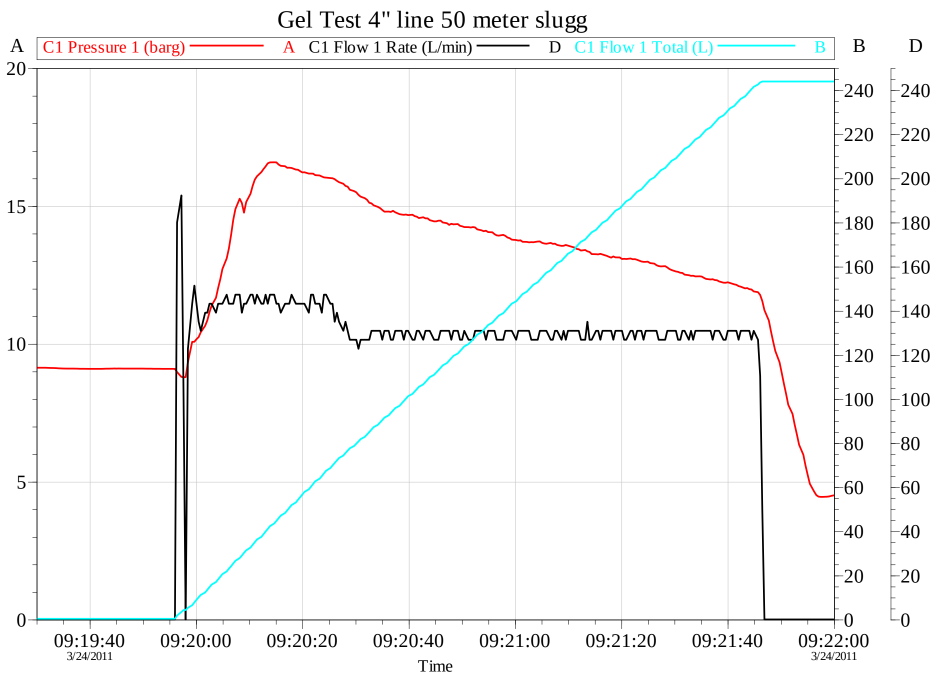
INSITE for Stimulation v3.5.1
25-Mar-11 14:16

12.1.7 The 4 inch pipe with 50 meters gel plugs pumped by HT-400 pump



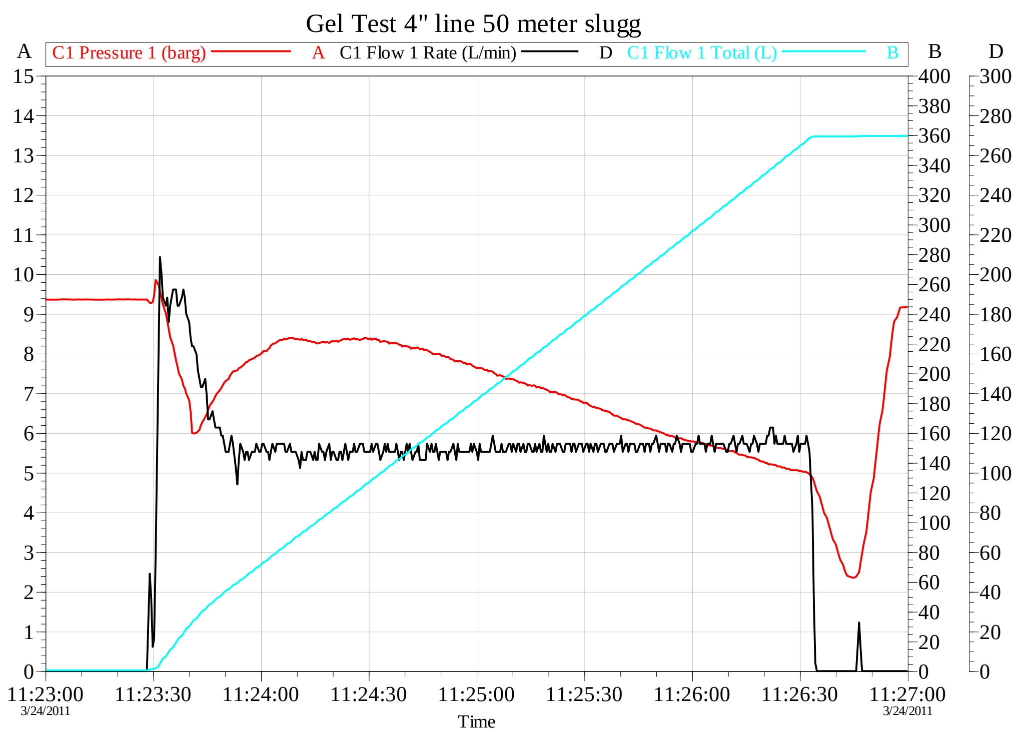
Date: 24.03.11	Run this plugg: 1. run	Settle time: 16 hours

INSITE for Stimulation v3.5.1
24-Mar-11 07:48



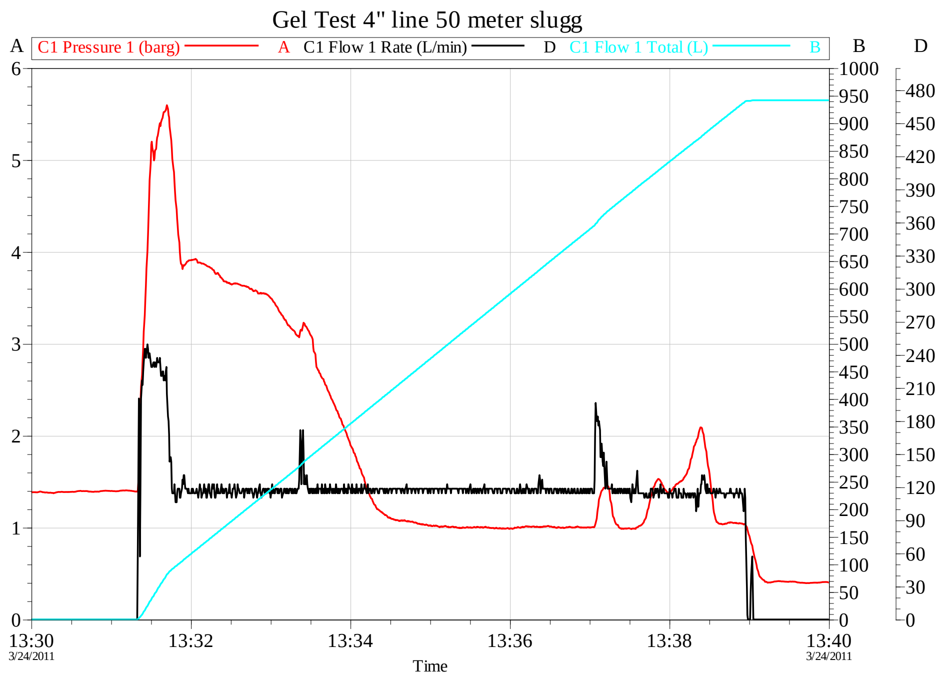
Date: 24.03.11	Run this plugg: 2. run	Settle time: 2 hours

INSITE for Stimulation v3.5.1
24-Mar-11 09:58



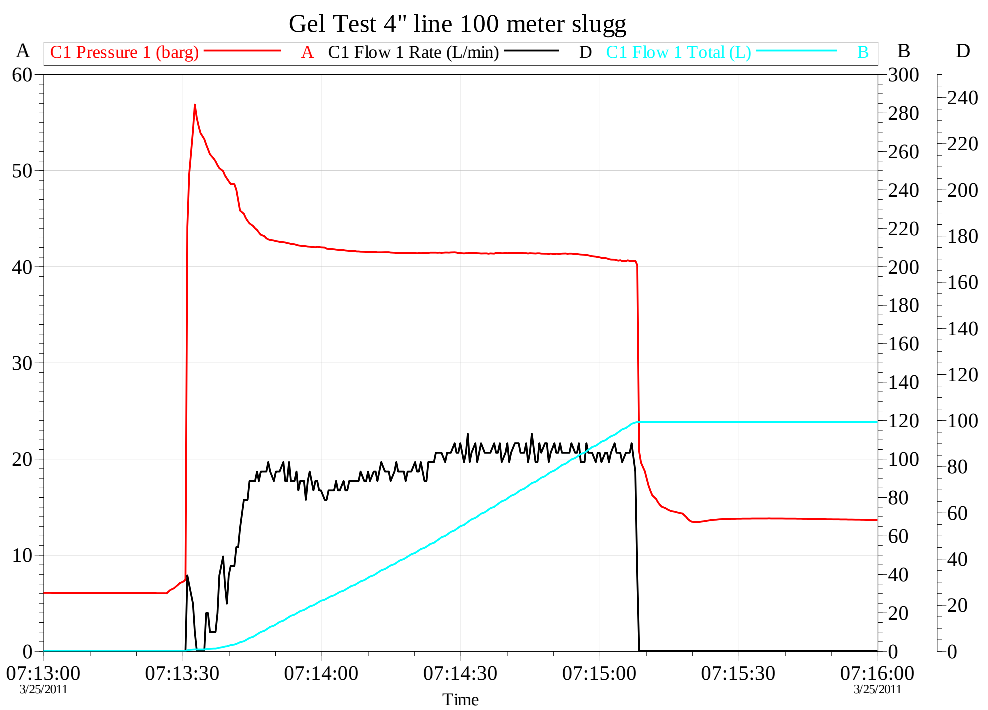
Date: 24.03.11	Run this plugg: 3. run	Settle time: 2 hours

INSITE for Stimulation v3.5.1
24-Mar-11 12:34

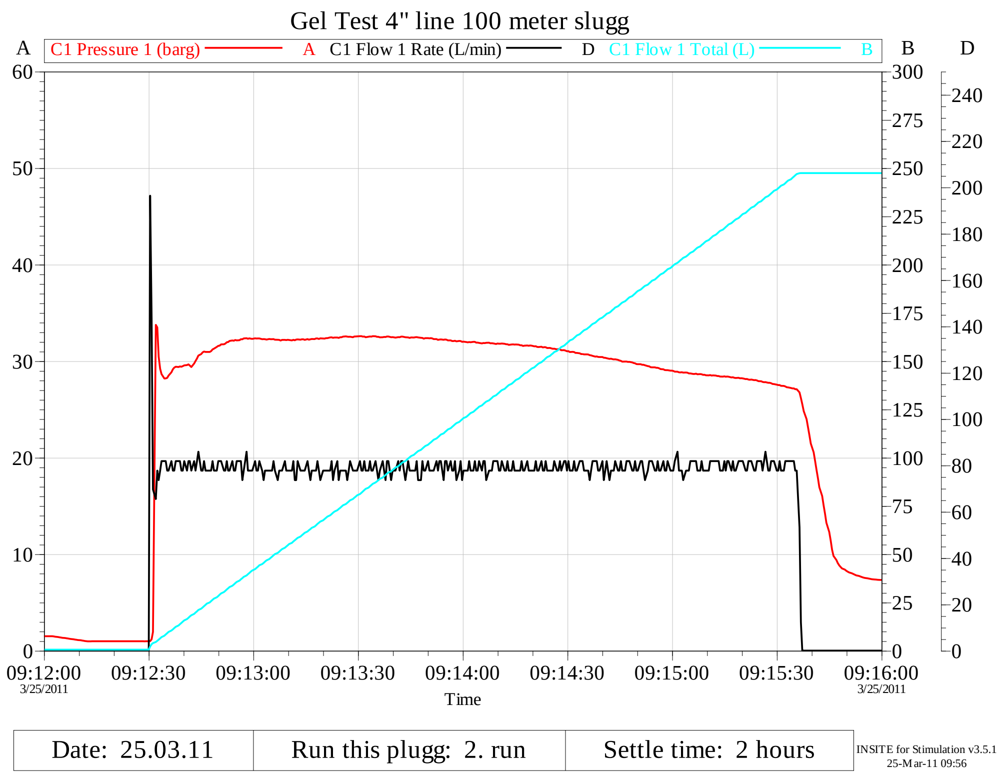


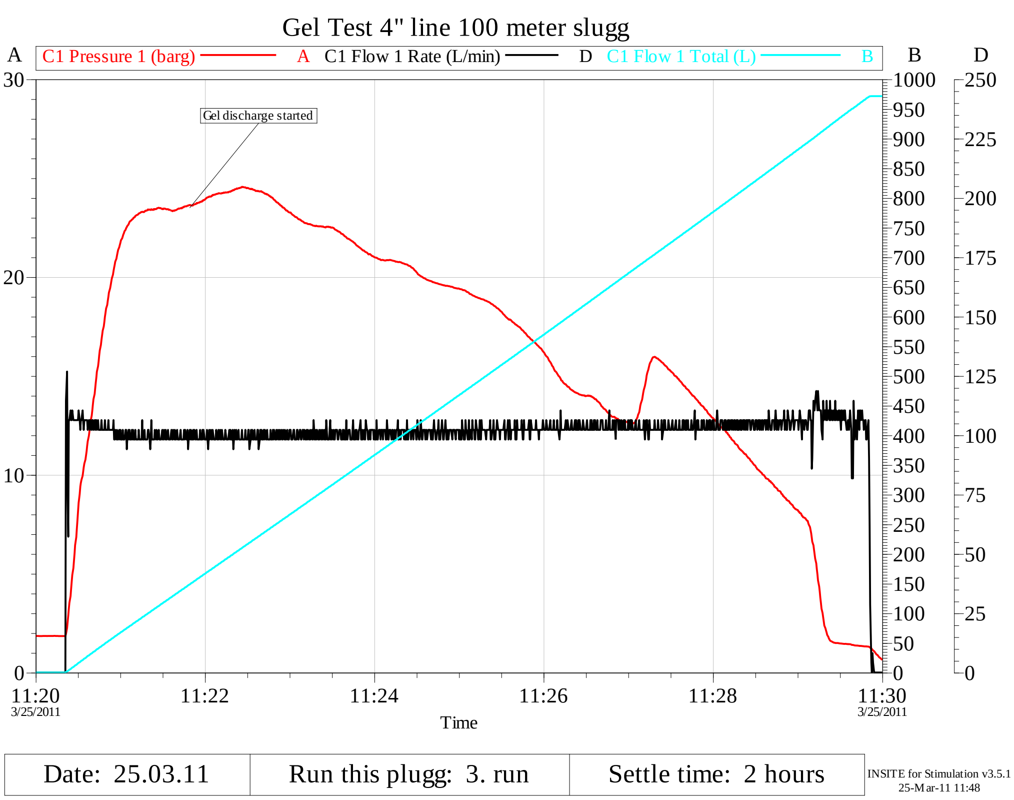
Date: 24.03.11	Run this plugg: 4. run	Settle time: 2 hours

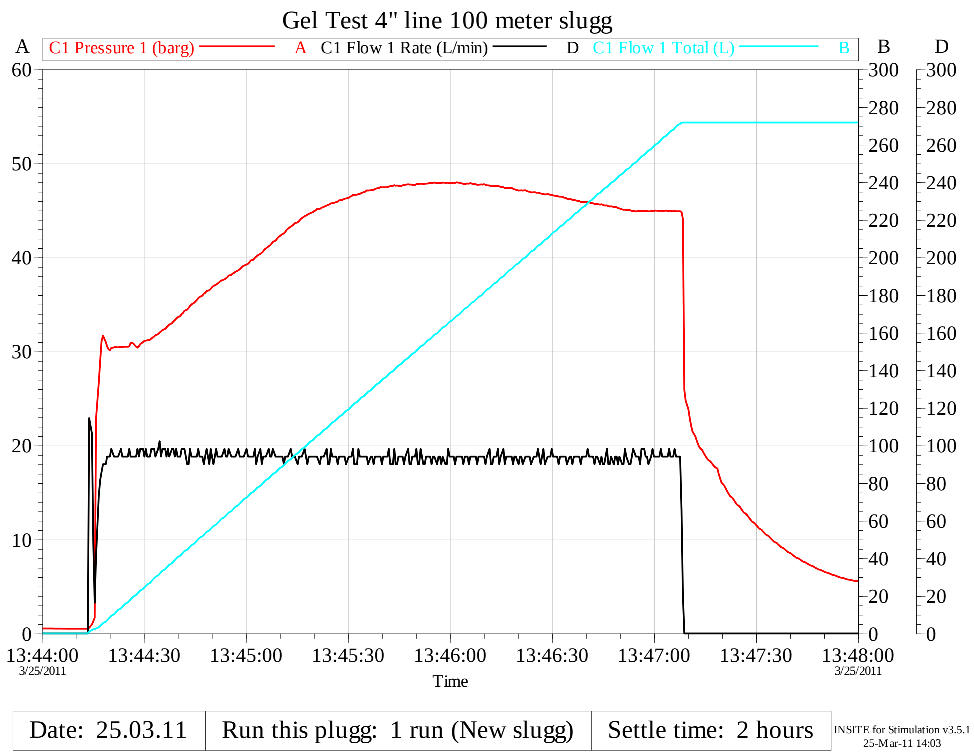
12.1.8 The 4 inch pipe with 100 meters gel plugs pumped by HT-400 pump



Date: 25.03.11	Run this plugg: 1. run	Settle time: 16 hours

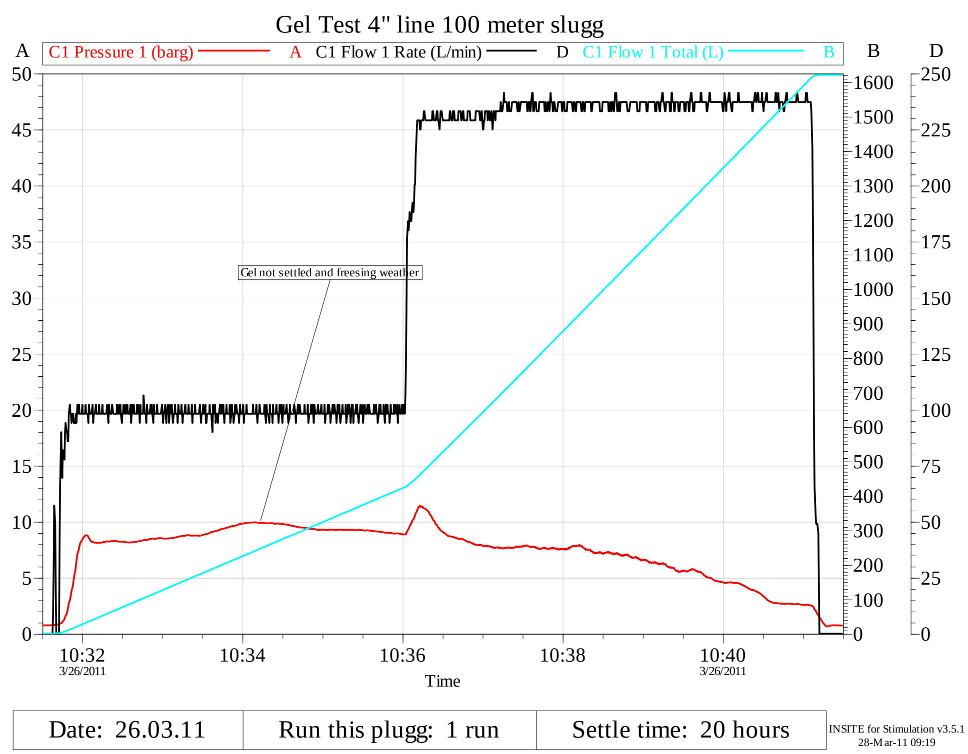

Gel Test 4" line 100 meter slugg
C1 Pressure 1 (barg) A
C1 Flow 1 Rate (L/min) D
C1 Flow 1 Total (L) B
Time
Date: 25.03.11
Run this plugg: 2. run
Settle time: 2 hours
INSITE for Stimulation v3.5.1
25-Mar-11 09:56


Gel Test 4" line 100 meter slugg
C1 Pressure 1 (barg) A
C1 Flow 1 Rate (L/min) D
C1 Flow 1 Total (L) B
Gel discharge started
Time
Date: 25.03.11
Run this plugg: 3. run
Settle time: 2 hours
INSITE for Stimulation v3.5.1
25-Mar-11 11:48



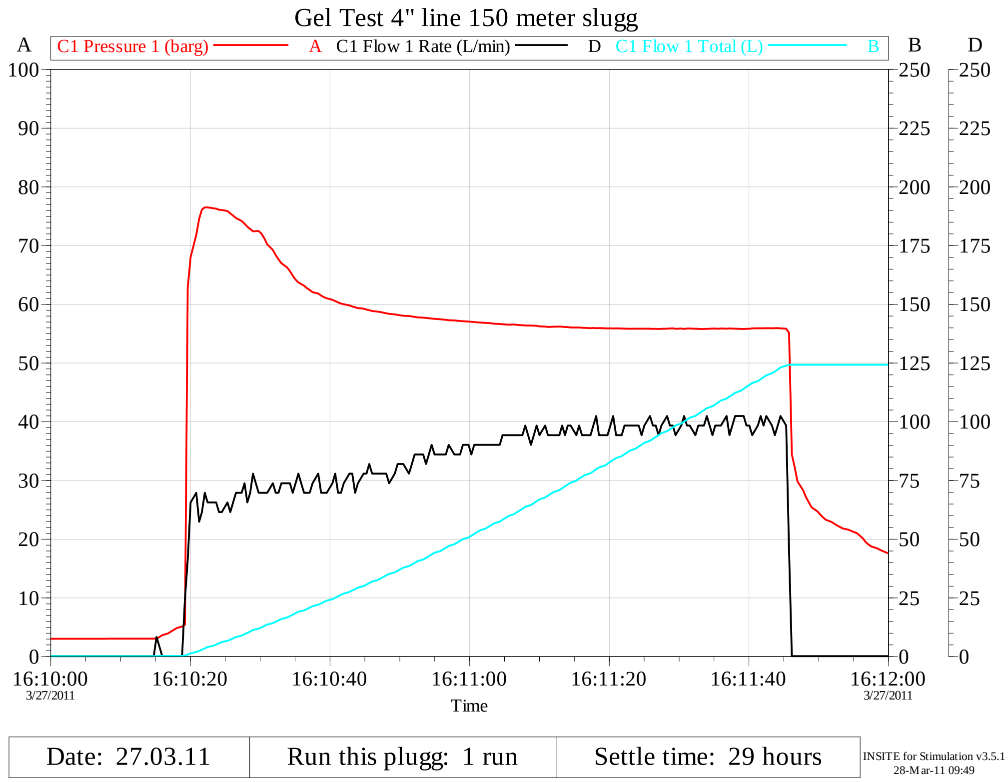
Date: 25.03.11	Run this plugg: 1 run (New slugg)	Settle time: 2 hours

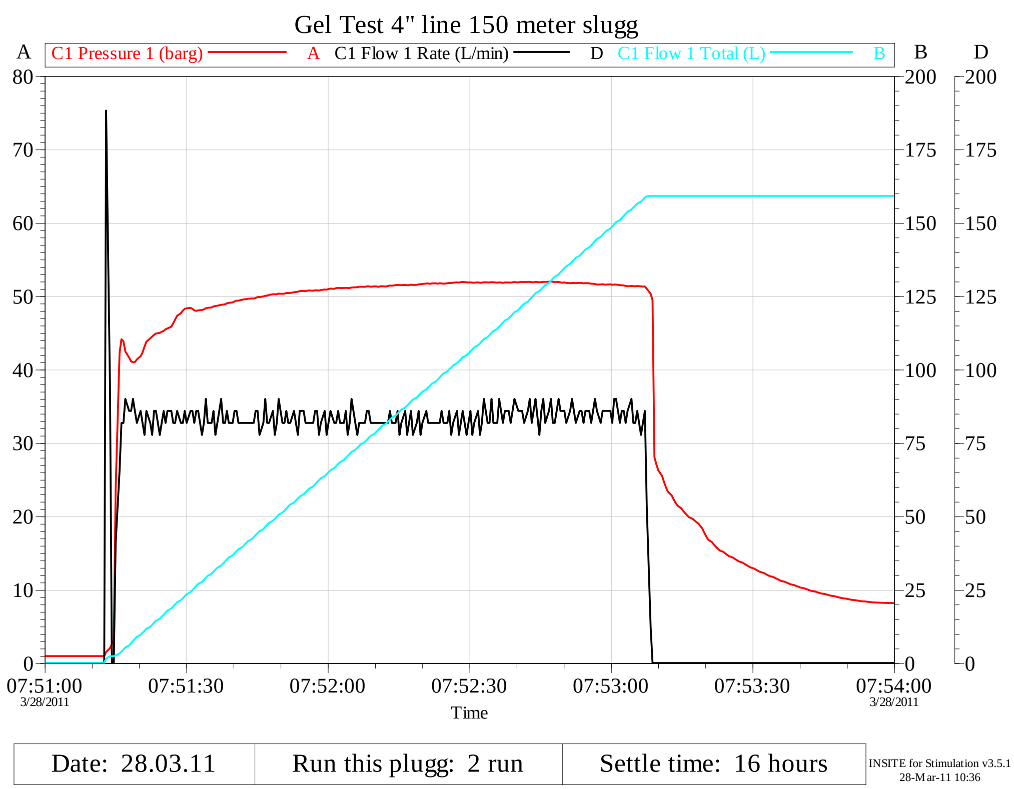
12.1.9 The 4 inch pipe with 100 meters gel plugs pumped by HT-400 pump. With freezing conditions involved

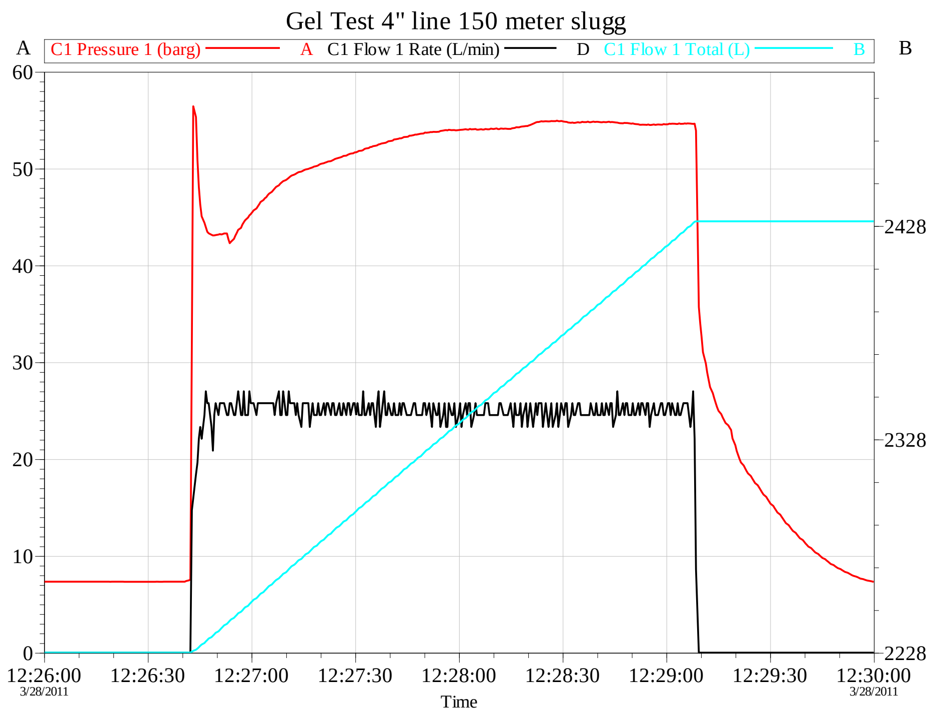


Date: 26.03.11	Run this plugg: 1 run	Settle time: 20 hours

12.1.10 The 4 inch pipe with 150 meters gel plugs pumped by HT-400 pump

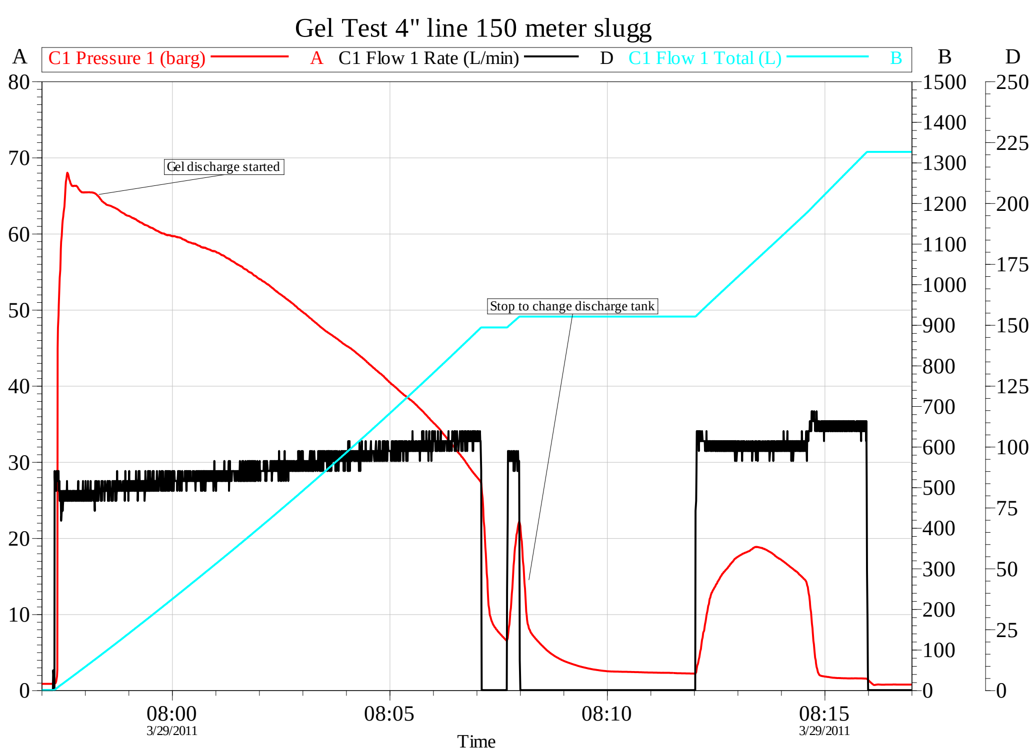






Date: 28.03.11	Run this plugg: 1 run (new slugg)	Settle time: 2 hours

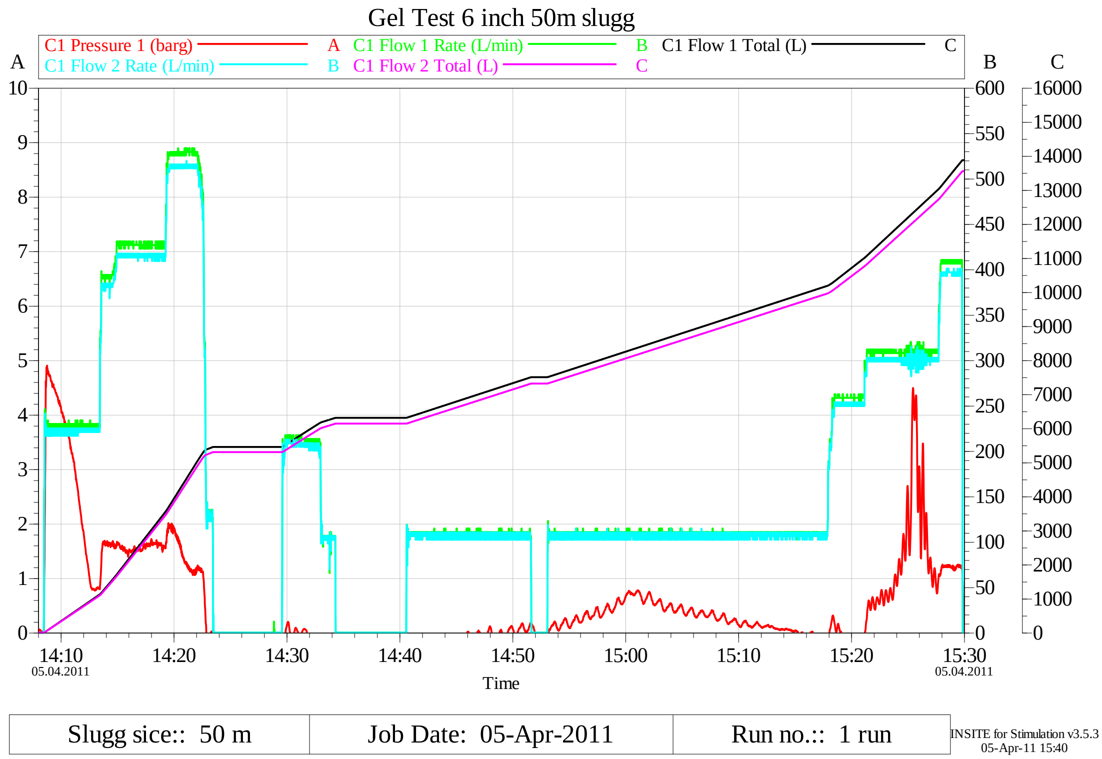
INSITE for Stimulation v3.5.1
28-Mar-11 13:47

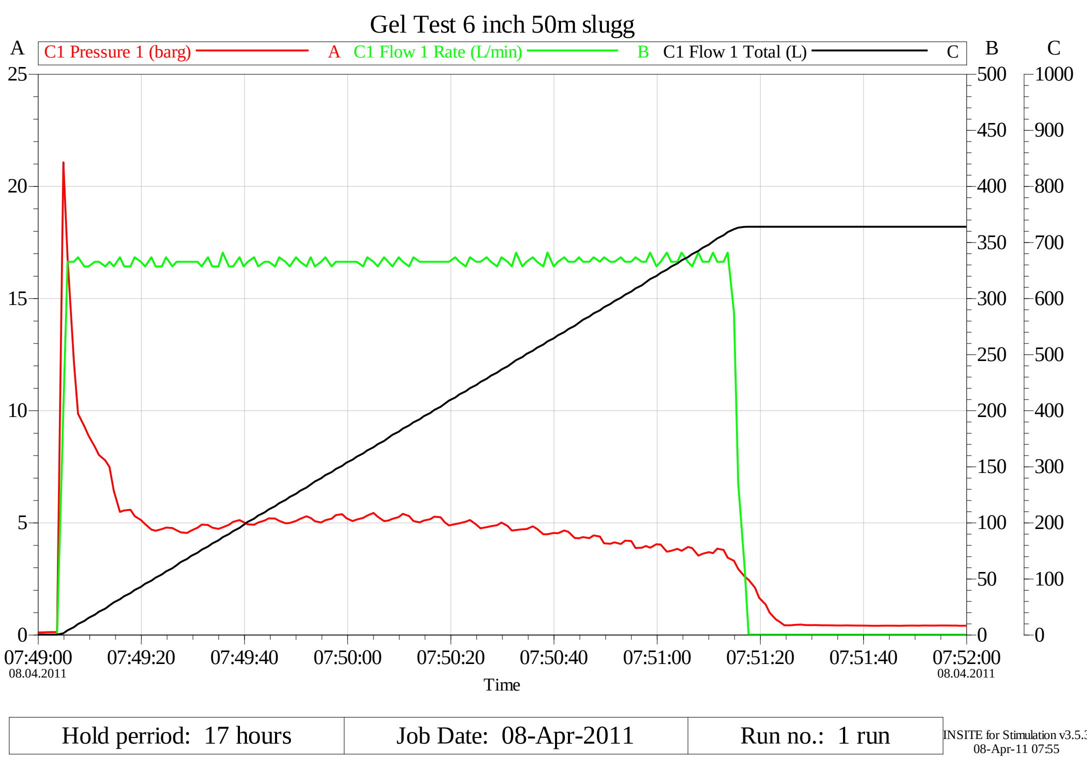


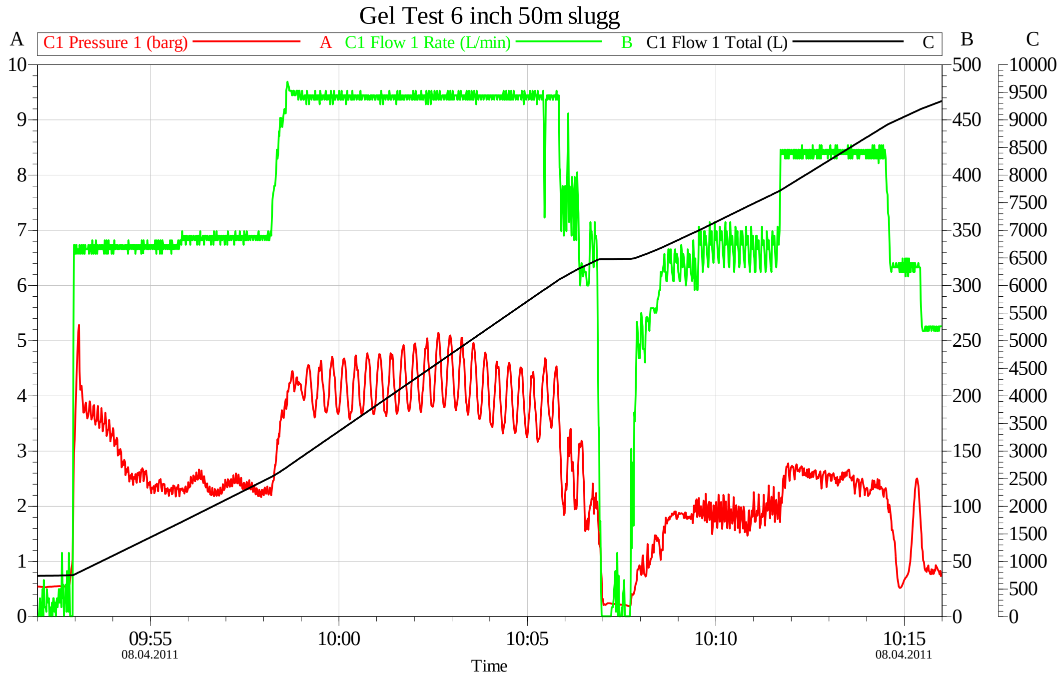
Date: 29.03.11	Run this plugg: 2 run (new slugg)	Settle time: 17 hours

INSITE for Stimulation v3.5.1
29-Mar-11 09:23

12.1.11 The 6.1 inch pipe with 50 meters gel plugs pumped by HT-400 pump



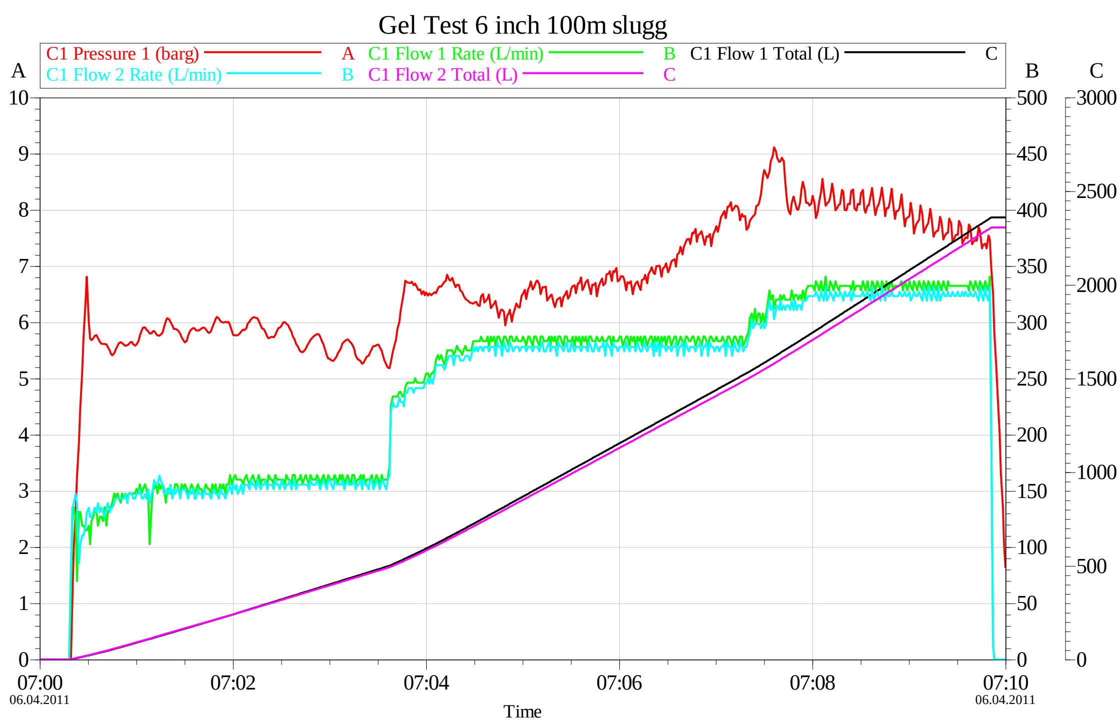




Hold perriod: 2 hours	Job Date: 08-Apr-2011	Run no.: 2 run

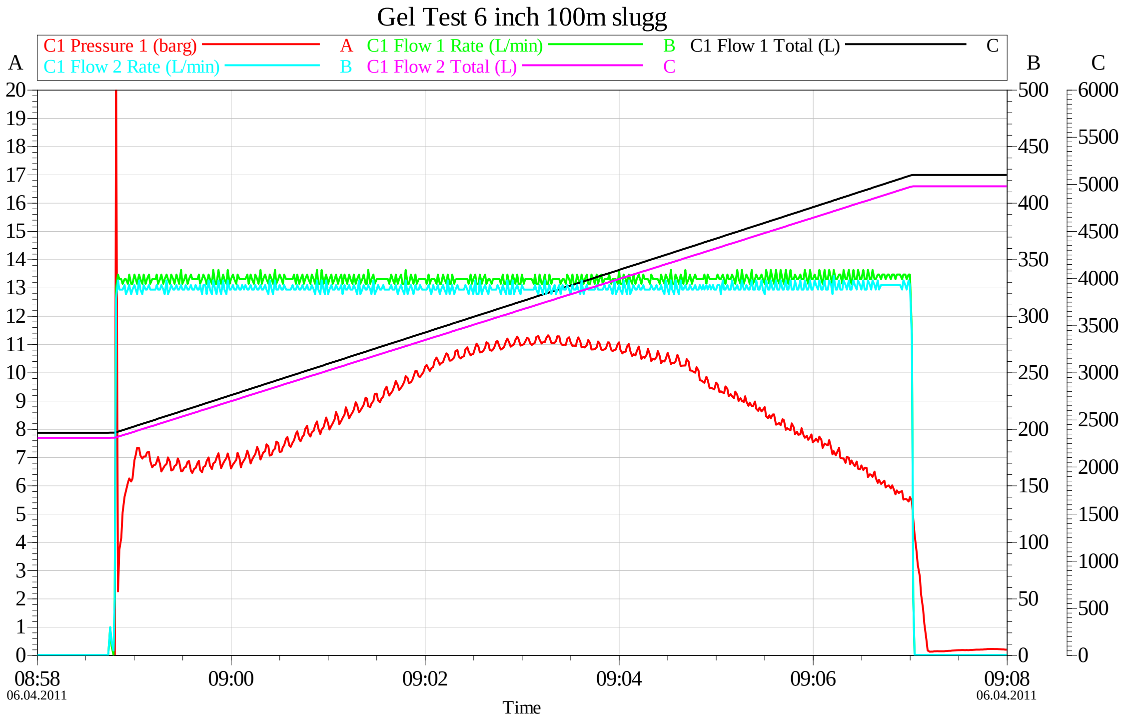
INSITE for Stimulation v3.5.3
08-Apr-11 14:13

12.1.12 The 6.1 inch pipe with 100 meters gel plugs pumped by HT-400 pump



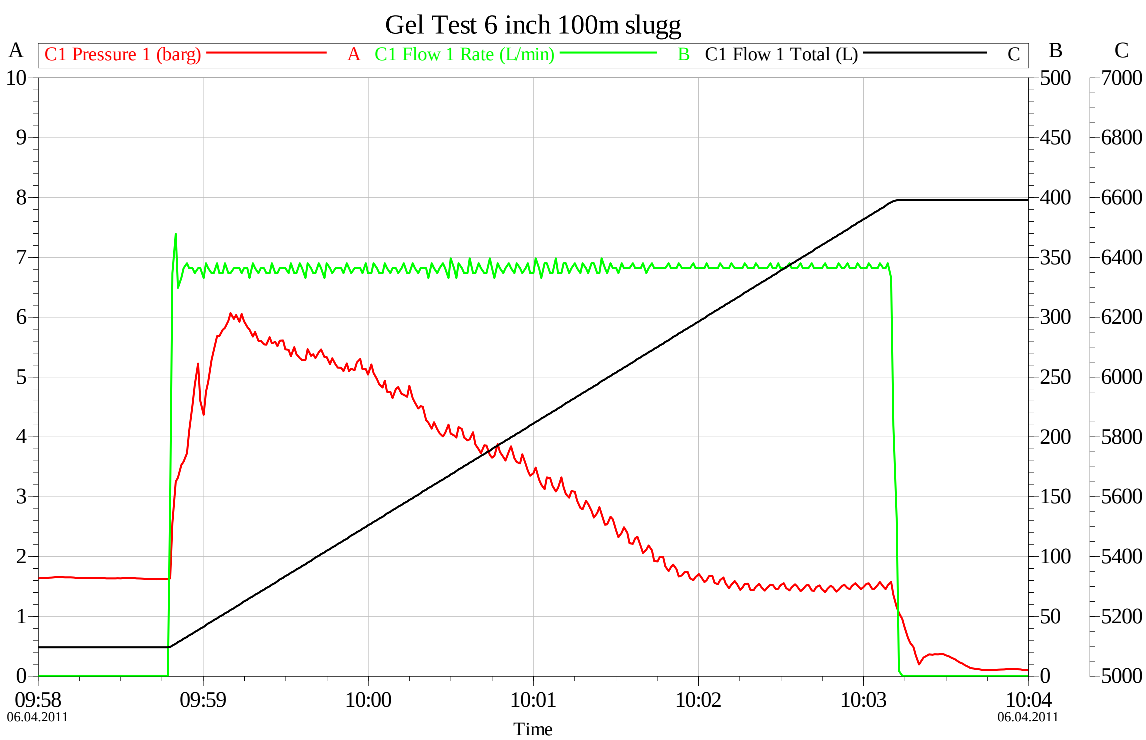
Hold perriod: 15 hours	Job Date: 06-Apr-2011	Run no.:: 1 run

INSITE for Stimulation v3.5.3
06-Apr-11 07:18



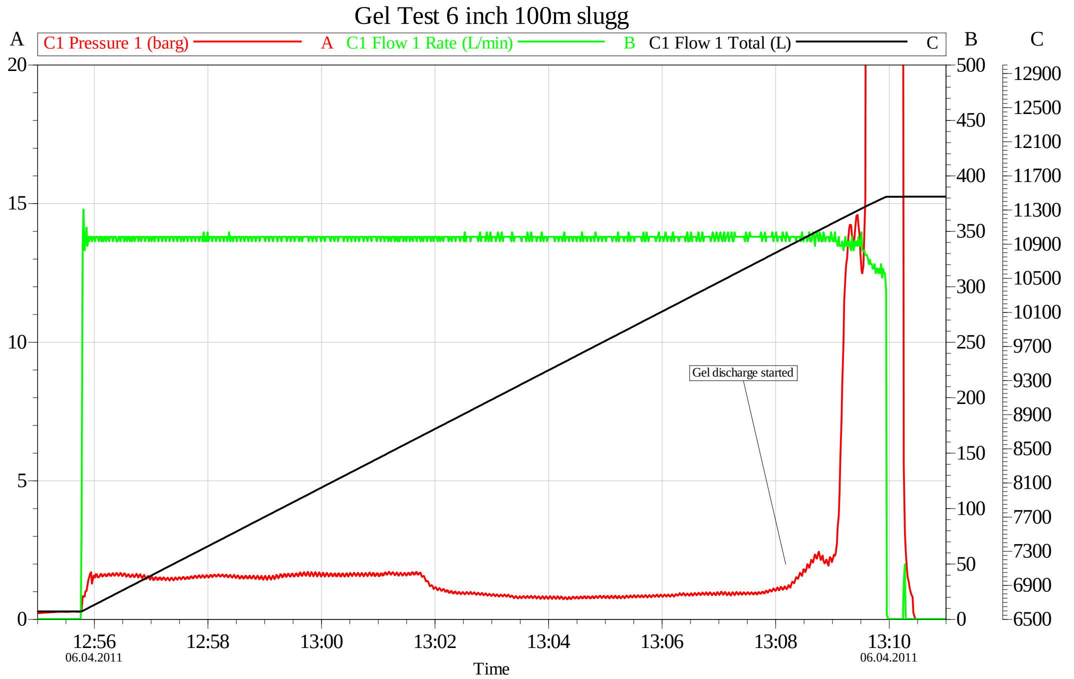
Hold perriod: 2 hours	Job Date: 06-Apr-2011	Run no.: 2 run

INSITE for Stimulation v3.5.3
06-Apr-11 09:22



Hold perriod: 1 hours	Job Date: 06-Apr-2011	Run no.: 3 run

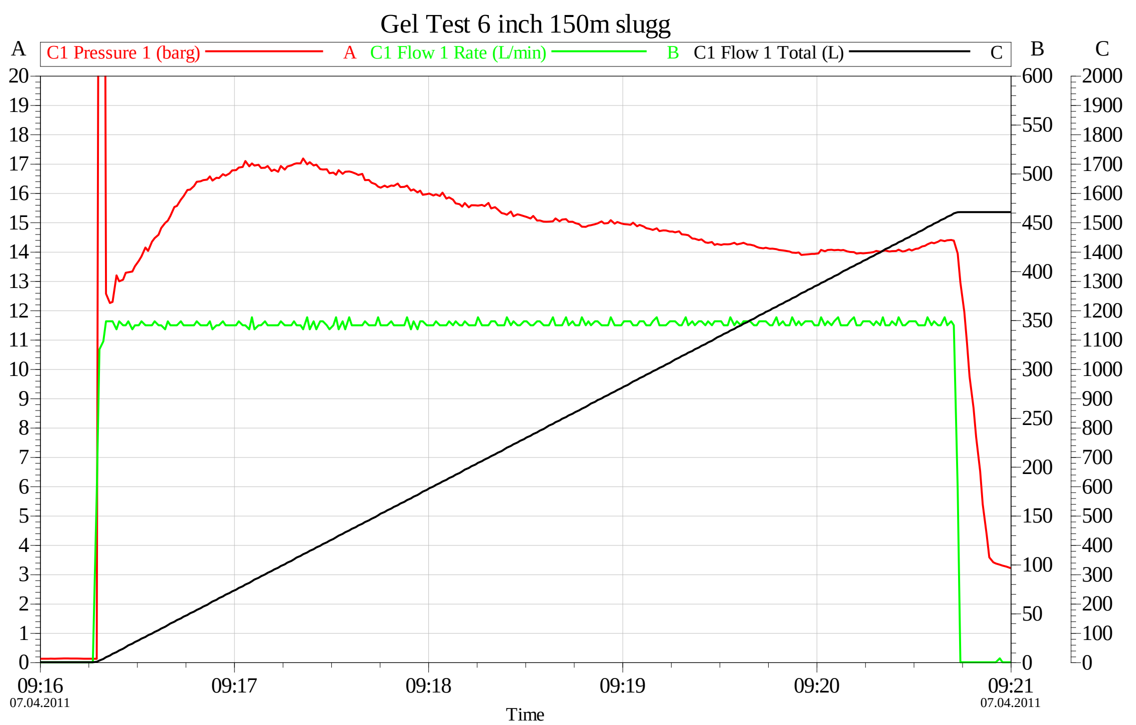
INSITE for Stimulation v3.5.3
06-Apr-11 11:09



Hold perriod: 3 hours	Job Date: 06-Apr-2011	Run no.: 4 run

INSITE for Stimulation v3.5.3
06-Apr-11 14:07

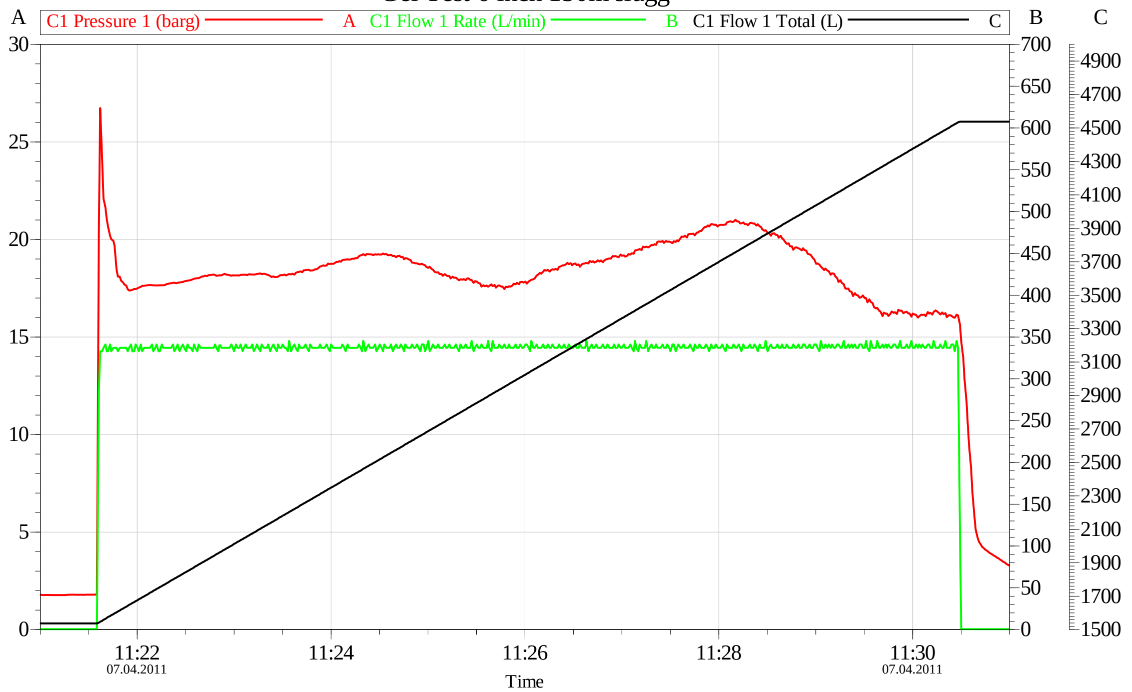
12.1.13 The 6.1 inch pipe with 150 meters gel plugs pumped by HT-400 pump



Hold perriod: 19	Job Date: 07-Apr-2011	Run no.: 1 run

INSITE for Stimulation v3.5.3
07-Apr-11 09:29

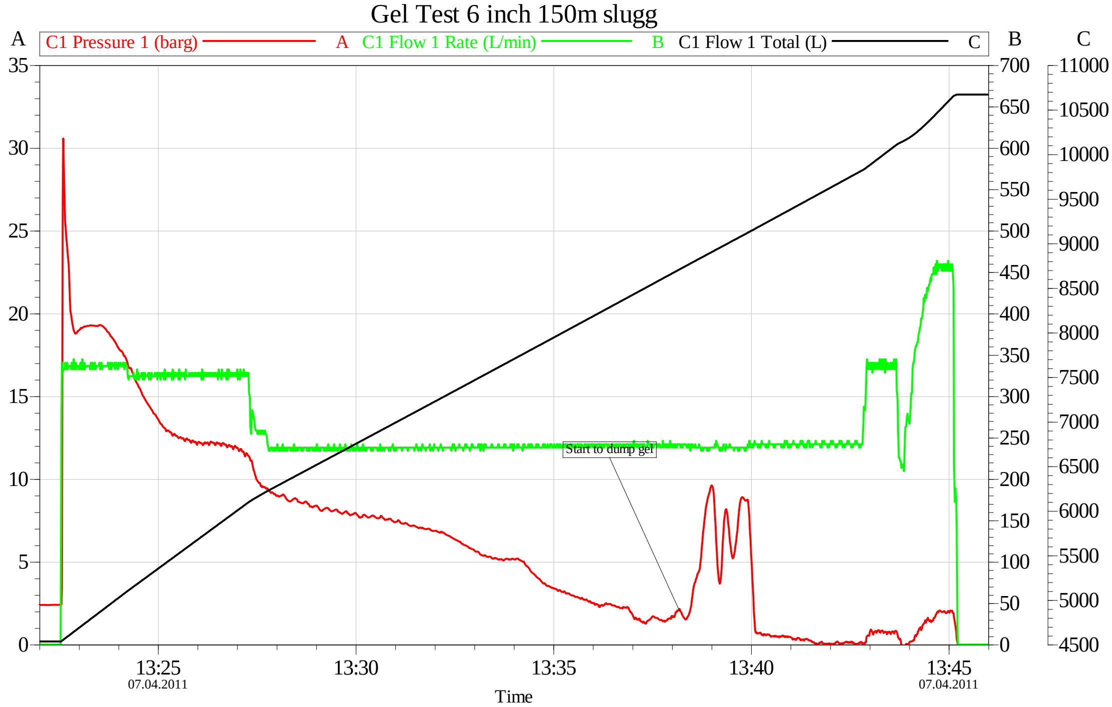
Gel Test 6 inch 150m slugg



Hold perriod: 2 hours	Job Date: 07-Apr-2011	Run no.: 2 run

INSITE for Stimulation v3.5.3
07-Apr-11 11:47

Gel Test 6 inch 150m slugg



Hold perriod: 2 hours	Job Date: 07-Apr-2011	Run no.: 3 run

INSITE for Stimulation v3.5.3
07-Apr-11 14:47

12.2 Gel pumping procedure

This chapter contains the procedure used during the gel tests in Risavika Harbor and IRIS research center. It also contains the data sheet for Temblok 50™ and CL-23 which is the gel and cross-linker that was used during the gel tests. The properties of the pumps used during the test are also seen in this chapter.

HALLIBURTON

Rev.	Date	Reason for Issue:	Prepared	Checked	Approved	Approved
0	14.03.11	Issued for Use	EAS	DAN	EAS	
2	11.03.11	Re-issued for IDC/Internal Review	K.U.	D.A.N.		
1	10.03.11	Issued for IDC/Internal review	K.U	D.A.N		
			ORIGINATOR			CLIENT

CLIENT:

Halliburton Pipeline and Process Services

CONTRACT NO.

8003862

PROJECT:

Gel Research Project

ACTIVITY:

EH-0563-T06

DOCUMENT TITLE:

Gel Pumping Procedure

DOCUMENT NO.:

GEL -	26 -	L -	XP -	002 -	0
Project / Entity ref.	**Originator code**	**Discipline code**	**Document type**	**Sequence no.**	**Revision**

TABLE OF CONTENT

1.0 INTRODUCTION

The Gel Research Project has been initiated to study what pressure is required in order to move a crosslinked GEL slug within steel piping. The project will investigate several different scenarios which include several different slug lengths as well as the diameter of the steel pipe in which the GEL has been installed.

1.1 Abbreviations

Crosslinker	-	CL-31 brand Halliburton gelling agent
Gel	-	Linear Temblok 50 brand Halliburton gel
GEL	-	Temblok 50 crosslinked with CL-31
HPPS	-	Halliburton Pipeline and Process Services
MSDS	-	Hazardous Materials Data Sheet
N/A	-	Not Applicable
L	-	Liter(s)
PPE	-	Personal Protective Equipment
PSV	-	Pressure Safety Valve
P&ID	-	Piping and instrumentation Diagram

2.0 SCOPE OF WORK

The tests to be performed shall utilise the same pumping spread. In contrast the discharge spread will vary, with a 2″ steel pipe used for the first set of tests. Upon the completion of these tests the discharge spread will be disconnected and a 4″ steel pipe used. The same tests will then be performed utilising this discharge spread. Piping and instrumentation diagrams of the pumping and discharge spreads can be found in section 7.0 of this document.

The following GEL tests will be conducted on both the 2″ and the 4″ steel pipe discharges:

- **50 m GEL slug length** shall be pumped into the steel pipe and allowed to settle. Once settled the pressure behind the GEL slug shall be increased steadily until the slug starts to move. As soon as the slug moves pumping shall be suspended and the pipe shall be depressurised. When the slug has settled once again the pressure will again be increased to record the pressure at which the slug moves.
  This process will be repeated for as many times as the discharge steel piping length allows. If the GEL slug exits the pipe before a sufficient number of tests have been performed a new GEL slug shall be pumped into the pipe. The exact number of tests to be performed is at the HPPS supervisor discretion.
- **100 m GEL slug length** shall be pumped into the steel pipe and allowed to settle. Then the same tests as described in the **50 m GEL slug length** shall be repeated for the 100 meter GEL slug.
- **150 m GEL slug length** shall be pumped into the steel pipe and allowed to settle. Then the same tests as described in the **50 m GEL slug length** shall be repeated for the 100 meter GEL slug.

Each of the tests shall include pressure and flow monitoring. The 7″ discharge line shown in P&ID GEL-26-L-XP-002-01 Section 7.0 shall not be tested at the Halliburton facilities and will as such not be referenced in this procedure.

3.0 OPERATIONAL SAFETY

3.1 Work Permits

Any precautions specified by work permits shall be fully adhered to at all times.

Prior to signing to accept work permits the Job Supervisor shall ensure that they fully understand all sections of the permit and the responsibility they are accepting with their signature.

3.2 Pre-Job Safety Meeting (Tool Box Talk)

Prior to the commencement of work on site a Pre-Job Safety Meeting shall be held to ensure that all parties involved in or affected by the work are aware of its nature and of the potential hazards involved. The meeting shall be held onsite and shall cover an outline of the work to be conducted. It shall also cover all recognised hazards, plans to control them and emergency response contingency plans. Subjects covered and discussed during the meeting shall include but should not be limited to the following:

- sequence, co-ordination and details of work to be carried out.
- hazards / control measures / emergency response contingency plans.
- safe areas / escape routes / muster points.
- barriers and signs.
- Instruction not to remove, tighten, flog-up or work on any part of the system whilst work on it is ongoing or where pressure is being maintained.

Those attending shall include:

- HPPS Engineer/Supervisor.
- HPPS personnel.
- Other relevant personnel, such as students, visitors etc.
- Relevant other contractor representative.

Where shift work is in operation the toolbox talk shall be given to personnel on both shifts.

The talk(s) shall be logged in the Tool Box Talk Report.

Separate Tool Box Talks should be held prior for all parts of the operation, i.e. rigging up, leak test of temporary equipment, pumping operation etc.

3.3 Equipment Safety

Access to the top of all framed units higher than 2 metres above deck / ground level shall involve the wearing and securing of safety harness.

The extent of barriers must be considered with the view to the direction in which plugs and blind flanges point. The location and extent of barriers will be decided upon during the Safe Job Analysis (SJA) before start of the operation.

The pressure testing equipment will be placed such that blind flanges, plugs etc, face away from personnel and equipment.

All equipment shall be located when onsite in a manner that leaves suitable and safe escape routes. Equipment shall be located so as to leave 1 metre gangways between each unit wherever possible.

All hoses shall be routed so as to:

- Prevent trip hazards.
- Prevent damage to hoses, chiksan and cables.
- Protect all personnel, site equipment and minimise impact on the environment in the event of hose or chiksan failure (i.e. away from access routes etc).

3.4 Actions in the Event of Emergency

In the event of an emergency during operations, all equipment shall be shut down immediately. Operations shall be stopped and the system isolated.

For information and safety guidelines regarding the Halliburton Tananger facilities see section 8.0 herein.

3.5 Operations

Never attempt any remedial works on any equipment under pressure.

Always tie down and secure hoses to prevent whipping in the event of failure.

Always check that no inappropriately rated pressure fittings or instruments have been accidentally used in the rig up or system.

3.6 Field Paperwork

The following Operational Field Paperwork shall be completed by the HPPS FE/Supervisor for the work scope covered. Only documentation from the current revision of the HMS system is to be used.

- Operations Log FO-NO-HES-PPS-005
- Tool Box Talk FO-NO-HES-PPS-025
- Leak Test Acceptance Certificate FO-NO-HES-PPS-043
- Gel Injection Report FO-NO-HAL-PPS-409
- Field Operation Query FO-NO-HES-PPS-011 (*if required*)

4.0 FUNCTION TESTING PREPARATIONS

- Ensure the work permit has been signed and approved.
- Ensure all temporary equipment is generally set up in accordance with P&IDs GEL-26-L-XP-001-01 and GEL-26-L-XP-002-01, reference section 7.0 herein.
- Perform a Tool Box Talk.
- Ensure all valves are tagged for easy identification.
- Fill the 4.5 m^3 freshwater tank with freshwater.
- Secure the return line to the HT-400 freshwater tank.
- Ensure that the crosslinker tank has the required amount of crosslinker for the job.
- Confirm that all attending personnel have familiarised themselves with the procedure and the chemicals to be used. The MSDSs should be understood and available, and all personnel must wear the necessary PPE as detailed in the MSDSs.
- Confirm that communications are working satisfactorily for the operation. If radios are used then a dedicated channel should be used for the operation.
- Ensure that discharge containers suitable to handle the chemicals are positioned at all bleed points in order to avoid any spills.

Note: As described in section 2.0 there will be two different discharge spreads used in these GEL tests, a 2″ discharge spread and a 4″ discharge spread. When the discharge spread is changed from the 2″ discharge spread to the 4″ discharge spread the entire system will have to be leak tested again in order to ensure the system integrity. Section 4.1 details the leak test for when the 2″ line is connected and section 4.2 details the leak test for when the 4″ line is connected. As these discharge lines will not be connected at the same time, ensure that the correct leak test is performed as referenced in the procedure.

4.1 330 Barg Leak Test of Temporary System with 2″ discharge spread

On completion of the rig-up of equipment, reference P&ID GEL-26-L-XP-001-01 and 2″ line in P&ID GEL-26-L-XP-002-01, HPPS shall perform a temporary systems leak test to 330 barg utilising the HT-400 positive displacement pump and the air hydro pump with freshwater as the pressurisation medium. This test shall test the pumping spread and the 2″ discharge spread from the pumps and to the end of the discharge line. During this test, a thorough leak check of the HPPS spread will be conducted during which time the pressure shall be maintained for a minimum of 15 minutes.

4.1.1 Ensure that all the valves are set as indicated in P&ID GEL-26-L-XP-001-01 and 2″ line in P&ID GEL-26-L-XP-002-01. White valves indicate open valves and black valves indicate closed valves.

4.1.2 Ensure that the PSVs are set to 345 barg and that the discharge valves on the PSVs are facing along the line direction. This is done in order to ensure that in the event of discharge there will not be any lateral movement of the valves.

4.1.3 Connect a $^1/_4$″ high pressure hose between **TL5** and **CO4**. This is to allow both sides of the non-return valve on the crosslinker line during the leak test, reference P&ID GEL-26-L-XP-001-01.

4.1.4 Install a blind cap with a $^1/_2$″ discharge valve at the end of the discharge line, reference note 1 on P&ID GEL-26-L-XP-002-01

4.1.5 Cordon off the test area and ensure that all personnel are informed of the operation. Secure pressurisation and instrumentation hoses by tying them off with rope approximately every two to three metres.

4.1.6 Open **FW1**, **FW2**, **ML1**, **ML3**, **ML4**, **ML6**, **ML7**, **ML8**, **ML10**, **LA1**, **LA3**, **TL1**, **TL3**, **TL4**, **TL6**, **TL7**, **CO3** and **CO5**. The control cabin bleed valves shall also be left open.

4.1.7 Start filling the entire system by starting the HT-400 and slowing inject freshwater through the temporary system, ensure that the pump's quick to neutral" has been set at 335 barg. Vent any entrapped air via the open vents **ML2**, **ML5**, **ML9**, **LA2**, **TL2**, **CO2** and through the $^1/_2$″ blind cap discharge valve. Close these valves as appropriate with **TL2** being the last valve which is closed when the system is topped up on account of it being the high point in the system.

4.1.8 Monitor the pressure gauges and vent any entrapped air through the instrument hoses venting at the test cabin bleed valves. When a steady stream of water is observed, close and plug the test cabin bleed valves.

4.1.9 Stop the HT-400 pump.

4.1.10 Carry out a final valve check before pressurising the temporary system.

4.1.11 Start the data acquisition package. Insert new charts into the chart recorders. During the pressurisation the pressure shall be recorded and plotted.

4.1.12 At a rate not exceeding 5 bar/min, slowly pressurise the temporary system using the Haskel Pump, against the closed valves **ML2**, **ML5**, **BV1**, **ML9**, **TL2, LA2**, **CO1**, **CO2** and the blind cap. Care to be exercised to ensure that the system is not over-pressurised.

4.1.13 On attaining 330 barg, stop the pressurisation pump.

4.1.14 Monitor the pressure while carrying out a leak check on all of the temporary connections.

4.1.15 Continue to monitor pressure and visually inspect the temporary connections for leaks for a minimum period of 15 min.

4.1.16 If leaks are found they should be identified immediately and repaired. De-pressurise the system for repair of the leak thereafter repeat the leak test as described in steps 4.1.1 to 4.1.15.

4.1.17 On completion of a satisfactory system leak test, depressurise the system via the bleed valve **TL2** and the bleed valve on the air hydro. Leave the system topped up with water.

4.1.18 On completion of depressurisation set all valves as detailed in P&ID GEL-26-L-XP-001-01 and 2″ line in P&ID GEL-26-L-XP-002-01, reference step 4.1.1.

4.1.19 Disconnect the $^1/_4$″ high pressure hose connected to **TL5** and **CO4**.

4.1.20 Remove the blind cap from the end of the discharge line.

4.1.21 Perform a lip test on the Gel in all of the tanks that will be used to ensure that the Gel is of good quality.

4.2 110 Barg Leak Test of Temporary System with 4″ discharge spread

On completion of the rig-up of equipment, reference P&ID GEL-26-L-XP-001-01 and 4″ line in P&ID GEL-26-L-XP-002-01, HPPS shall perform a temporary systems leak test to 110 barg utilising the HT-400 positive displacement pump and the air hydro pump with freshwater as the pressurisation medium. This test shall test the pumping spread and the 4″ discharge spread from the pumps and to the end of the discharge line. During this test, a thorough leak check of the HPPS spread will be conducted during which time the pressure shall be maintained for a minimum of 15 minutes.

4.2.1 Ensure that all the valves are set as indicated in P&ID GEL-26-L-XP-001-01 and 4″ line in P&ID GEL-26-L-XP-002-01. White valves indicate open valves and black valves indicate closed valves.

4.2.2 Ensure that the PSVs are set to 125 barg and that the discharge valves on the PSVs are facing along the line direction. This is done in order to ensure that in the event of discharge there will not be any lateral movement of the valves.

4.2.3 Connect a $^1/_4$″ high pressure hose between **TL5** and **CO4**. This is to allow both sides of the non-return valve on the crosslinker line during the leak test, reference P&ID GEL-26-L-XP-001-01.

4.2.4 Install a 4″ valve at the end of the discharge line, reference note 2 on P&ID GEL-26-L-XP-002-01.

4.2.5 Cordon off the test area and ensure that all personnel are informed of the operation. Secure pressurisation and instrumentation hoses by tying them off with rope approximately every two to three metres.

4.2.6 Open **FW1**, **FW2**, **ML1**, **ML3**, **ML4**, **ML6**, **ML7**, **ML8**, **ML10**, **LB1**, **LB3**, **TL1**, **TL3**, **TL4**, **TL6**, **TL7**, **CO1**, **CO3** and **CO5**. The control cabin bleed valves shall also be left open.

4.2.7 Start filling the entire system by starting the HT-400 and slowing inject freshwater through the temporary system, ensure that the pump's quick to neutral" has been set at 115 barg. Vent any entrapped air via the open vents **ML2**, **ML5**, **ML9**, **LB2**, **TL2**, **CO1**, **CO2** and through the 4″ valve at the end of the discharge line. Close these valves as appropriate with **TL2** being the last valve which is closed when the system is topped up on account of it being the high point in the system. Ensure that all of these valves are closed before moving on to the next step.

4.2.8 Monitor the pressure gauges and vent any entrapped air through the instrument hoses venting at the test cabin bleed valves. When a steady stream of water is observed, close and plug the test cabin bleed valves.

4.2.9 Stop the HT-400 pump.

4.2.10 Carry out a final valve check before pressurising the temporary system.

4.2.11 Start the data acquisition package. Insert new charts into the chart recorders. During the pressurisation the pressure shall be recorded and plotted.

4.2.12 At a rate not exceeding 5 bar/min, slowly pressurise the temporary system using the Haskel Pump, against the closed valves **ML2**, **ML5**, **BV1**, **ML9**, **TL2, LB2**, **CO2** and the closed 4″ valve at the end of the discharge line. Care to be exercised to ensure that the system is not over-pressurised.

4.2.13 On attaining 110 barg, stop the pressurisation pump.

4.2.14 Monitor the pressure while carrying out a leak check on all of the temporary connections.

4.2.15 Continue to monitor pressure and visually inspect the temporary connections for leaks for a minimum period of 15 min.

4.2.16 If leaks are found they should be identified immediately and repaired. De-pressurise the system for repair of the leak thereafter repeat the leak test as described in steps 4.2.1 to 4.2.15.

4.2.17 On completion of a satisfactory system leak test, depressurise the system via the bleed valve **TL2** and the bleed valve on the air hydro. Leave the system topped up with water.

4.2.18 On completion of depressurisation set all valves as detailed in P&ID GEL-26-L-XP-001-01 and 2″ line in P&ID GEL-26-L-XP-002-01, reference step 4.2.1.

4.2.19 Disconnect the $^{1}/_{4}$″ high pressure hose connected to **TL5** and **CO4**.

4.2.20 Remove the 4″ valve from the end of the discharge line.

4.2.21 Perform a lip test on the Gel in all of the tanks that will be used to ensure that the Gel is of good quality.

5.0 GEL TESTING WITH 2″ STEEL PIPE DISCHARGE

Note: During the testing of valves detailed in section 5.1, 5.2 and 5.3 detailed logs will be maintained and HalWin charts printed off and annotated with the relevant information. When a new test is started or when continuing an operation on a new day new charts shall be installed in the pressure recorders.

5.1 50 m GEL slug testing

5.1.1 Ensure the preparations in section 4.0 have been completed.

5.1.2 Conduct a Tool Box Talk.

5.1.3 Start the data acquisition package. Insert a new chart into the chart recorder. During the operation the pressure shall be recorded and plotted.

5.1.4 Close valves **ML2**, **ML5**, **ML9**, **LA2**, **TL2**, **TL5** and **CO2**.

5.1.5 Open valves **FW1**, **GO2**, **ML1**, **ML3**, **ML4**, **ML6**, **BV1**, **ML8**, **ML10**, **LA1**, **LA3**, **TL1**, **TL3**, **TL4**, **TL6**, **CO1** and **CO3**.

5.1.6 Start pumping Gel with the HT-400 pump at the lowest rate achievable. The Gel will force the pipeline water out the **BV1** bleed valve. When Gel is observed coming out **BV1**, suspend pumping. The Gel shall be bled into a suitable container. Close valve **BV1**, **GO2** and open **ML7** before moving to the next step.

5.1.7 Start pumping crosslinker with the crosslinker injection pump at a low rate decided upon by the HPPS supervisor. The crosslinker will force water out the **CO4** bleed valve. When crosslinker is observed coming out **CO4**, suspend pumping and close the **CO4**. The crosslinker shall be bled into a suitable container.

5.1.8 Carry out a final valve check before proceeding to the next step.

5.1.9 Open **GO2** and **CO5**.

5.1.10 Start pumping Gel with the HT-400 pump and crosslinker with the crosslinker injection pump. The injection rate for the crosslinker injection shall be adjusted according to the HT-400 pumping rate as detailed in “Pumping table for GEL testing” found in section 7.0 herein. When the Gel and the crosslinker mix they will produce GEL.

5.1.11 Pump Gel until 100.5 L has been pumped by the HT-400 pump and then stop both pumps. This volume will correspond to a slug 50 meters long when it enters the 2″ steel pipe.

5.1.12 Close **CO5** and **GO2** and open **FW2**.

5.1.13 Pump freshwater with the HT-400 pump at the lowest rate achievable. Pump approx. 50 L of freshwater in order to propel the GEL into the steel pipe and then stop. Take a sample at **LA2** and control that there is no GEL exiting the valve. If GEL is observed restart the HT-400 pump and pump more water. The necessary volume shall be decided by the HPPS supervisor.

5.1.14 When only water is observed exiting the **LA2** valve the GEL slug has been propelled into the correct position. Proceed to bleed water through **LA2** until the system is depressurised to ambient pressure, thereafter close **LA2**.

5.1.15 Allow the GEL slug to settle for at least 60 minutes. The exact time will be determined by the HPPS supervisor and may be adjusted during the operation. It shall however never be less than 60 minutes.

5.1.16 After the holding period open valve **TL7** and start building pressure at a rate not exceeding 5 barg/min until the GEL slug moves. When the slug moves stop pumping.

Note: By observing when discharge appears at the end of the discharge line, the movement of the slug can be deduced. When discharge is observed the slug is moving.

5.1.17 Close **TL7** and bleed the pressure down to ambient via **LA2** and then close **LA2**.

5.1.18 Allow the GEL slug to settle in the pipe for at least 30 minutes. The exact time will be determined by the HPPS supervisor and may be adjusted during the operation. It shall however never be less than 30 minutes.

5.1.19 Open valve **TL7** and start building pressure at a rate not exceeding 5 barg/min until the GEL slug moves. When the slug moves stop pumping.

Note: By observing when discharge appears at the end of the discharge line, the movement of the slug can be deduced. When discharge is observed the slug is moving.

5.1.20 Repeat steps 5.1.17 to 5.1.19 until the HPPS supervisor determines that enough testing has been performed.

Note: If the GEL slug should exit the steel pipe before enough tests have been performed then ensure that **TL7** and **FW2** are closed and repeat steps 5.1.9 to 5.1.22.

5.1.21 When enough tests have been performed close **TL7** and **GO2**.

5.1.22 Start pumping freshwater with the HT-400 pump at a rate determined by the HPPS supervisor and flush the GEL slug out of the steel pipe.

Note: The GEL shall be deposited into suitable containers. When full the GEL in these containers shall be disposed of by a qualified contractor.

5.1.23 When the system has been flushed the operation shall be deemed complete.

5.2 100 m GEL slug testing

5.2.1 The test for the 100 meter GEL slug will be performed in the same manner as for the 50 meter GEL slug as detailed in section 5.1.

Note: In step 5.1.11 the volume shall be changed from 100.5 L to 201.1 L in order to represent the change from the 50 meter slug to the 100 meter slug. This change shall be implemented at all times when the 100 meter GEL slug operation is ongoing.

5.3 150 m GEL slug testing

5.3.1 The test for the 150 meter GEL slug will be performed in the same manner as for the 50 meter GEL slug as detailed in section 5.1.

Note: In step 5.1.11 the volume shall be changed from 100.5 L to 301.6 L in order to represent the change from the 50 meter slug to the 150 meter slug. This change shall be implemented at all times when the 150 meter GEL slug operation is ongoing.

5.3.2 Upon completion of the 150 meter GEL slug operation for the 2″ discharge line ensure that the system is depressurised through the bleed valves. Following this the 2″ discharge spread shall be rigged down.

6.0 GEL TESTING WITH 4″ STEEL PIPE DISCHARGE

Note: During the testing of valves detailed in section 6.1, 6.2 and 6.3 detailed logs will be maintained and HalWin charts printed off and annotated with the relevant information. When a new test is started or when continuing an operation on a new day new charts shall be installed in the pressure recorders.

6.1 50 m GEL slug testing

6.1.1 Ensure the testing preparations in section 4.0 have been completed.

6.1.2 Conduct a Tool Box Talk.

6.1.3 Start the data acquisition package. Insert a new chart into the chart recorder. During the operation the pressure shall be recorded and plotted.

6.1.4 Close valves **ML2**, **ML5**, **ML9**, **LB2**, **TL2**, **TL5** and **CO2**.

6.1.5 Open valves **FW1**, **GO2**, **ML1**, **ML3**, **ML4**, **ML6**, **BV1**, **ML8**, **ML10**, **LB1**, **LB3**, **TL1**, **TL3**, **TL4**, **TL6**, **CO1** and **CO3**.

6.1.6 Start pumping Gel with the HT-400 pump at the lowest rate achievable. The Gel will force the pipeline water out the **BV1** bleed valve. When Gel is observed coming out **BV1**, suspend pumping. The Gel shall be bled into a suitable container. Close valve **BV1**, **GO2** and open **ML7** before moving to the next step.

6.1.7 Start pumping crosslinker with the crosslinker injection pump at a low rate decided upon by the HPPS supervisor. The crosslinker will force water out the **CO4** bleed valve. When crosslinker is observed coming out **CO4**, suspend pumping and close **CO4**. The crosslinker shall be bled into a suitable container.

6.1.8 Carry out a final valve check before proceeding to the next step.

6.1.9 Open **GO2** and **CO5**.

6.1.10 Start pumping Gel with the HT-400 pump and crosslinker with the crosslinker injection pump. The injection rate for the crosslinker injection pump shall be adjusted according to the HT-400 pumping rate as detailed in “Pumping table for GEL testing” found in section 7.0. When the Gel and the crosslinker mix they will mix and produce GEL.

6.1.11 Pump Gel until 402.2 L has been pumped by the HT-400 pump and then stop both pumps. This volume will correspond to a slug 50 meters long when it enters the 2″ steel pipe.

6.1.12 Close **CO5** and **GO2** and open **FW2**.

6.1.13 Pump freshwater with the HT-400 pump at the lowest rate achievable. Pump approx. 50 L of freshwater in order to propel the GEL into the steel pipe and then stop. Take a sample at **LB2** and control that there is no GEL exiting the valve. If GEL is observed restart the HT-400 pump and pump more water. The necessary volume shall be decided by the HPPS supervisor.

6.1.14 When only water is observed exiting the **LB2** valve the GEL slug has been propelled into the correct position. Proceed to bleed water through **LB2** until the system is depressurised to ambient pressure, thereafter close **LB2**.

6.1.15 Allow the GEL slug to settle for at least 60 minutes. The exact time will be determined by the HPPS supervisor and may be adjusted during the operation. It shall however never be less than 60 minutes.

6.1.16 After the holding period open valve **TL7** and start building pressure at a rate not exceeding 5 barg/min until the GEL slug moves. When the slug moves stop pumping.

Note: By observing when discharge appears at the end of the discharge line, the movement of the slug can be deduced. When discharge is observed the slug is moving.

6.1.17 Close **TL7** and bleed the pressure down to ambient via **LB2** and then close **LB2**.

6.1.18 Allow the GEL slug to settle in the pipe again for at least 30 minutes. The exact time will be determined by the HPPS supervisor and may be adjusted during the operation. It shall however never be less than 30 minutes.

6.1.19 Open valve **TL7** and start building pressure at a rate not exceeding 5 barg/min until the GEL slug moves. When the slug moves stop pumping.

Note: By observing when discharge appears at the end of the discharge line, the movement of the slug can be deduced. When discharge is observed the slug is moving.

6.1.20 Repeat steps 6.1.17 to 6.1.19 until the HPPS supervisor determines that enough testing has been performed.

Note: If the GEL slug should exit the steel pipe before enough tests have been performed then ensure that **TL7** and **FW2** are closed and repeat steps 6.1.9 to 6.1.22.

6.1.21 When enough tests have been performed close **TL7** and **GO2**.

6.1.22 Start pumping freshwater with the HT-400 pump at a rate determined by the HPPS supervisor and flush the GEL slug out of the steel pipe.

Note: The GEL shall be deposited into suitable containers. When full the GEL in these containers shall be disposed of by a qualified contractor.

6.1.23 When the system has been flushed the operation shall be deemed complete.

6.2 100 m GEL slug testing

6.2.1 The test for the 100 meter GEL slug will be performed in the same manner as for the 50 meter GEL slug as detailed in section 6.1.

6.2.2 **Note:** In step 6.1.11 the volume shall be changed from 402.2.5 L to 804.4 L in order to represent the change from the 50 meter slug to the 100 meter slug. This change shall be implemented at all times when the 100 meter GEL slug operation is ongoing.

6.3 150 m GEL slug testing

Note: The HPPS supervisor shall decide if testing is to be done with the 150 meter slug when using the 4″ steel pipe discharge. When deciding this, pressure readings from the testing operations described in sections 5.1, 5.2, 5.3, 6.1, and 6.2 shall be reviewed. If the HPPS supervisor decide that these results indicate that the 150 meter gel slug will be hard to move under the set pressure restriction of 110 barg then this test shall be abandoned.

6.3.1 The test for the 150 meter GEL slug will be performed in the same manner as for the 50 meter GEL slug as detailed in section 6.1.

Note: In step 6.1.11 the volume shall be changed from 402.2 L to 1206.5 L in order to represent the change from the 50 meter slug to the 150 meter slug. This change shall be implemented at all times when the 150 meter GEL slug operation is ongoing.

6.3.2 Upon completion of the 150 meter GEL slug operation for the 4″ discharge line ensure that the system is depressurised through the bleed valves. Following this the 4″ discharge spread shall be rigged down.

7.0 PUMP RATE TABLE, DRAWINGS, EQUIPMENT AND MSDS INFORMATION

The following documents are to be used as a reference during the work and all personnel should familiarise themselves with the enclosed documents and drawings.

Table description
Pumping table for GEL testing

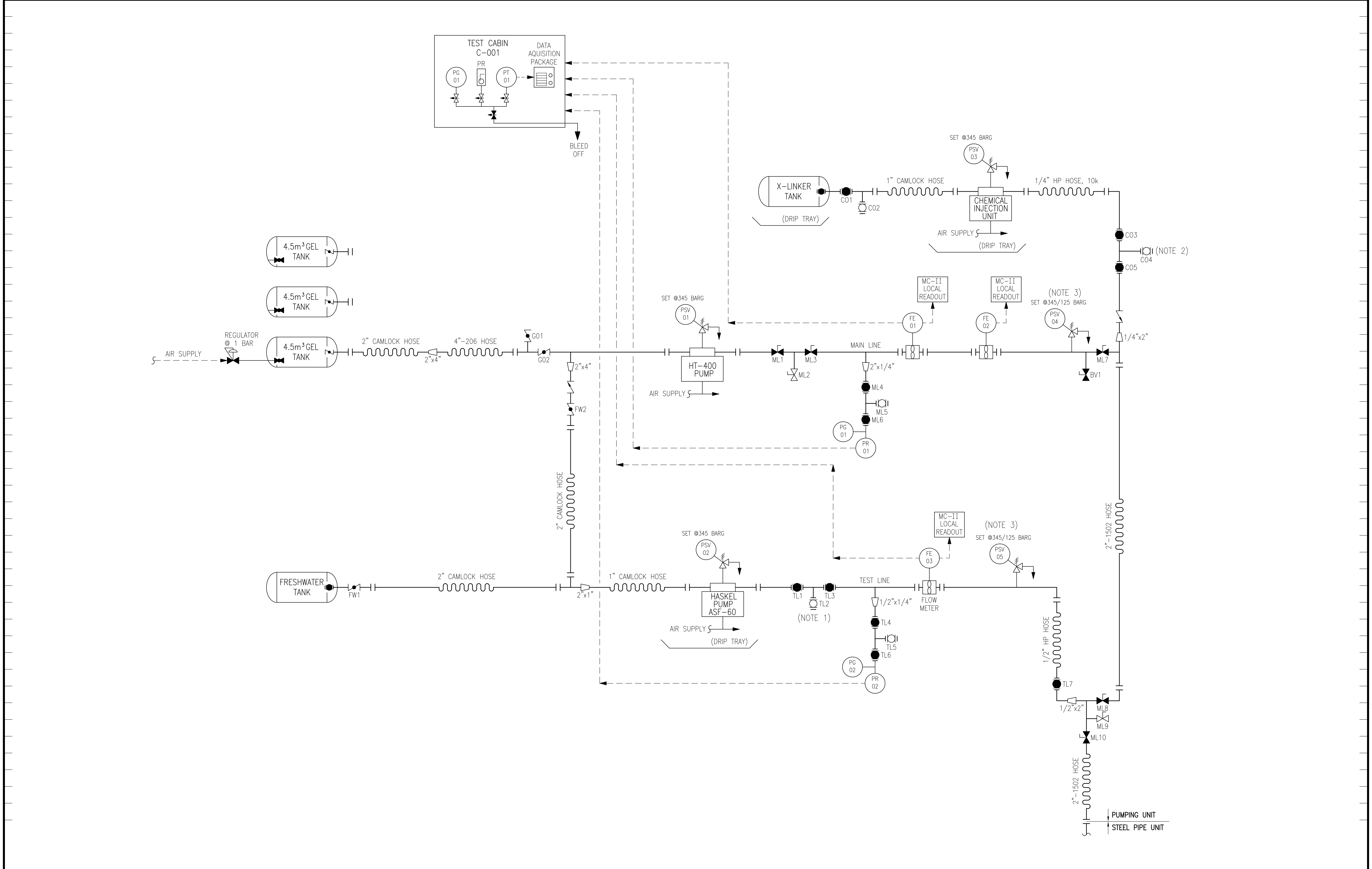
Drawing Number	Revision	Description
GEL-26-L-XP-001-01	2	P&ID Pumping spread
GEL-26-L-XP-002-01	2	P&ID Discharge spread

Equipment
Test Cabin
HT-400 Power pack
HT-400 Pump end
Haskel pump
Crosslinker injection pump

Chemical	Description
CL-31	Crosslinker
Temblok 50	Gel

Pumping table for GEL testing		
Temblok 50 volume/min Vt [Ltrs/min]	**CL-31 Vc [Ltrs]**	**Crosslinker pump [strokes/min]**
20	0.15	3
30	0.23	4
40	0.30	5
50	0.38	7
60	0.45	8
70	0.53	9
80	0.6	11
90	0.68	12
100	0.75	13
125	0.94	16
150	1.13	20
175	1.32	23
200	1.50	26
225	1.69	30
250	1.88	33
275	2.06	36
300	2.25	39
325	2.44	43
350	2.63	46
375	2.81	49
400	3.00	53
450	3.48	59
500	3.75	66
550	4.13	72
600	4.50	79
650	4.88	86
700	5.25	92
750	5.63	99
800	6.00	105
850	6.38	112
900	6.75	118
950	7.13	125
1000	7.50	132
1050	7.88	138
1100	8.25	145
1150	8.63	151
1200	9.00	158

Note: This table was calculated based on a chemical injection pump which pumps 57 ml/stroke. If the pump to be used differ in any way from this than a new pumping table must be made.



REV. No.	DATE	REASON FOR ISSUE	PREPARED	CHECKED	APPROVED	REVIEWED VERIFIED	REVIEWED VERIFIED
0	14.03.11	ISSUED FOR USE.	RK	EAS	DN		
2	11.03.11	ISSUED FOR CLIENT REVIEW.	ESt	KU	DN		
1	01.03.11	ISSUED FOR IDC.	ESt	TML	KU		
			CONTRACTOR				

NOTES:

1. HIGH POINT FOR VENTING AIR.
2. CHEMICALS TO BE COLLECTED IN SUITABLE CONTAINER.
3. 125 BARG PSV TO BE USED DURING TESTS IN 2" PIPE.
   145 BARG PSV TO BE USED DURING TESTS IN 4" PIPE.

DRAWING NUMBER	DRAWING TITLE
REFERENCE DRAWINGS	

CONTRACTOR NAME: **HALLIBURTON**

HARDWARE GROUP/ SERVICE DEPARTMENT: DFO

DRAWING TITLE: PUMPING GEL IN PIPELINE APPLICATIONS

P&ID

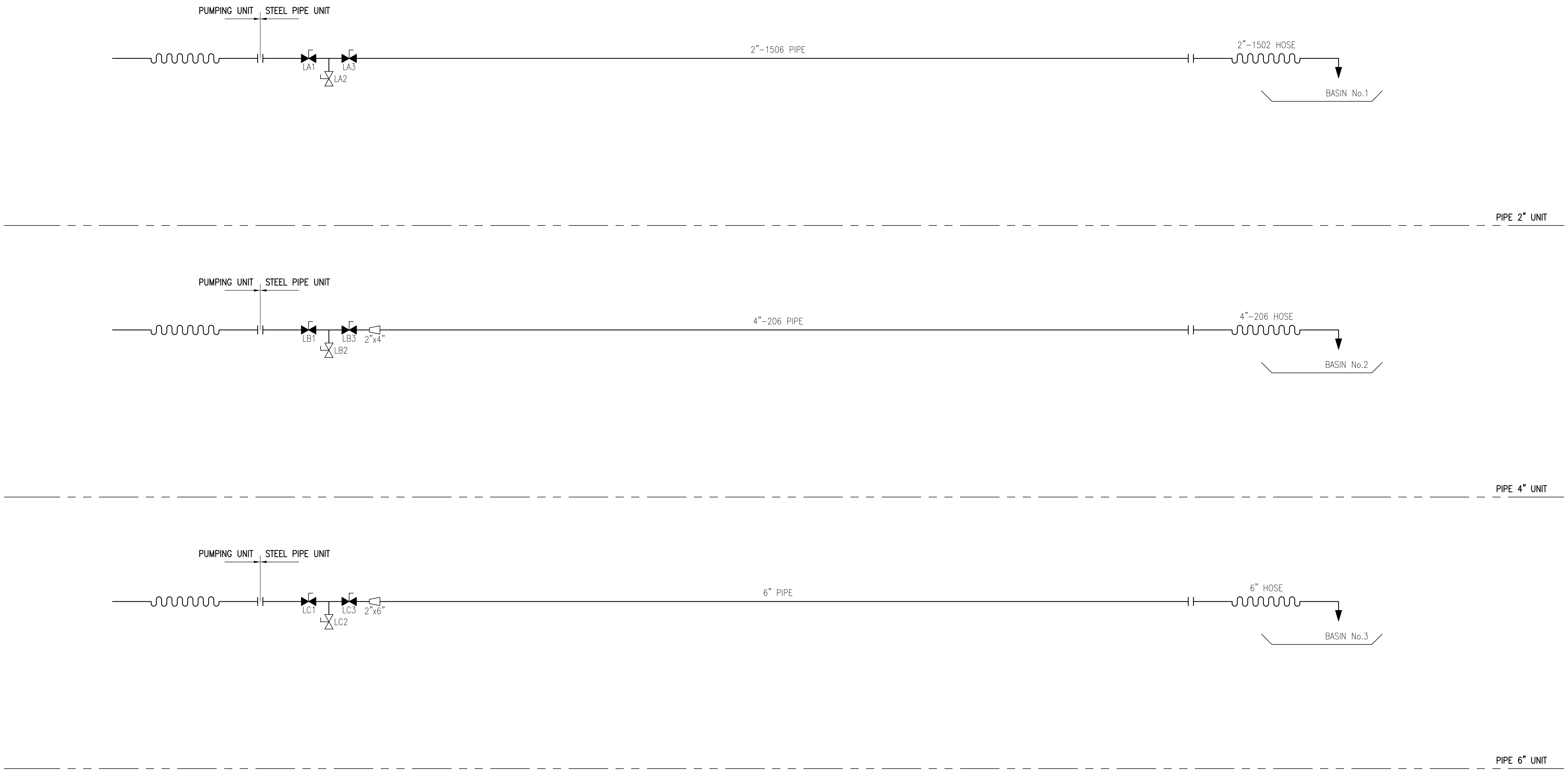
DOCUMENT CATEGORY: | RETENTION CODE:

CONTRACT No.: TBC | CTR. No.:

SCALE: N.T.S. | PROJECTION | DWG. SIZE: A1

CAD FILE CODE: D:\CAD\GEL PROJECT\GEL-26-L-XP-001-01.dwg

DRAWING NUMBER: GEL-26-L-XP-001-01 | REVISION: 0



REV. No.	DATE	REASON FOR ISSUE	PREPARED	CHECKED	APPROVED	REVIEWED / VERIFIED	REVIEWED / VERIFIED
1	23.02.11	ISSUED FOR IDC.	ESt	EAS			

CONTRACTOR

NOTES:

DRAWING NUMBER	DRAWING TITLE

REFERENCE DRAWINGS

CONTRACTOR NAME
HALLIBURTON

DOCUMENT CATEGORY: | RETENTION CODE:
CONTRACT No.: TBC | CTR. No.:
SCALE: N.T.S. | PROJECTION | DWG. SIZE: A1

HARDWARE GROUP/ SERVICE DEPARTMENT: DFO

DRAWING TITLE:
PUMPING GEL IN PIPELINE APPLICATIONS

P&ID

CAD FILE CODE: O:\CAD\GEL PROJECT\GEL-26-L-XP-002-01.dwg

DRAWING NUMBER: GEL–26–L–XP–002–01

REVISION: 1

Norsok Test Cabin – NSK1062 – 16 ft

Specifications:

Model:	Overpressure Test Cabin
Type:	16 ft, A60, Overpressure Test Cabin for Zone 1 and Zone 2
Dimensions:	Length: 4877 mm, Width: 2438 mm, Height: 3000 mm
Weight	14,300 Kg (MGW), 9,900 Kg (WLL)
Utilities Required:	Compressed Air & 380-690 V, 50/60 Hz, 3-Phase, 32 A Electric Power
Control System:	Automatic Voltage Selector Touch Screen Cabin Safety, Control and Monitoring System.

Further Specifications:

The unit is fitted with an over-pressurising ventilation system with an integrated air conditioner unit. A calibrated gas detector is located in the ventilation air inlet.
In addition to the pre-installed Electric Power Plug, the unit comes with plugs ready-to-connect Phone, PA, Alarm and Rig Signal Plug Systems.
The unit also have smoke detector, Ex.Phone, Emergency Escape Hatch (with window) and Emergency Lighting with Battery back-up.
The Unit is built to meet all requirements in Norsok Z-015 Rev. 3 Temporary Equipment and is certified by DnV to 2.7-1 and 2.7-2 and meets SAM and ATEX requirements.

Additional Information:

The unit is fitted with height adjustable office furniture and computer equipment for 2 operators.
To ensure safe communication, the unit is also fitted with UHF and VHF antennas and VHF radio.
The unit is also prepared for data monitoring and recording with dual Compupac Installation in addition to 2 ea wall mounted pressure monitoring and recording units.
Piping system for safe and easy installation of Helium Leak detection equipment is also available.

Containerised Diesel Power Pack - NSK1093A – Cat C18

The Diesel Power Pack needs to be connected to a HT400 or Centrifugal Pump Skid prior to operation.

Specifications:

Unit ID Number	NSK1093A
Type:	Containerised Diesel Power Pack
Length:	4571 mm
Width:	2438 mm
Height:	3036 mm
Weight (GW):	14000 kg
Diesel Engine:	550 hhp – Caterpillar C-18 Diesel Engine 18 litre
Automatic Gearbox:	Allison Transmission CEC – S6610M – 5 speed
Remote Control Panel:	Electronic Remote Control Panel, complete with 25 m. cable
Foam Fire Fighting System:	Swordsman Foam System, 65 liter (NFPA 11)
Utilities Required:	8-10 bar air @ 150 cfm (*Starting Purposes*)
Utilities Required:	230 V 16A AC Electric Power Supply
Diesel Consumption:	up to 120 Litre/hr
Design Standard	Norsok Z-015, Temporary Equipment, DNV 2.7-1
Operational Limitations	Hazardous Area Zone 2

HT400 Pump Skid – NSK1093B

HT400 Triplex Pump installed in an ISO container frame with a 1200 litre diesel fuel tank.
Skid needs to be connected to a Power Pack Container prior to operation.

Skid Data:

Length:	3050 mm
Width:	2440 mm
Height:	3040 mm
Weight:	6400 kg (S.W.L 9000 kg)

Operation Data HT 400 Pump:

				*SPK in 4 ½" Fluid End	
Optional Pump Sizes	**6"**	**4 ½"**	**4"**	**2"**	**1 ¾"**
Max Working Pressure (bar)	430	772	965	772	772
Max Flow Rate (m^3/min)	2.79	1.56	1.23	0.30	0.22

*Small Plunger Kit (SPK)

DNV Approved According to:

Suction Connection:	4" Fig. 206 M Hammer Union
Discharge Connection:	2" or 3" Fig.1502 FM Hammer Union
Fluids:	Water, Mud, Cement Slurries, Acids, Diesel
Safety:	Field Adjustable Pressure shut down & Pressure Safety Valve
Classification:	CE Marked, DnV 2.7-1, Norsok Z-015

Recommended Operational Limitations:

Less than 1 hour	full load
Between 1 and 4 hours	90% of full load
Between 4 and 8 hours	75% of full load
Continuous Operation	50% of full load

DATA SHEET

TEST UNIT LIQUID

TYPE 100 WITH HASKEL GSF-60 PUMP

Type 100 with
Haskel GSF-60 Pump

Air driven test unit for pressure and burst testing. The test unit can as well be used for injection of liquids and chemicals. Most of our units are supplied with safety valve on the outlet to protect the Operator of the pump.

Weight : kg

Height : 600 mm

Width : 650 mm

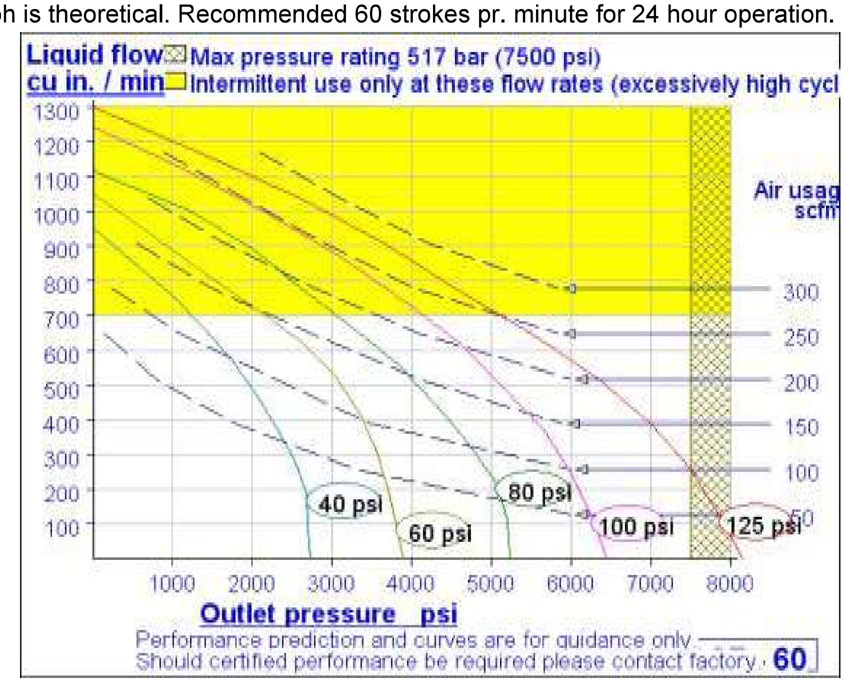
Lifting/Transport: Depth : 450 mm

Stainless Steel Frame, Small and Handy.

Pump:	Haskel GSF-60
Pressure range @ 7 Bar supply:	420 Bar
Displacement per Cycle:	57 cc

Air supply:	1" Crowsfoot
Fluid inlet:	1" Crowsfoot
HP outlet:	9/16" AEMP

The pump graph is theoretical. Recommended 60 strokes pr. minute for 24 hour operation.



DATA SHEET

TEST UNIT LIQUID

TYPE 100 WITH HASKEL ASF-60 PUMP

Type 100 with
Haskel ASF-60 Pump

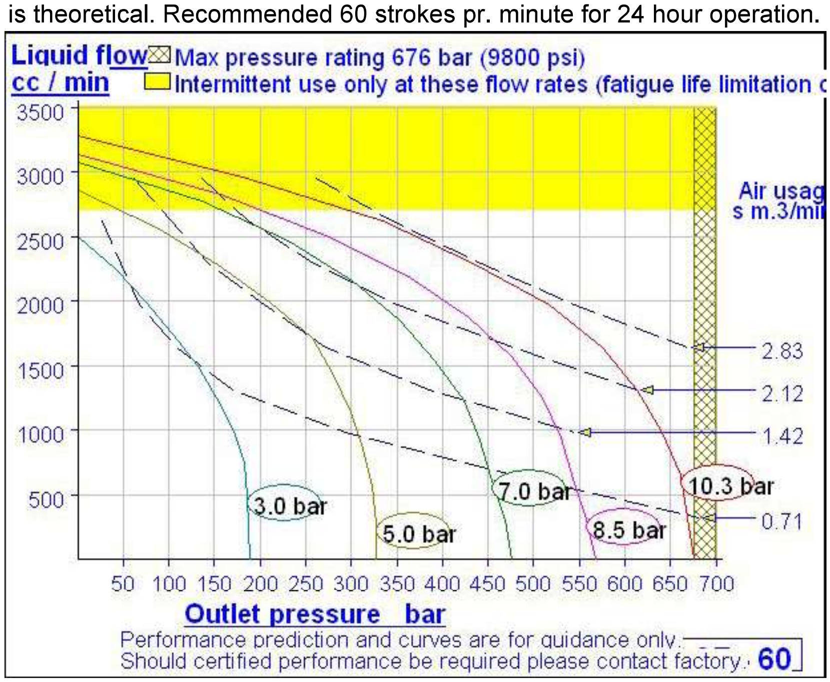
Air driven test unit for pressure and burst testing. The test unit can as well be used for injection of liquids and chemicals. Most of our units are supplied with safety valve on the outlet to protect the Operator of the pumps. On request we can deliver pumps with stroke counters and 30 ltr. reservoir.

Weight : 43 Kg
Height : 600 mm
Width : 650 mm
Lifting/Transport: Depth : 450 mm
Stainless Steel Frame, Small and Handy.

Pump:	Haskel ASF-60
Pressure range @ 7 Bar supply:	420 Bar
Displacement per Cycle:	11 cc

Air supply:	1" Crowsfoot
Fluid inlet:	1" Crowsfoot
HP outlet:	3/8" AEMP

The pump graph is theoretical. Recommended 60 strokes pr. minute for 24 hour operation.



Proserv A/S, Risavika Havnering 97, 4056 Tananger, Norway
Tlf. 51 71 80 01, Fax. 51 71 80 00, e-mail. proserv@proserv.no, www.proserv.no

SIKKERHETSDATABLAD
CL-31

1. Identifikasjon av stoffet / produktet og av selskapet / foretaket

Utgitt dato	26.07.2005
Revisjonsdato	18.11.2009
Kjemikaliets navn	CL-31
Kjemikaliets bruksområde	Cross-linker
Firmanavn	Halliburton AS
Postadresse	Eldfiskvegen 1
Postnr.	4065
Poststed	Stavanger
Land	Norge
Telefon	51837000
Telefaks	51838383
E-post	AnneKristin.Haugan@Halliburton.com
Hjemmeside	http://www.Halliburton.com
Kontaktperson	Anne Kristin Haugan
Utarbeidet av	Teknologisk Institutt as v/ Knut Finsveen
Nødtelefon	Giftinformasjonen:22 59 13 00

2. Fareidentifikasjon

Klassifisering i henhold til 67/548/EEC eller 1999/45/EC	C; R34
Farebeskrivelse	Helse: Etsende. Brann og eksplosjon: Produktet er ikke klassifisert som brannfarlig. Miljø: Produktet er ikke klassifisert som miljøskadelig.

3. Sammensetning /opplysning om innholdsstoffer

Komponentnavn	Identifikasjon	Klassifisering	Innhold
kaliumhydroksid	CAS-nr.: 1310-58-3 EC-nr.: 215-181-3	C; R22, R35	< 5 %
kaliummetaborat	CAS-nr.: 13709-94-9 EC-nr.: 237-262-2		30 - 60 %

Kolonneforklaring	CAS-nr. = Chemical Abstracts Service; EU (Einecs- eller Elincsnummer) = European inventory of Existing Commercial Chemical Substances; Ingrediensnavn = Navn iflg. stoffliste (stoffer som ikke står i stofflisten må oversettes hvis mulig). Innhold oppgitt i; %, %vkt/vkt, %vol/vkt, %vol/vol, mg/m3, ppb, ppm, vekt%, vol%
FH/FB/FM	T+ = Meget giftig, T = Giftig, C = Etsende, Xn = Helseskadelig, Xi = Irriterende, E = Eksplosiv, O = Oksiderende, F+ = Ekstremt brannfarlig, F = Meget brannfarlig, N = Miljøskadelig.
Komponentkommentarer	Se seksjon 16 for forklaring av risikosetninger.

4. Førstehjelpstiltak

Generelt	I tvilstilfelle bør lege kontaktes.
Innånding	Frisk luft, ro og varme. Kontakt lege hvis ikke alt ubehag gir seg.
Hudkontakt	Fjern tilsølt tøy. Vask straks huden med såpe og vann. Etseskader skal

	behandles av lege.
Øyekontakt	Skyll straks med rikelige mengder vann i opp til 15 minutter. Fjern evt. kontaktlinser og åpne øyet godt opp. Kontakt lege umiddelbart. Fortsett å skylle også på vei til lege. Ved lengre tids skylling, anvend lunkent vann for å unngå skade på øyet.
Svelging	Skyll munnen grundig og gi rikelige mengder melk eller vann forutsatt at den skadde ikke er bevisstløs. Drikk et par glass vann eller melk. FREMKALL IKKE BREKNING! Kontakt lege øyeblikkelig.

5. Tiltak ved brannslukning

Passende brannslukningsmidler	Pulver, skum eller karbondioksid. Vannspray, -tåke eller -dis.
Uegnet brannslukningsmidler	Bruk ikke full vannstråle.
Brann- og eksplosjonsfarer	Produktet er ikke klassifisert som brannfarlig. Kan danne giftige eller eksplosive damper i kontakt med enkelte metaller. Ved brann dannes: Karbondioksid (CO_2). Karbonmonoksid (CO).
Personlig verneutstyr	Bruk friskluftmaske når produktet er involvert i brann. Ved rømning brukes godkjent rømningsmaske. Se forøvrig pkt 8.
Annen informasjon	Beholdere i nærheten av brann flyttes straks eller kjøles med vann.

6. Tiltak ved utilsiktet utslipp

Sikkerhetstiltak for å beskytte personell	Benytt personlig verneutstyr som angitt i pkt 8. Pass på! Produktet er etsende.
Sikkerhetstiltak for å beskytte ytre miljø	Forhindre utslipp til kloakk, vassdrag eller grunn.
Metoder for opprydding og rengjøring	Absorber i vermikulitt, tørr sand eller jord og fyll i beholdere. Spill samles opp i egnede beholdere og leveres som farlig avfall (se pkt. 13).

7. Håndtering og lagring

Håndtering	Bruk angitt verneutstyr. Unngå kontakt med huden og øynene. Unngå innånding av damper og sprøytetåke.
Oppbevaring	Oppbevares på et kjølig, godt ventilert sted. Lagres som etsende stoff. Lagres adskilt fra: Oksidasjonsmidler. Syrer.

8. Eksponeringskontroll / personlig verneutstyr

Administrative normer

Komponentnavn	Identifikasjon	Verdi	Norm år
kaliumhydroksid	CAS-nr.: 1310-58-3 EC-nr.: 215-181-3	15 min.: 2 mg/m³ T	2007

Eksponeringskontroll

Begrensning av eksponering på arbeidsplassen	Sørg for tilstrekkelig ventilasjon. Det må ikke spises, drikkes eller røykes under arbeidet. Personlig verneutstyr bør velges i henhold til CEN-standard og i samarbeid med leverandøren av personlig verneutstyr.
Åndedrettsvern	Ved utilstrekkelig ventilasjon: Bruk egnet åndedrettsvern med kombinasjonsfilter, type A2/P2.
Håndvern	Bruk vernehansker av: Butylgummi. Neoprengummi. Gjennomtrengningstid > 8 timer.
Øyevern	Benytt godkjent øyevern ved risiko for sprut.
Annet hudvern enn håndvern	Benytt hensiktsmessige verneklær for beskyttelse mot hudkontakt.
Annen informasjon	Nøddusj og mulighet for øyeskylling må finnes på arbeidsplassen. Det oppgitte verneutstyr er veiledende. Risikovurderingen (Faktisk risiko) kan føre til andre krav.

9. Fysiske og kjemiske egenskaper

Tilstandsform	Væske
Lukt	Karakteristisk
Farge	Klar.
Løselighet i vann	Løselig.
Relativ tetthet	**Verdi:** 1,31 g/cm³
pH (handelsvare)	**Verdi:** > 13,5
Viskositet	**Verdi:** 5-10 cP @ 20 °C

10. Stabilitet og reaktivitet

Forhold som skal unngås	Må ikke utsettes for høye temperaturer eller direkte sollys.
Materialer som skal unngås	Sterke oksydasjonsmidler. Sterke syrer.
Farlige spaltningsprodukter	Ingen under normale forhold. Ved brann dannes: Karbondioksid (CO_2). Karbonmonoksid (CO). Borforbindelser.
Stabilitet	Stabil under normale temperaturforhold og anbefalt bruk.

11. Toksikologisk informasjon

Øvrige helsefareopplysninger

Generelt	Ved bruk representerer de etsende egenskaper den største faren.
Innånding	Damper virker etsende. Kan gi skader på slimhinner i nese, svelg, bronkier og lunger.
Hudkontakt	Etsende. Kan gi alvorlig etseskade på huden.
Øyekontakt	Virker etsende. Øyeblikkelig førstehjelp er nødvendig.
Svelging	Etsende ved svelging. Gir brennende smerter i munn, svelg og spiserør. Fare for store varige skader.

12. Miljøopplysninger

Øvrige miljøopplysninger

Økotoksisitet	Produktet er ikke klassifisert som miljøskadelig.
Mobilitet	Løselig i vann.
Persistens og nedbrytbarhet	Produktet er bionedbrytbart.
Bioakkumulasjonspotensial	Bioakkumulerer ikke.
Andre skadevirkninger / annen informasjon	Utslipp av produktet til vann kan lokalt gi høy pH med fare for fiskedød.

13. Fjerning av kjemikalieavfall

Avfallskode EAL	EAL: 06 02 05 andre baser
NORSAS	7135 Basisk organisk avfall
Produktet er klassifisert som farlig avfall	Ja
Egnede metoder til fjerning av kjemikaliet	Leveres som farlig avfall til godkjent behandler eller innsamler. Koden for farlig avfall (EAL-kode) er veiledende. Bruker må selv angi riktig EAL-kode hvis bruksområdet avviker.

14.Transportinformasjon

Varenavn (nasjonalt)	KALIUMHYDROKSIDLØSNING
Farlig gods ADR	**UN-nr.:** 1814 **Klasse:** 8 **Fare nr.:** 80 **Emballasjegruppe:** III **Varenavn:** KALIUMHYDROKSIDLØSNING

Farlig gods RID	**UN-nr.:** 1814 **Klasse:** 8 **Emballasjegruppe:** III **Varenavn:** KALIUMHYDROKSIDLØSNING
Farlig gods IMDG	**UN-nr.:** 1814 **Klasse:** 8 **Emballasjegruppe:** III **EmS:** F-A, S-B **Varenavn:** POTASSIUM HYDROXIDE SOLUTION
Farlig gods ICAO/IATA	**UN-nr.:** 1814 **Klasse:** 8 **Emballasjegruppe:** III **Varenavn:** POTASSIUM HYDROXIDE SOLUTION

15. Opplysninger om lover og forskrifter

Faresymbol

Etsende

Sammensetning på merkeetiketten	kaliumhydroksid: < 5 %
R-setninger	R34 Etsende.
S-setninger	S26 Får man stoffet i øynene; skyll straks grundig med store mengder vann og kontakt lege. S36/37/39 Bruk egnede verneklær, vernehansker og vernebriller/ansiktsskjerm. S45 Ved uhell eller illebefinnende er omgående legebehandling nødvendig; vis etiketten om mulig.
Referanser (Lover/Forskrifter)	Forskrift om klassifisering, merking m.v. av farlige kjemikalier, fastsatt av Miljøverndepartementet og Arbeids- og inkluderingsdepartementet, 16.juli 2002, med senere endringer, gjeldende fra 22. april 2009. Forskrift om registrering, vurdering, godkjenning og begrensning av kjemikalier (REACH) Vedlegg II: Sikkerhetsdatablad. Veiledning om administrative normer for forurensning i arbeidsatmosfære fra Direktoratet for Arbeidstilsynet, den til enhver tid gjeldende utgave. Avfallsforskriften, FOR 2004-06-01 nr 930, fra Miljøverndepartementet. ADR/RID veg-/jernbanetransport av farlig gods 2009, Direktoratet for samfunnssikkerhet og beredskap. Databladet er utarbeidet med basis i opplysninger gitt av produsenten.

16. Andre opplysninger

Liste over relevante R-setninger (i seksjon 2 og 3).	R22 Farlig ved svelging. R34 Etsende. R35 Sterkt etsende.
Opplysninger som er nye, slettet eller revidert	Tidligere utgitt i annet format.
Leverandørens anmerkninger	Informasjonen i dette dokument skal gjøres tilgjengelig til alle som håndterer produktet.
Kvalitetssikring av informasjonen	Dette HMS-databladet er kvalitetssikret av Teknologisk Institutt as, som er sertifisert iht. NS-EN ISO 9001:2000.
Ansvarlig for Sikkerhetsdatablad	Halliburton AS

SAFETY DATA SHEET
CL-31

1. Identification of the substance/preparation and of the company/undertaking

Date issued	12.07.2005
Revision date	18.11.2009
Product name	CL-31
Use of the substance/preparation	Cross-linker
Company name	Halliburton AS
Postal address	Eldfiskvegen 1
Postcode	NO-4065
Place name	Stavanger
Country	Norway
Tel	+47 51837000
Fax	+47 51838383
E-mail	AnneKristin.Haugan@Halliburton.com
Website	http://www.Halliburton.com
Name of contact	Anne Kristin Haugan
Prepared by	National Institute of Technology as, Norway v/ Knut Finsveen
Emergency telephone	Giftinformasjonen:22 59 13 00

2. Hazards identification

Classification according to 67/548/EEC or 1999/45/EC	C; R34
Description of hazard	Health: Causes burns. Fire and explosion: The product is not classified as flammable. Environment: The product is not classified as harmful to the environment.

3. Composition/information on ingredients

Component name	Identification	Classification	Contents
potassium hydroxide	CAS no.: 1310-58-3 EC no.: 215-181-3	C; R22, R35	< 5 %
potassium metaborate	CAS no.: 13709-94-9 EC no.: 237-262-2		30 - 60 %

Column headings	CAS no. = Chemical Abstracts Service; EU (Einecs or Elincs number) = European inventory of Existing Commercial Chemical Substances; Ingredient name = Name as specified in the substance list (substances that are not included in the substance list must be translated, if possible). Contents given in; %, %wt/wt, %vol/wt, %vol/vol, mg/m3, ppb, ppm, weight%, vol%
HH/HF/HE	T+ = Very toxic, T = Toxic, C = Corrosive, Xn = Harmful, Xi = Irritating, E = Explosive, O = Oxidizing, F+ = Extremly flammable, F = Very flammable, N = Environmental hazard
Component comments	See section 16 for explanation of Risk-phrases listed above.

4. First-aid measures

General	If in doubt, get medical advice.
Inhalation	Fresh air and rest. Get medical attention if any discomfort continues.
Skin contact	Remove contaminated clothing. Wash the skin immediately with soap and

	water. Chemical burns must be treated by a physician.
Eye contact	Immediately flush with plenty of water for up to 15 minutes. Remove any contact lenses and open eyes wide apart. Immediately consult a doctor. Continue rinsing during the journey to the doctor. By prolonged rinsing, use lukewarm water to avoid damage to the eye.
Ingestion	Rinse mouth thoroughly with water and give large amounts of milk or water to people not unconscious. Drink a few glasses of water or milk. DO NOT induce vomiting. Get medical attention immediately.

5. Fire-fighting measures

Suitable extinguishing media	Foam, carbon dioxide or dry powder. Water spray, fog or mist.
Improper extinguishing media	Do not use water jet.
Fire and explosion hazards	The product is not classified as flammable. May form toxic or explosive vapours in presence of certain metals. Fire creates: Carbon dioxide (CO_2). Carbon monoxide (CO).
Personal protective equipment	Use fresh air equipment when the product is involved in fire. In case of evacuation, an approved protection mask should be used. See also sect. 8.
Other Information	Containers close to fire should be removed immediately or cooled with water.

6. Accidental release measures

Personal precautions	Use protective equipment as referred to in section 8. Look out! The product is corrosive.
Environmental precautions	Do not allow to enter into sewer, water system or soil.
Methods for cleaning	Absorb in vermiculite, dry sand or earth and place into containers. Collect in suitable containers and deliver as hazardous waste according to section 13.

7. Handling and storage

Handling	Use protective equipment as referred to in section 8. Avoid contact with skin and eyes. Avoid inhalation of vapours and spray mists.
Storage	Store in a cool, well-ventilated place. Corrosive storage. Keep away from: Oxidizing agents Acid.

8. Exposure controls/personal protection

Exposure limit values

Component name	Identification	Value	Year
potassium hydroxide	CAS no.: 1310-58-3 EC no.: 215-181-3	15 min.: 2 mg/m³ T	2007

Exposure controls

Occupational exposure controls	Provide adequate ventilation. Do not eat, drink or smoke during work. Personal protection equipment should be chosen according to the CEN standards and in discussion with the supplier of the personal protective equipment
Respiratory protection	In case of inadequate ventilation: Use respiratory equipment with combination filter, type A2/P2.
Hand protection	Use protective gloves made of: Butyl rubber. Neoprene. Penetration time > 8 hours.
Eye protection	If risk of splashing, wear safety goggles or face shield.
Skin protection (other than of the hands)	Wear appropriate protective clothing to protect against skin contact.
Other Information	Eye wash facilities and emergency shower must be available when handling this product. The listed protective equipment is a suggestion. A risk assessment (of actual risk) may lead to other requirements.

9. Physical and chemical properties

Physical state	Fluid
Odour	Characteristic
Colour	Clear
Solubility in water	Soluble.
Specific gravity	**Value:** 1,31 g/cm³
pH (as supplied)	**Value:** > 13,5
Viscosity	**Value:** 5-10 cP @ 20 °C

10. Stability and reactivity

Conditions to avoid	Avoid exposure to high temperatures or direct sunlight.
Materials to avoid	Strong oxidizing agents. Strong acids.
Hazardous decomposition products	None under normal conditions. Fire creates: Carbon dioxide (CO2). Carbon monoxide (CO). Boric compounds.
Stability	Stable under normal temperature conditions and recommended use.

11. Toxicological information

Other information regarding health hazards

General	In industrial use, the corrosive properties represents the highest level of danger.
Inhalation	Vapour causes burns. May cause damage to mucous membranes in nose, throat, lungs and bronchial system.
Skin contact	Causes burns. May cause serious chemical burns to the skin.
Eye contact	Corrosive. Immediate first aid is necessary.
Ingestion	Causes burns if swallowed. Causes burning sensation in the mouth, throat and esophagus. May cause serious permanent damage.

12. Ecological information

Other ecological information

Ecotoxicity	The product is not classified as dangerous for the environment.
Mobility	Soluble in water.
Persistence and degradability	The product is biodegradable.
Bioaccumulative potential	Will not bio-accumulate.
Other adverse effects / Remarks	Alkalies cause increased pH values in the water. A high pH value harms aquatic organisms.

13. Disposal considerations

EWC waste code	EWC: 06 02 05 other bases
NORSAS	7135 Organic bases
Product classified as hazardous waste	Yes
Specify the appropriate methods of disposal	Disposed of as hazardous waste by approved contractor. The code for hazardous waste (EWC code) is indicative. The user must be able to set the correct EWC code on the intended use differs.

14. Transport information

Product name (national)	POTASSIUM HYDROXIDE SOLUTION
Dangerous goods ADR	**UN no.:** 1814 **Class:** 8 **Hazard no.:** 80

	Packing group: III **Proper shipping name:** POTASSIUM HYDROXIDE SOLUTION
Dangerous goods RID	**UN no.:** 1814 **Class:** 8 **Packing group:** III **Proper shipping name:** POTASSIUM HYDROXIDE SOLUTION
Dangerous goods IMDG	**UN no.:** 1814 **Class:** 8 **Packing group:** III **EmS:** F-A, S-B **Proper shipping name:** POTASSIUM HYDROXIDE SOLUTION
Dangerous goods ICAO/IATA	**UN no.:** 1814 **Class:** 8 **Packing group:** III **Proper shipping name:** POTASSIUM HYDROXIDE SOLUTION

15. Regulatory information

Hazard symbol

Corrosive

Composition on the label	potassium hydroxide: < 5 %
R phrases	R34 Etsende.
S phrases	S26 Får man stoffet i øynene; skyll straks grundig med store mengder vann og kontakt lege. S36/37/39 Bruk egnede verneklær, vernehansker og vernebriller/ansiktsskjerm. S45 Ved uhell eller illebefinnende er omgående legebehandling nødvendig; vis etiketten om mulig.
References (laws/regulations)	Norwegian regulation on classification and labelling of dangerous chemicals. Valid from April 22, 2009. Directive (EC) No 1907/2006 (REACH) Annex II: Safety data sheets. Administrative norms for pollution of the atmosphere , from Norwegian labour inspection authority. The Hazardous Waste Regulations Dangerous Goods regulations The Safety Data Sheet is based on information provided by the producer.

16. Other information

List of relevant R phrases (under headings 2 and 3).	R22 Harmful if swallowed. R34 Causes burns. R35 Causes severe burns.
Information which has been added, deleted or revised	Layout changed.
Supplier's notes	The information contained in this SDS must be made available to all those who handle the product.
Checking quality of information	This SDS is quality controlled by National Institute of Technology in Norway, certified according to the Quality Management System requirements specified in NS-EN ISO 9001:2000.
Responsible for safety data sheet	Halliburton AS

SIKKERHETSDATABLAD
Temblok 50

1. Identifikasjon av stoffet / produktet og av selskapet / foretaket

Utgitt dato	08.07.2008
Revisjonsdato	16.11.2010
Kjemikaliets navn	Temblok 50
Kjemikaliets bruksområde	Additiv.

Fremstiller

Firmanavn	Halliburton AS
Postadresse	Eldfiskvegen 1
Postnr.	4065
Poststed	Stavanger
Land	Norge
Telefon	51837000
Telefaks	51838383
E-post	AnneKristin.Haugan@Halliburton.com
Hjemmeside	http://www.Halliburton.com
Kontaktperson	Anne Kristin Haugan
Utarbeidet av	Teknologisk Institutt as v/ Tone S. Lyngdal
Nødtelefon	Giftinformasjonen:22 59 13 00

2. Fareidentifikasjon

Farebeskrivelse	Helse: Produktet er ikke klassifisert som helseskadelig. Brann og eksplosjon: Produktet er ikke klassifisert som brannfarlig. Miljø: Produktet er ikke klassifisert som miljøskadelig.
Andre farer	Se også avsnitt 5, 11 og 12.

3. Sammensetning /opplysning om innholdsstoffer

Komponentnavn	Identifikasjon	Klassifisering	Innhold
Natriumkarbonat	CAS-nr.: 497-19-8 EC-nr.: 207-838-8 Indeksnr.: 011-005-00-2	Xi; R36	0 - 5 %
Sitronsyre	CAS-nr.: 77-92-9 EC-nr.: 201-069-1	Xi; R41	1 - 5 %

Kolonneforklaring	CAS-nr. = Chemical Abstracts Service; EU (Einecs- eller Elincsnummer) = European inventory of Existing Commercial Chemical Substances; Ingrediensnavn = Navn iflg. stoffliste (stoffer som ikke står i stofflisten må oversettes hvis mulig). Innhold oppgitt i; %, %vkt/vkt, %vol/vkt, %vol/vol, mg/m3, ppb, ppm, vekt%, vol%
FH/FB/FM	T+ = Meget giftig, T = Giftig, C = Etsende, Xn = Helseskadelig, Xi = Irriterende, E = Eksplosiv, O = Oksiderende, F+ = Ekstremt brannfarlig, F = Meget brannfarlig, N = Miljøskadelig.
Komponentkommentarer	Balansen opp til 100 % er ikke-klassifiserte stoffer eller under grensen for å tas med i beregningen. Se seksjon 16 for forklaring av risikosetninger.

4. Førstehjelpstiltak

Generelt	I tvilstilfelle bør lege kontaktes.

Innånding	Frisk luft, ro og varme. Kontakt lege hvis ikke alt ubehag gir seg.
Hudkontakt	Fjern tilsølt tøy. Vask straks huden med såpe og vann. Kontakt lege hvis ikke alt ubehag gir seg.
Øyekontakt	Skyll straks med rikelige mengder vann i opp til 15 minutter. Fjern evt. kontaktlinser og åpne øyet godt opp. Ved lengre tids skylling, anvend lunkent vann for å unngå skade på øyet. Kontakt lege hvis ubehaget vedvarer.
Svelging	Skyll munnen grundig. Drikk et par glass vann eller melk. Fremkall ikke brekning. Kontakt lege hvis større mengde er svelget. Gi aldri væske til en bevisstløs person.

5. Tiltak ved brannslukning

Passende brannslukningsmidler	Vannspray, skum, pulver eller karbondioksid.
Brann- og eksplosjonsfarer	Produktet er ikke klassifisert som brannfarlig. Ved brann eller høy temperatur dannes: Karbonmonoksid (CO). Karbondioksid (CO_2). Nitrøse gasser (NO_x).
Personlig verneutstyr	Bruk friskluftmaske når produktet er involvert i brann. Ved rømning brukes godkjent rømningsmaske. Se forøvrig pkt 8.
Annen informasjon	Beholdere i nærheten av brann flyttes straks eller kjøles med vann.

6. Tiltak ved utilsiktet utslipp

Sikkerhetstiltak for å beskytte personell	Benytt personlig verneutstyr som angitt i pkt 8. Sørg for tilstrekkelig ventilasjon.
Sikkerhetstiltak for å beskytte ytre miljø	Forhindre utslipp til kloakk, vassdrag eller grunn.
Metoder for opprydding og rengjøring	Absorber i vermikulitt, tørr sand eller jord og fyll i beholdere. Spill samles opp i egnede beholdere og leveres til destruksjon som avfall iht. pkt. 13.

7. Håndtering og lagring

Håndtering	Bruk angitt verneutstyr. Unngå søl og kontakt med huden og øynene. Unngå danning av sprøytetåke/aerosoler. Unngå innånding av aerosoler.
Oppbevaring	Lagres på et godt ventilert sted beskyttet mot varmekilder. Lagres i tett lukket beholder.

8. Eksponeringskontroll / personlig verneutstyr

Eksponeringskontroll

Begrensning av eksponering på arbeidsplassen	Sørg for tilstrekkelig ventilasjon. Det må ikke spises, drikkes eller røykes under arbeidet. Personlig verneutstyr bør velges i henhold til CEN-standard og i samarbeid med leverandøren av personlig verneutstyr.
Åndedrettsvern	Ved utilstrekkelig ventilasjon eller hvis det er fare for innånding av damper må det brukes egnet åndedrettsvern med kombinasjonsfilter (type A2/P2).
Håndvern	Bruk vernehansker av: Naturgummi eller plast. Gjennombruddstid er ikke kjent. Det angitte hanskematerialet er foreslått etter en gjennomgang av enkeltstoffene i produktet og kjente hanskeguider
Øyevern	Benytt øyevern ved risiko for sprut.
Annet hudvern enn håndvern	Benytt hensiktsmessige verneklær for beskyttelse mot hudkontakt.
Annen informasjon	Nøddusj og mulighet for øyeskylling må finnes på arbeidsplassen. Det oppgitte verneutstyr er veiledende. Risikovurderingen (Faktisk risiko) kan føre til andre krav.

9. Fysiske og kjemiske egenskaper

Tilstandsform	Væske
Lukt	Ingen karakteristisk lukt.
Farge	Ugjennomsiktig

Løselighet i vann	Løselig.
Relativ tetthet	**Verdi:** ~ 1,01 g/cm³
pH (bruksløsning)	**Verdi:** 6

Andre fysiske og kjemiske egenskaper

Fysiske og kjemiske egenskaper	Frysepunkt: -4°C

10. Stabilitet og reaktivitet

Farlige spaltningsprodukter	Ved brann eller høy temperatur dannes: Karbonmonoksid (CO). Karbondioksid (CO_2). Nitrøse gasser (NOx).
Stabilitet	Stabil under normale temperaturforhold og anbefalt bruk.

11. Toksikologisk informasjon

Øvrige helsefareopplysninger

Innånding	Damper og sprøytetåke kan irritere luftveiene og forårsake halsirritasjon og hoste.
Hudkontakt	Langvarig kontakt kan forårsake rødhet, irritasjon og tørr hud.
Øyekontakt	Sprut kan medføre irritasjon og rødhet.
Svelging	Kan virke irriterende og fremkalle magesmerter, brekninger og diaré.

12. Miljøopplysninger

Øvrige miljøopplysninger

Økotoksisitet	Produktet er ikke klassifisert som miljøskadelig.
Mobilitet	Løselig i vann.
Persistens og nedbrytbarhet	Produktet er lett bionedbrytbart.
Bioakkumulasjonspotensial	Forventes ikke å bioakkumulere.

13. Fjerning av kjemikalieavfall

Avfallskode EAL	EAL: 16 03 06 annet organisk avfall enn det nevnt i 16 03 05
Produktet er klassifisert som farlig avfall	Nei
Egnede metoder til fjerning av kjemikaliet	Koden for avfall (EAL-kode) er veiledende. Bruker må selv angi riktig EAL-kode hvis bruksområdet avviker.

14.Transportinformasjon

Andre relevante opplysninger	Ikke farlig i forbindelse med transport under UN, IMO, ADR/RID og IATA/ICAO regler.

15. Opplysninger om lover og forskrifter

S-setninger	Sikkerhetsdatablad er tilgjengelig på anmodning fra yrkesmessige brukere.
Referanser (Lover/Forskrifter)	Forskrift om klassifisering, merking m.v. av farlige kjemikalier, fastsatt av Miljøverndepartementet og Arbeids- og inkluderingsdepartementet, 16.juli 2002, med senere endringer, gjeldende fra 22. april 2009. Forskrift om registrering, vurdering, godkjenning og begrensning av kjemikalier (REACH) Vedlegg II: Sikkerhetsdatablad. Veiledning om administrative normer for forurensning i arbeidsatmosfære fra Direktoratet for Arbeidstilsynet, den til enhver tid gjeldende utgave. Avfallsforskriften, FOR 2004-06-01 nr 930, fra Miljøverndepartementet. ADR/RID veg-/jernbanetransport av farlig gods 2009, Direktoratet for samfunnssikkerhet og beredskap. Databladet er utarbeidet med basis i opplysninger gitt av produsenten.

16. Andre opplysninger

Liste over relevante R-setninger (i seksjon 2 og 3).	R36 Irriterer øynene. R41 Fare for alvorlig øyeskade.
Viktigste kilder ved utarbeidelsen av Sikkerhetsdatabladet (ikke norske)	Sikkerhetsdatablad fra leverandør datert: 08.07.2008 , Halliburton AS
Opplysninger som er nye, slettet eller revidert	Versjon: 1(08.07.2008). Punkter endret: 1-16. Ansvarlig: Halliburton. Versjon: 2(01.02.2010). Punkter endret: 1-16. Ansvarlig: TSL. Versjon: 3(16.11.2010). Punkter endret: 1,9,16. Ansvarlig: TSL.
Leverandørens anmerkninger	Informasjonen i dette dokument skal gjøres tilgjengelig til alle som håndterer produktet.
Kvalitetssikring av informasjonen	Dette sikkerhetsdatabladet er kvalitetssikret av Teknologisk Institutt as, som er sertifisert iht. ISO 9001:2008.
Ansvarlig for Sikkerhetsdatablad	Halliburton AS

SAFETY DATA SHEET
Temblok 50

1. Identification of the substance/preparation and of the company/undertaking

Date issued	08.07.2008
Revision date	16.11.2010
Product name	Temblok 50
Use of the substance/preparation	Additive.

Producer

Company name	Halliburton AS
Postal address	Eldfiskvegen 1
Postcode	NO-4065
Place name	Stavanger
Country	Norway
Tel	+47 51837000
Fax	+47 51838383
E-mail	AnneKristin.Haugan@Halliburton.com
Website	http://www.Halliburton.com
Name of contact	Anne Kristin Haugan
Prepared by	The National Institute of Technology as, Norway by Tone S. Lyngdal

2. Hazards identification

Description of hazard	Health: The product is not classified as hazardous to health. Fire and explosion: The product is not classified as flammable. Environment: The product is not classified as harmful to the environment.
Other hazards	Refer to section 5, 11 and 12 for complementary information.

3. Composition/information on ingredients

Component name	Identification	Classification	Contents
Sodium carbonate	CAS no.: 497-19-8 EC no.: 207-838-8 Index no.: 011-005-00-2	Xi; R36	0 - 5 %
Citric acid	CAS no.: 77-92-9 EC no.: 201-069-1	Xi; R41	1 - 5 %

Column headings	CAS no. = Chemical Abstracts Service; EU (Einecs or Elincs number) = European inventory of Existing Commercial Chemical Substances; Ingredient name = Name as specified in the substance list (substances that are not included in the substance list must be translated, if possible). Contents given in; %, %wt/wt, %vol/wt, %vol/vol, mg/m3, ppb, ppm, weight%, vol%
HH/HF/HE	T+ = Very toxic, T = Toxic, C = Corrosive, Xn = Harmful, Xi = Irritating, E = Explosive, O = Oxidizing, F+ = Extremly flammable, F = Very flammable, N = Environmental hazard
Component comments	The remaining ingredients up to 100 % consist of not classified components or of components in concentrations below the limit to be included in the calculation of hazard class. See section 16 for explanation of Risk-phrases listed above.

4. First-aid measures

General	If in doubt, get medical advice.

Inhalation	Fresh air and rest. Get medical attention if any discomfort continues.
Skin contact	Remove contaminated clothing. Wash the skin immediately with soap and water. Get medical attention if any discomfort continues.
Eye contact	Immediately flush with plenty of water for up to 15 minutes. Remove any contact lenses and open eyes wide apart. By prolonged rinsing, use luke warm water to avoid damage to the eye. Contact physician if discomfort continues.
Ingestion	Rinse mouth thoroughly. Drink a few glasses of water or milk. Do not induce vomiting. Contact physician if larger quantity has been consumed. Never give liquid to an unconscious person.

5. Fire-fighting measures

Suitable extinguishing media	Water spray, foam, dry powder or carbon dioxide.
Fire and explosion hazards	The product is not classified as flammable. Fire or high temperatures create: Carbon monoxide (CO). Carbon dioxide (CO2). Nitrous gases (NOx).
Personal protective equipment	Use fresh air equipment when the product is involved in fire. In case of evacuation, an approved protection mask should be used. See also sect. 8.
Other Information	Containers close to fire should be removed immediately or cooled with water.

6. Accidental release measures

Personal precautions	Use protective equipment as referred to in section 8. Provide adequate ventilation.
Environmental precautions	Do not allow to enter into sewer, water system or soil.
Methods for cleaning	Absorb in vermiculite, dry sand or earth and place into containers. Collect in suitable containers and deliver as waste according to section 13.

7. Handling and storage

Handling	Use protective equipment as referred to in section 8. Avoid spilling, skin and eye contact. Avoid forming spray/aerosol mists. Avoid inhalation of aerosols.
Storage	Store in a well-ventilated place protected against heat sources. Store in tightly closed container.

8. Exposure controls/personal protection

Exposure controls

Occupational exposure controls	Provide adequate ventilation. Do not eat, drink or smoke during work. Personal protection equipment should be chosen according to the CEN standards and in discussion with the supplier of the personal protective equipment
Respiratory protection	In case of inadequate ventilation or risk of inhalation of vapours, use suitable respiratory equipment with combination filter (type A2/P2).
Hand protection	Use protective gloves made of: Rubber or plastic. Penetration time is not known. The recommended material of gloves is recommended after a study of the single components in the product.
Eye protection	Wear safety goggles if there is a risk of splash.
Skin protection (other than of the hands)	Wear appropriate protective clothing to protect against skin contact.
Other Information	Eye wash facilities and emergency shower must be available when handling this product. The listed protective equipment is a recommendation. A risk assessment of the actual risk may lead to other requirements.

9. Physical and chemical properties

Physical state	Fluid

Odour	No characteristic odour.
Colour	Opaque.
Solubility in water	Soluble.
Specific gravity	**Value:** ~ 1,01 g/cm³
pH (aqueous solution)	**Value:** 6

Other physical and chemical properties

Physical and chemical properties	Freezing point: -4°C

10. Stability and reactivity

Hazardous decomposition products	Fire or high temperatures create: Carbon monoxide (CO). Carbon dioxide (CO_2). Nitrous gases (NO_x).
Stability	Stable under normal temperature conditions and recommended use.

11. Toxicological information

Other information regarding health hazards

Inhalation	Vapours and spray mist may irritate throat and respiratory system and cause coughing.
Skin contact	Prolonged contact may cause redness, irritation and dry skin.
Eye contact	Splashes may irritate and cause redness.
Ingestion	May irritate and cause stomach pain, vomiting and diarrhoea.

12. Ecological information

Other ecological information

Ecotoxicity	The product is not classified as dangerous for the environment.
Mobility	Soluble in water.
Persistence and degradability	The product is easily biodegradable.
Bioaccumulative potential	Not expected to bioaccumulate.

13. Disposal considerations

EWC waste code	EWC: 16 03 06 organicwastes other than those mentioned in 16 03 05
Product classified as hazardous waste	No
Specify the appropriate methods of disposal	The waste code (EWC-Code) is intented as a guide. The code must be chosen by the user, if the use differs from the one mentioned above.

14. Transport information

Other applicable information.	Not considered as dangerous goods under UN, IMO, ADR/RID or IATA/ICAO regulations.

15. Regulatory information

S phrases	Safety Data Sheet available on request from professional users.
References (laws/regulations)	Norwegian regulation on classification and labelling of dangerous chemicals. Valid from April 22, 2009. Directive (EC) No 1907/2006 (REACH) Annex II: Safety data sheets. Administrative norms for pollution of the atmosphere , from Norwegian labour inspection authority. The Hazardous Waste (England and Wales) Regulations 2005 with amendments. Dangerous Goods regulations The Safety Data Sheet is based on information provided by the producer.

16. Other information

List of relevant R phrases (under headings 2 and 3).	R36 Irritating to eyes. R41 Risk of serious damage to eyes.
Sources of key data used to compile the safety data sheet	Suppliers Safety data sheet dated: 08.07.2008 , Halliburton AS
Information which has been added, deleted or revised	Version: 1(08.07.2008). Amendment, section: 1-16. Responsible: Halliburton. Version: 2(01.02.2010). Amendment, section: 1-16. Responsible: TSL. Version: 3(16.11.2010). Amendment, section: 1,9,16. Responsible: TSL.
Supplier's notes	The information contained in this SDS must be made available to all those who handle the product.
Checking quality of information	This SDS is quality controlled by National Institute of Technology in Norway, certified according to the Quality Management System requirements specified in ISO 9001:2008.
Responsible for safety data sheet	Halliburton AS

8.0 EMERGENCY PROCEDURES

8.1 General Information

The Tananger facility is primarily used as a maintenance and modification centre for equipment owned and operated by Halliburton. It is also a warehouse and logistics centre for Halliburton’s offshore activities on the Norwegian Continental Shelf.

Halliburton will ensure that all employees and visitors at the Tananger premises can work and move about in a safe manner.

- Normal working hours are from 0800 – 1600 hrs.
- Private cars and motorcycles are not allowed in Halliburton’s base and workshop area.
- Private cars shall be parked in the designated parking areas.
- The speed limit is 15 km/hr. in the maintenance area.
- Smoking is prohibited to dedicated areas outdoors.
- Halliburton’s equipment, tools and products shall not be removed from the area without permission from the supervisor or the warehouse manager.

Work Permits

All non-standard work (listed below) require a work permit:

- Hot work.
- Testing of operational equipment.
- Use of radioactive sources.

Spill of Oil -Chemicals

- Immediately take action to prevent the spreading of the spill.
- Ensure that the area is closed off.
- Put absorbing materials on the spill.
- Report to your supervisor and wait for further instructions.

Waste Management

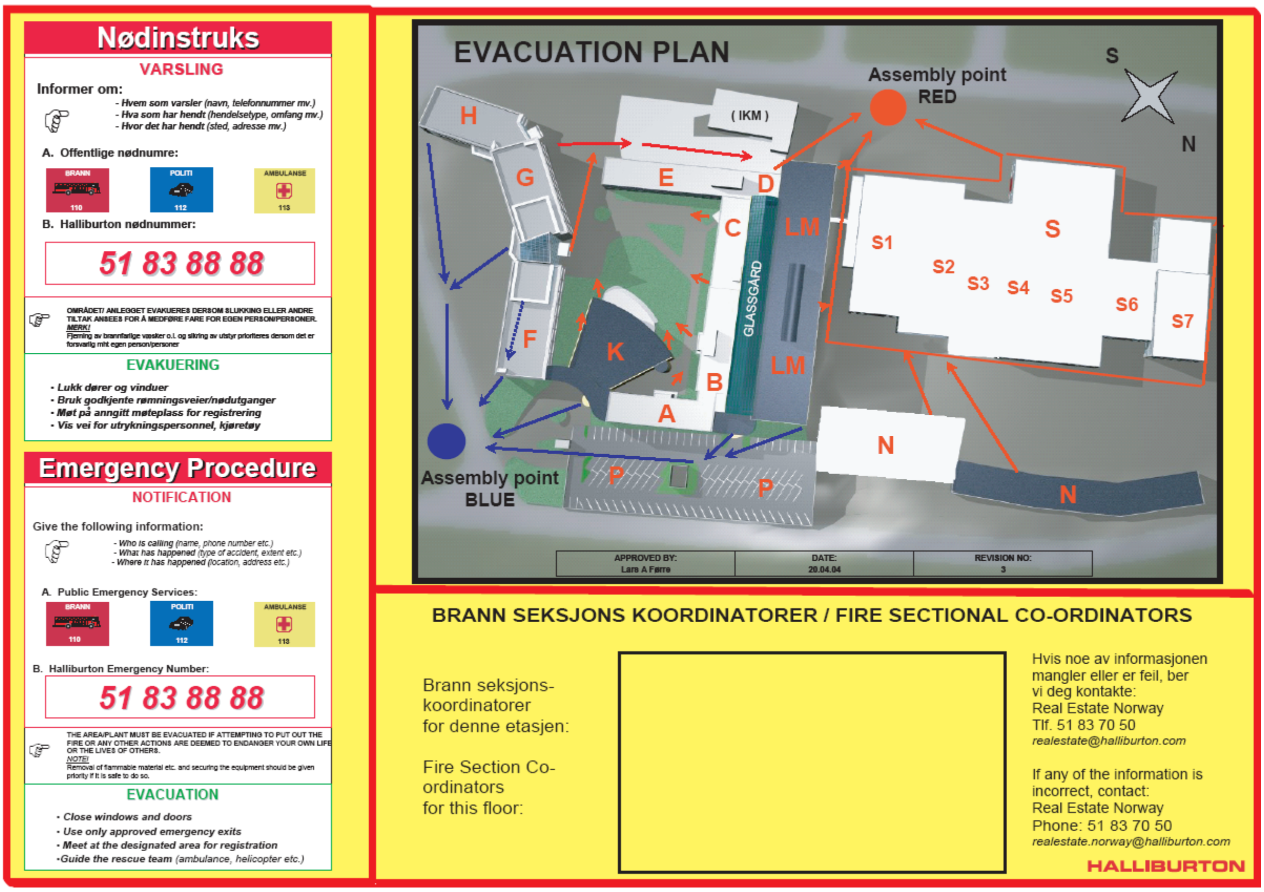
- All waste shall be sorted before it is thrown away.
- Containers are placed in various areas in the workshop. Environmental stations are located in Hall 5 and Hall 7.
- Large waste containers are placed outside.
- All visitors shall take part in Halliburton’s Waste Management Program.

Visitors

- Visitors shall register at the reception.
- Visitors shall be picked up and taken to the destination by an employee.
- Visitor shall be taken to the reception when the visit is over.
- Service personnel will be given a special service card.
- Access to service vehicles is required for the workshop area.

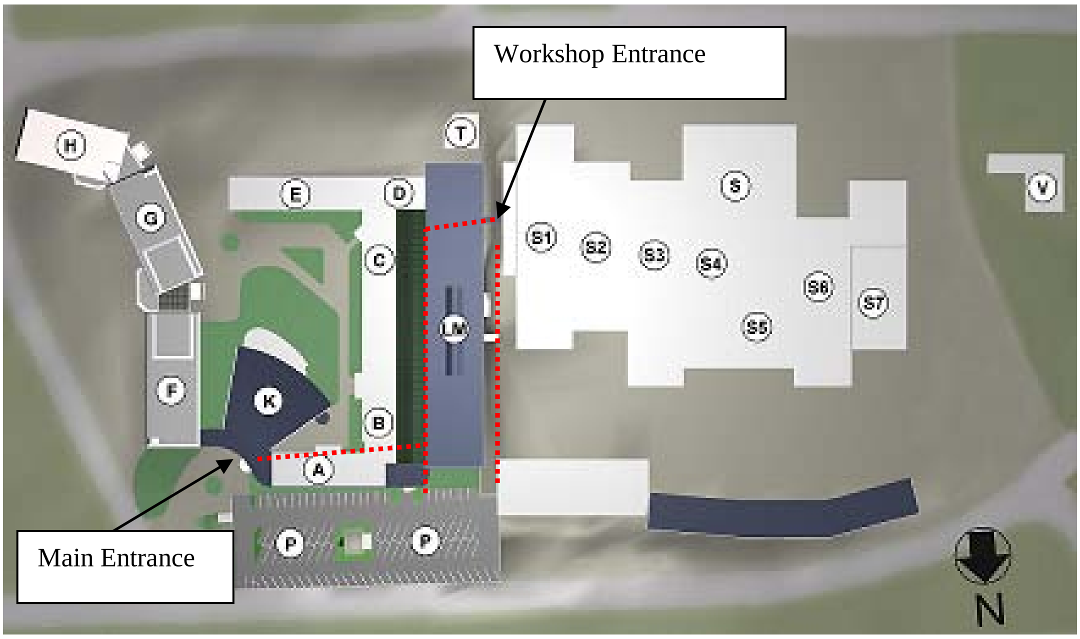
8.2 Evacuation Plan

- The evacuation plan is placed in various locations around the workshop. All visitors to the workshop should familiarise themselves with the evacuation plan.
- When an alarm sounds all personnel shall muster in the appropriate muster area.



8.3 Access and ID Cards

- Access to the workshop is though the main entrance on the 1st floor or via the bridge from the office building.
- These doors require an access card that can be collected from the main entrance.
- No other doors shall be used to access the workshop.



.... = Access route

8.4 First Aid

- If anyone needs first aid treatment, please contact the first aid team in the workshop. Posters with details of the first aid team personnel are found in the workshop.
- Stretchers are placed in Hall 1 and Hall 7.
- First aid kits are placed in each workshop.
- For serious accidents or the need for medical assistance, call **8888** immediately. (Public assistance will be called for as needed.).

REMEMBER Halliburton's **EMERGENCY CALL LINE: 8888** (manned 24 hours a day).

8.5 PPE

- All workshop personnel shall as a minimum have their own safety shoes, helmet and safety glasses.
- Safety shoes and safety glasses are mandatory indoors.
- Special work shall require suitable working clothes (PPE).
- Safety shoes/boots, safety glasses and helmet are mandatory outside the workshop.
- Other personal protective equipment shall be worn as needed/required.
- Visitors will find personal protective equipment in the room by the stairs on the east side of the building before entering the workshop. (The shoes are not work shoes).
- Personnel who do not abide by these guidelines can be reprimanded in accordance with Halliburton's work rules.
- See Personal Protective Equipment Policy BP-NO-SS-HSE-001 Reference section 8.0 herein.

9.0 PERSONAL PROTECTIVE EQUIPMENT POLICY

<table>
<tr><td colspan="2">PERSONAL PROTECTIVE EQUIPMENT/
PERSONLIG VERNEUTSTYR</td><td colspan="4">HALLIBURTON MANAGEMENT SYSTEM
HSE&SQ Norway Process</td></tr>
<tr><td>DOCUMENT NO.:
GD-NO-HAL-HSE-001</td><td>PREPARED BY:
HSE&SQ</td><td>APPROVED BY:
JORUNN SÆTRE</td><td>REVISION NO
3</td><td>DATE:
17.12.10</td><td>PAGE:
45 OF 48</td></tr>
<tr><td colspan="2">Introduction
This policy and its requirements applies to all company personnel working at, or visiting Halliburton facilities (see also 3rd party vendors and contractors, and visitors);

“Safe” Zones
“Safe” zones may be established within facilities. These must be marked clearly with yellow lines on the floor.

Relevant Regulations/Standards
Regulation 1425 -Use of Personal Protective Equipment in the Work Place – Labour Inspection publication no. 524
Halliburton HSE standards - Category 7.
Dir. 89/656/EEC - Use of PPE in the Workplace

3rd Party Vendors and Contractors
Halliburton requires that 3rd party vendors and contractors working at Halliburton facilities perform their business in accordance with Halliburton safety rules and their own safe working methods. Halliburton also requires that such parties provide and use PPE, including clothing, that affords appropriate protection against the assessed risks to which those personnel are exposed.

Visitors
Visitors are required to comply with the company’s general PPE requirements as outlined below. Sufficient quantities of hard hats, steel toed foot wear safety glasses and reflector vests should be made available for visitors. A Halliburton Supervisor or other management employee must accompany all non-Halliburton visitors, whenever they enter an area requiring the use of PPE.

Employee’s Responsibilities
Employees are obliged to use PPE in accordance with the instructions and training that they have been given, and must take all reasonable steps to care for and correctly store PPE when not in use. Where an item of PPE becomes defective or is lost, the employee must report the loss or defect immediately to his or her immediate supervisor, who will arrange replacement.</td><td colspan="4">Introduksjon
Denne policy og dens krav gjelder for alle ansatte som arbeider i eller besøker Halliburton’s område (Se også tredje part leverandører og kontraktører, og besøkende).

”Sikre” soner
“Sikre” soner kan etableres innen bygninger og områder. Disse må merkes tydelig med gule streker på gulvet.

Relevante forskrifter/standarder
Forskrift 1425 – Bruk av personlig verneutstyr på arbeidsplassen – Arbeidstilsynets publikasjon no. 524
Halliburton HSE Standards – Category 7
DIR. 89/656/EEC – BRUK AV PVU PÅ ARBEIDSPLASSEN
Tredje part leverandører og kontraktører
Halliburton krever at tredje part leverandører og kontraktører som arbeider i firmaets område, utfører sine tjenester i henhold til Halliburton’s sikkerhetsregler og deres egne metoder for sikkert arbeid. Halliburton krever også at disse parter sørger for og bruker personlig verneutstyr, inkludert klær som gir tilstrekkelig beskyttelse mot den vurderte risiko som personell er utsatt for.

Besøkende
Besøkende skal følge firmaets generelle krav til personlig verneutstyr som beskrevet under. Tilstrekkelig antall hjelmer, vernefottøy, vernebriller og refleks vester skal gjøres tilgjengelig for besøkende. En Halliburton arbeidsleder eller annet ledende personell må følge alle ikke-Halliburton besøkende, hver gang de går inn i et område som krever bruk av personlig verneutstyr.

De ansattes ansvar
De ansatte er pliktige å bruke personlig verneutstyr i henhold til instrukser og opplæring de er blitt gitt, og må ta alle forholdsregler for å lagre utstyret riktig når det ikke er i bruk. Hvis personlig verneutstyr blir ødelagt eller kommer bort, må den ansatte straks rapportere tapet eller den ødelagte delen til hans eller hennes nærmeste overordnede, som vil sørge for utskiftning.</td></tr>
</table>

Supervisor's Responsibilities The responsible supervisor shall assist in obtaining proper personal protective equipment and ensure that the issued personal protective equipment is fitted for the user. Responsible supervisor shall further ensure that relevant protective equipment for special work is available in adequate quantities; respiratory protection, filters, chemical resistant clothing, special hand protection/gloves etc.	**Lederens ansvar** Den ansvarlige leder skal hjelpe til med å skaffe riktig verneutstyr og sørge for at utstyret er tilpasset brukeren. Ansvarlig leder skal videre sørge for at relevant verneutstyr for spesielt arbeid er tilgjengelig i tilstrekkelig antall; åndedrettsvern, filter, klær som tåler kjemikalier, spesiell håndvern/hansker etc.
General PPE Requirements All offshore installations, rigs, vessels and onshore locations: ▪ Hard hat (CE approved); must be worn when outside on base area/yard, bulk/chemical plants and as required by signs posted inside base buildings; ▪ Safety glasses (CE approved) with side protection; ▪ Steel toed foot wear (CE approved) – protective shoes (with ankle protection) in leather, rubber or other material that offers the best protection against expected hazards, e.g. acids, alkalis, solvents, petroleum derivatives, drilling fluids etc; ▪ Hearing protection (CE approved) – must be readily accessible and worn when working in areas where noise levels reach or exceed 83dBA; ▪ Hearing protection during helicopter transport ▪ Shuttling – During shuttling double ear protection (ear plugs and ear muffs) must be worn during entire flight. Ear protection (ear plugs) to be in place before leaving skylobby and to be removed after arrival at destination skylobby. ▪ Flight to / from shore – Double ear protection (ear plugs and ear muffs) should be worn during the entire flight. Ear protection (ear plugs) to be in place before boarding / disembarking. ▪ Work clothing; Long sleeve, fire- retardant coveralls or long sleeve work coat and pants. Coat can be worn in the laboratory. During winter season an approved thermal jacket can be used. ▪ *When working/walking on outside areas reflector vest should be worn or other approved working clothes with reflector.* ▪ Other appropriate, PPE such as gloves (cotton, leather, PVC etc), apron, face shield, fall protection etc, needed to minimize risk.	**Generelle krav til personlig verneutstyr** Alle offshore installasjoner, rigger, fartøy og landanlegg: ▪ Hjelm (CE godkjent); må brukes ute på base området, bulk/kjemikalie anlegg og som påkrevet i henhold til skilting inne i bygningene; ▪ Vernebriller (CE godkjent) med sidebeskyttelse; ▪ Vernefottøy (CE godkjent) vernefottøy (med hælkappe) i lær, gummi eller annet materiale som gir best beskyttelse mot forventet risiko, f.eks. syrer, alkaliske stoffer, løsemidler, petroleumderivater, borevæsker etc. ▪ Hørselsvern (CE godkjent) – må være lett tilgjengelig og brukt i områder der støynivået er på eller over 83dBA; ▪ Hørselsvern under helikopter transport ▪ Skytteltrafikk – Under skytteltrafikk skal det benyttes dobbelt hørselsvern (øreplugger og hørselsvern). Hørselsvern (øreplugger) skal være på plass før avreise fra "skylobby" og fjernes etter ankomst til bestemmelsesstedet "skylobby". ▪ Fly til / fra land – Dobbelt hørselsvern (øreplugger og hørselsvern) skal brukes under hele flyturen. Hørselsvern (øreplugger) skal være på plass før ombordstigning / avstigning. ▪ Arbeidstøy; langermet, brannhemmende kjeledresser eller langermet arbeidsjakke og arbeidsbukse. På laboratoriet kan laboratoriefrakker benyttes. Om vinteren kan godkjent varmejakke benyttes. *Ved arbeid/ferdsel på uteområdene skal det benyttes refleksvest eller godkjent arbeidstøy med refleks.* ▪ Annet hensiktsmessig verneutstyr som hansker, (bomull, lær, PVC etc), forkle, ansiktsvern, fallbeskyttelse etc, nødvendig for å minske risiko.

Exceptions to the above are limited to the following: ▪ Visitors not involved in regular base - or workshop activities *are exempt from wearing long sleeve, fire- retardant coveralls or long sleeve work coat and pants.* ▪ Office or clerical work area ▪ Meeting/training room ▪ Locker room ▪ Designated safe zone or 'yellow stripe zone'. *Note: Walking to and from offices in the morning, afternoon and evening shift is exempt use of PPE.* ▪ *Approved marked smoking area is exempt use of hardhat, safety glasses and reflector vest.* **Additional PPE Requirements** There are certain work environments where the need for additional PPE has been identified due to the nature of the hazards normally encountered. These areas and the additional PPE required are as follows: <u>Bulk cement/sand/mud plants</u> Respiratory protective devices face shields and goggles are to be worn as appropriate when working in the presence of dust or fumes, as per MSDS guidelines. <u>Nitrogen loading areas</u> Pant legs must be worn on the outside of boots Heavy leather gloves (welding style gloves) <u>Equipment maintenance/repair shop</u> Chemical resistant gloves will be required when using any solvent While welding or cutting, heavy leather gloves, welding hoods <u>and</u> safety glasses are required <u>Chemical terminal</u> Chemical handling or transfer of chemicals can sometimes require the following PPE to be used: Chemical resistant gloves Chemical resistant boots Chemical resistant goggles or face shield Chemical resistant apron or coveralls Respiratory protection as per MSDS and when exposure indicates <u>Wash rack/high pressure washer/lube area</u> Hand protection. Wire mesh face shield <u>General maintenance</u> General requirements	**Unntak** til det overnevnte er begrenset til: ▪ Besøkende som ikke deltar i det ordinære arbeidet på basen eller i verkstedet er *fritatt for bruk av langermet, brannhemmende kjeledresser eller langermet arbeidsjakke og arbeidsbukse.* ▪ Kontorområder ▪ Møte- og kursrom ▪ Garderober ▪ Bestemte sikkerhetssoner eller "gul stripete sone". *Merk: Ferdsel til og fra kontorene morgen, ettermiddag og ved kveldskift er fritatt bruk av PPE.* ▪ *Godkjent oppmerket røykeområde er fritatt bruk av hjelm, vernebriller og refleks vest.*Fall protection when indicated by global HSE Standard BP-GL-BU-HSE-GHS0604, Fall Protection **Tilleggskrav til personlig verneutstyr** Der finnes arbeidsmiljø hvor behovet for ytterligere personlig verneutstyr er identifisert på grunnlag av farer som normalt oppstår. Disse områdene og kravene til ytterligere personlig verneutstyr er: <u>Bulk sement-/sand-/mudanlegg</u> Egnet åndedrettsvern, ansiktsvern og vernebriller skal brukes når det utføres arbeid i nærheten av støv eller damp, i henhold til retningslinjer gitt i HMS-datablad. <u>Nitrogen lasteområder</u> Buksen må være trukket utenpå støvlene Lærhansker (type sveisehansker) <u>Verksted for vedlikehold/reparasjon av utstyr</u> Hansker som er motstandsdyktige mot kjemikalier skal brukes ved bruk av løsemidler Ved sveising eller kutting, er det påkrevet med lærhansker, sveisemaske <u>og</u> vernebriller <u>Kjemikalievarelager</u> Håndtering eller transport av kjemikalier kan noen ganger kreve følgende personlig verneutstyr: Hansker for kjemikaliebruk Støvler for kjemikaliebruk Briller eller ansiktsskjold for kjemikaliebruk Forkle og kjeledress for kjemikaliebruk Åndedrettsvern som beskrevet i HMS-datblad og når eksponering indikerer det <u>Vaskeplass/høyttrykkspyling/smøre område</u> Håndbeskyttelse Nettingvisir <u>Generelt vedlikehold</u> Generelle krav

Warehouse General requirements Working in heights above 2 meters Fall protection when indicated by Global HSE standard BP-GL-BU-HSE-GHS0604, Fall Protection Purchase and Replacement The company will provide and replace at no cost to the employee, all personal protective equipment, provided that all the following circumstances are met: the need for PPE has been established by risk assessment performed by a technically competent person; the PPE supplied and worn meets the standard specified by the risk assessment; the employee has been instructed with regard to the purpose for which the PPE has been provided and the risks it will afford protection against; the employee has been instructed in the correct method of use and his/her responsibility with regard to the maintenance and care of the PPE; PPE requiring replacement is returned to the company on an ‘old for new’ basis; in the event that an item of PPE is lost, this loss is reported to the immediate supervisor as soon as the loss is discovered Note 1: Where possible the company will provide a choice of PPE that meets the specification, from which the employee may select his/her preference. Note 2: The Company retains the right to limit the cost of individual items of PPE, provided that specified standards of protection are met.	Varelager Generelle krav Arbeid i høyden over 2 meter Fallbeskyttelse når det er indikert av Global HSE Standard BP-GL-BU-HSE-GHS0604, Fallbeskyttelse Innkjøp og utskifting Firmaet vil skaffe og skifte ut alt personlig verneutstyr, uten kostnad for den ansatte, under forutsetning av at: behovet for personlig verneutstyr er oppstått som følge av risikovurdering utført av en teknisk kompetent person; verneutstyret møter standarden som er spesifisert av risikovurderingen; den ansatte er klar over hvilken hensikt verneutstyret har og hva det skal beskytte mot; den ansatte har fått opplæring i bruk av verneutstyret og hans/hennes ansvar med hensyn til vedlikehold og stell; personlig verneutstyr som krever utskifting blir returnert til firmaet på en “gammel for ny” basis; i tilfelle personlig verneutstyr forsvinner, at dette blir rapportert direkte til nærmeste overordnet så snart svinnet blir oppdaget Note 1: Hvis mulig, vil firmaet skaffe et utvalg av personlig verneutstyr som tilfredsstiller spesifikasjonene, og som den ansatte kan velge fra. Note 2: Firmaet forbeholder retten til å begrense kostnaden ved personlig verneutstyr, så sant de spesifiserte standarder er møtt.