PAPER ID: 2008098

Drilling Fluid Design to Meet the Ultra Deepwater Challenges

Md Imtiaz, Dewarshi Nayan, Anamitra Munsi, Kajal Nitin Seth and Manika Tiwari
Room No 234, Emerald Hostel, ISM- Dhanbad, Dhanbad 826004, Jharkhand, India

Presenting Author, E-mail: mdimtiaz1098@spemail.org

Abstract

Global Oil demand is expected to soar up in the upcoming years as consumption is anticipated to take a leap of 50% within next two decades. But easily accessible reserves are depleting at a higher rate. So the industry is venturing for deep-water reserve exploitation. To thrive with the challenges facing the industry, new rugged technologies for drilling and production are being seriously focused. Also Health, Safety and Environment (HSE) are gradually becoming the top priority. Moreover costs incurred to operate in offshore add to the worries.

This paper focuses on the problems prevailing in the ultra-deep water drilling operations and their probable solutions with some flagship technologies. Remote locations, high expenditure, environmental barriers, low fracture gradients, long risers, mud losses and encountering Gas Hydrates are the main challenges to the industry. Academia and industry are working in tandem to come up with new technologies in order to encounter these challenges. Criteria for selecting the most suitable drilling fluids to drill in deep-water are discussed. This consists of rheology optimization, hydraulics modelling, gas hydrate prediction and choosing the most perfect drilling fluid according to the lithology of sub-surface. New technologies to monitor the condition down-the-hole are highlighted.

In deep-water, selecting drilling fluids which will not undergo significant changes in properties in the well conditions for long, unpredicted periods are very important. Inhibitive fluids with less dilution and low consumption rate are of utmost need to curtail the logistics and supply problems.

Introduction

The demand of oil and gas is continuously increasing and current reserves are depleting at a very fast rate and there are not sufficient discoveries on land and shallower waters so there is a rapid increase in deep and ultra deepwater regions. These regions have been found to prospective much greater than the reserves present today on shallower regions. The definition of deepwater has changed over different geographic and chronological conditions. Deep water for water depth greater than 400-500 m and ultra deepwater for water depth greater than 1500-1700 m.

Deepwater drilling poses various unique problems while drilling. From the drilling fluid point of view various problems that are encountered are

- Large circulating mud volumes
- Low mud temperature in riser and pits
- Hole and riser cleaning
- Gas hydrate risk

Gas-hydrate formation during deepwater offshore drilling and production is a well-recognized operational hazard. In water depths greater than 1,000 ft. at the sea bed conditions the pressure and temperature becomes favourable for the formation of gas hydrates which hampers the flow and proper circulation of fluid in the system. If high enough hydrostatic present in the mud line then the tendency to form gas hydrates in BOP stack, choke and kill lines during drilling operations. At extreme water depth and low temperatures the thermodynamic inhibitors are not able to prevent hydrate formations. Kinetic inhibitors and crystal modifiers are to be used in these situations to ensure the suppression of hydrates and reassure flow in the system.

Drilling Fluid Design for Deepwater Drilling

Different drilling fluid systems when are analyzed for their hydrate formation tendency the hydrate – phase equilibrium was most significantly affected by the amount of salt and bentonite present relative to any other component present in the system. The different components that were present in the mud systems were bentonite, thinner, caustic, barite, salt, xantham gum, partially hydrolyzed polyacrylamide (PHPA), oil, drill solids, and methanol etc. Among these components PHPA and bentonite generally promote the formation of gas hydrates because these compounds keep them stable at elevated temperatures.

Low Dosage gas Hydrate inhibitors are divided into two categories; Kinetic hydrate inhibitor and antiangglomerants. There are two types of hydrate prevention methods: thermodynamic and kinetic.

Thermodynamic methods employ pressure and/or temperature control or additives like salts, alcohols, or glycols. A common thread of thermodynamic hydrate control is that the water/gas system is kept outside the hydrate envelope. Hydrates will never form in a thermodynamically prevented system. Kinetic inhibitors and antiangglomerants called Low Dosage Hydrate Inhibitors (LDHI) allow producers or operators to pump and process the gas/water at hydrate conditions without forming any hydrate blockage.

Oil based mud are also not very suitable for hydrate suppressions. They form hydrates but show a limited inhibition typically in range of (5 to 10 °F). However a volume water can rapidly form hydrates in about 20 minutes which would take about an hour for completions in pure water based systems because of high solubility of gas in oil and water as dispersed phase provides greater surface area for the hydrates formation. Inhibition in oil based drilling fluids is based on the dispersed water content present in the mud. Water based polypropylene glycols are also suggested as the replacement for the oil based drilling fluids. They provide lubricity, can maintain borehole stability and can suppress the hydrate formations. A 30 %by weight solution of a proprietary polypropylene glycol showed at 5.6 °F more suppression compared to 20% by wt NaCl/PHPA drilling fluid. The drilling fluid systems can provide additional advantages like good hole cleaning, high penetration rates etc

Some frilling fluid has been design and tested are shown in table: 1, list various concentrations of different chemicals and chemical mixtures which when used in the various different concentrations would bring different impact on the hydration suppression tendency which determines the reduction in hydrocarbon equilibrium temperature caused by the addition of inhibitors in the fluid system. Synthetic fluids with about 30% by wt Cacl2 in internal phase did not form any hydrates at about 63.7 °F.Fluid formed of 23.8% by wt Na formate and 28.6% by wt ethylene glycol exhibited similar properties. Decrease in the concentration of the salt i.e. CaCl2 however causes the hydrates to form. NaBr in 23 % by wt and ethylene glycol in 25 % by wt showed the degree of suppression of about 45.4 °F. Solution of 20 wt % NaCl and 10 wt % ethylene glycol showed a degree of suppression 39.4 F. Among the different formulations for the mud highest degree of hydrate suppression was showed by mixture of 5 wt % KCl, 15 wt % NaCl and 10 wt % Ethylene glycol which was 32.1 F. When ethylene glycol was replaced by polyglycol the temperature was reduced to 29.4 F. Without the glycol it reduced to 25.5 F because glycol has hydroxyl group forms hydrogen bonds with water molecules and does not allow water to participate in hydrate formation. Sea water showed degree of hydrate suppression only 2.7 F.

*** Table: 1 is provided by Baker Hughes**

Drilling Fluid	ΔT (F)
80:20 Syn-Teq with 30% CaCl2	No Formation
80:20 Syn-Teq mud with 30% CaCl2	No Formation
23.8 wt% Na-formate+28.6 wt% EG	No Formation
23 wt% NaBr +25 wt% EG	45.4
20 wt% NaCl +10 wt% EG	39.4
40 wt% Na-formate	39.2
20 wt% NaCl +10 wt% Aqua-Col™ S	36.6
20 wt% NaCl +20 wt% Geo-Meg D207	36.5
20 wt% NaCl +10 wt% HF-100N	36.4
5 wt% KCl +15 wt% NaCl +10 wt% EG mud	32.1
20 wt% Na-formate110 wt% Aqua-Col™S	30.2
10 wt% KCl +10 wt% NaCl +10 wt% Aqua-Col™S	30
15 wt% KCl +30 wt% HF-100N	29.9
5 wt% KCl +15 wt% NaCl +10 wt% Aqua-Col™ mud	29.4
20 wt% NaCl	25.2
5 wt% KCl +15 wt% NaCl mud	25
40 wt% Na-formate mud	22.5
10 wt% KCl +10 wt% NaCl	21.1
80/20 synthetic mud w/15 wt% CaCl2	19.7
20 wt% KCl	17.6
10 wt% KCl +10 wt% HF-100N	13.1
10 wt% KCl +10 wt% Aqua-Col™S	11.5
21 wt% ammonium calcium nitrate	7
9.33 wt% 9.33% LIGCO ® (lignite) with 1.86% NaCH	4.7
SeaWater	2.7

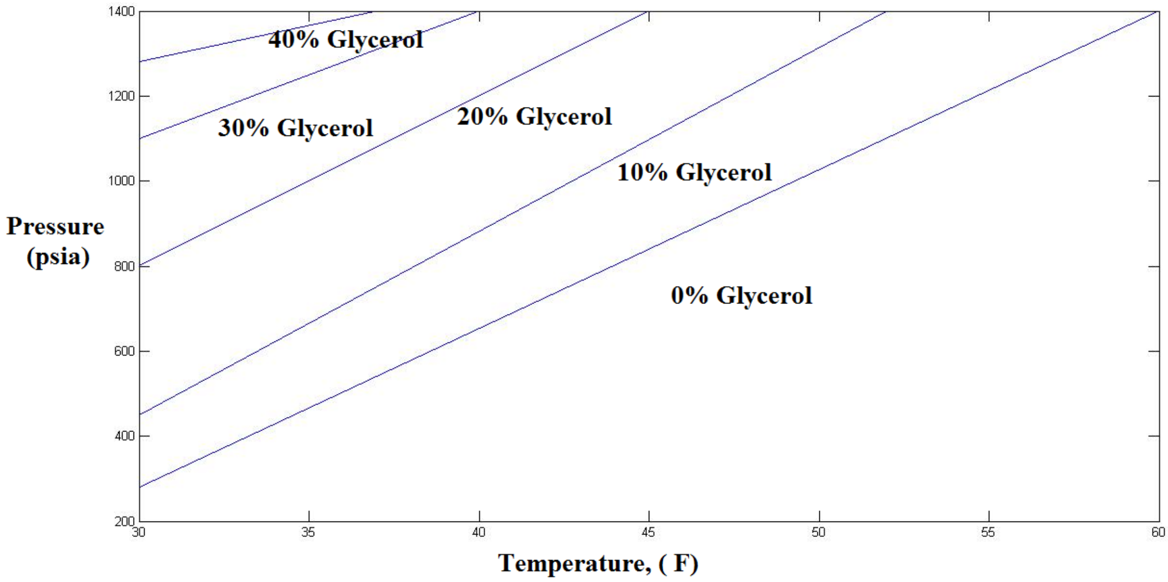
Table : 1

Gas Hydrate Simulation

For the gas-hydrate simulation, the gas composition listed in Table 2 was used. Figure 1*, Figure 2*, Figure 3* show the impact of salt/glycerol mixtures of 20 wt%, 10%, 2.5% sodium chloride respectively. In each case, the sodium chloride is mixed with concentrations of glycerol ranging from 0 to 40 wt %. It is obvious that such combinations of inhibitors suppress hydrate formation much more favourably than individual inhibitors. Similar results can be expected for other systems composed of alcohols·(e.g., methanol, ethanol, and glycol) and salt (e.g., sodium bromide and calcium chloride).

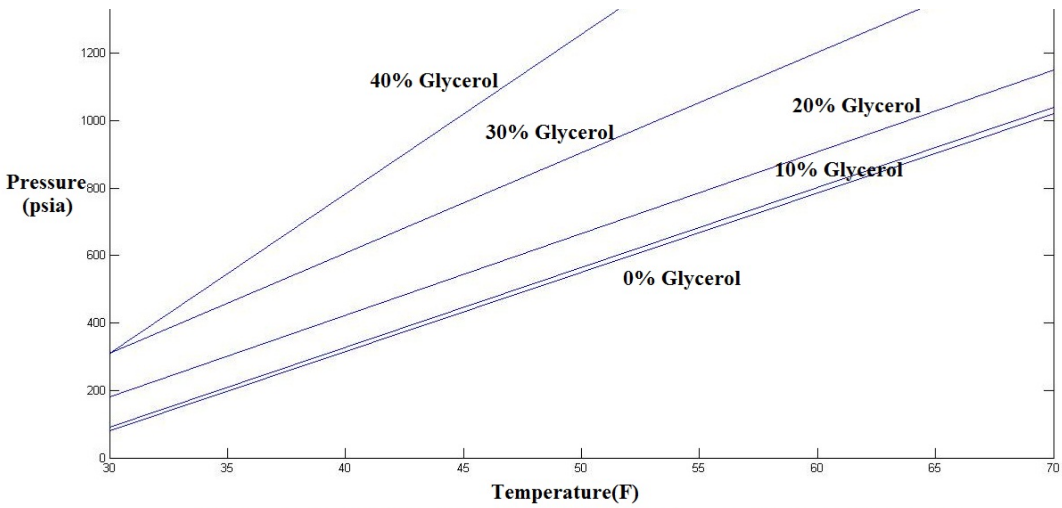
Component	Concentration (mol %)
Methane	87.29
Iso-Butane	0.49
n-pentane	0.39
ethane	7.55
n-butane	0.79
propane	3.09
nitrogen	0.4

Table :2



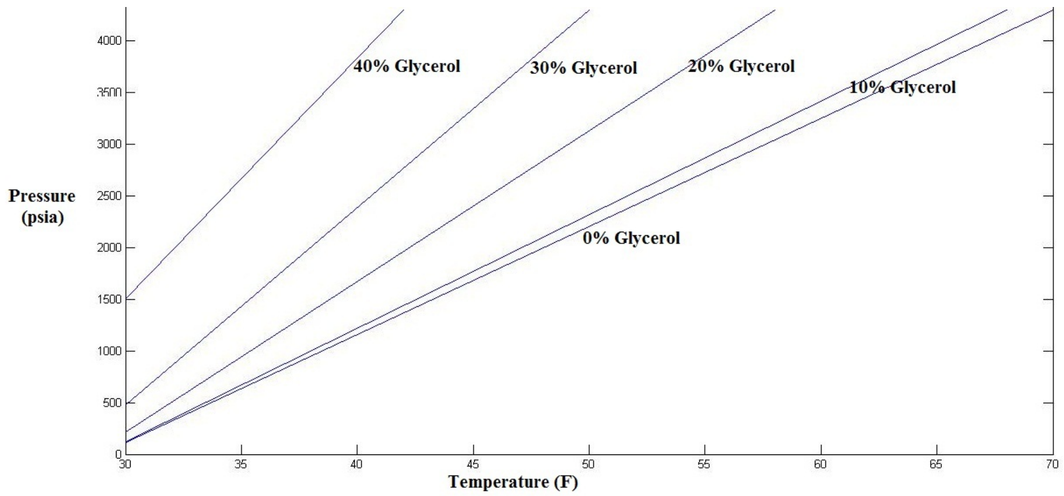
Gas-hydrate inhibition of glycerol in 20 wt% NaCI brine, on addition of glycerol.

Figure : 1



Gas-hydrate inhibition in 10 wt% NaCI brine, on addition of glycerol.

Figure : 3



Gas-hydrate inhibition In 2.5 wt% NaCI brine, on addition of glycerol.

Figure : 2

Conclusion

The glycols are considerably less effective inhibitors, on weight basis, than the salts. However, a greater degree of suppression can be achieved by using mixtures of salts and glycols. Among the tested glycols, ethylene glycol showed the best performance compared to Aqua-Col™S, Geo-Meo™ D207, and HP-100N™. The most common drilling fluids used in deepwater drilling are the 20 to 23 wt% NaCl/polymer systems. On a weight basis, NaCl is the most effective hydrate inhibitor, followed by KCl, CaCl2, NaBr, Na-formate, and calcium nitrate. Ethylene glycol had the best performance among the glycols tested A drilling-fluid formulation was developed having a maximum hydrate suppression of 32.1 F. This drilling fluid was formulated from 5 wt% KCl 15 wt% NaCl 10 wt% ethylene glycol.

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***Figure: 1, 2, 3 is measured at Core Laboratories**