CONSIDERATIONS REGARDING THE MANAGEMENT OF ECOLOGICAL DRILLING FLUIDS USED FOR OFFSHORE DRILLING

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***Abstract**: The exploration and exploitation of oil reserves in areas with deep and ultra-deep water is carried out with huge risks and costs. Increasing the depth of water brings different challenges in the wells to be drilled. Unlike their continental shelf and onshore counterparts, deep waters are characterized by young depositional formations that lead to a narrow window between pore pressures and fracture gradient. Low fracture gradients can necessitate lighter drilling fluids and lighter cement slurry, while rising pore pressures can often upset the delicate fracture gradient, destabilizing the wellbore. The paper aims to identify and analyze the critical issues related to the drilling fluid used for offshore drilling in deepwater areas.*

***Keywords:** offshore drilling, ecological drilling fluids, higher depths*

1. Introduction

Offshore drilling specifications have, as a special challenge, the placing of the drilling rig on a working deck which is not affected by the waves. All constructions made so far are the result of research carried out, of practical tests with optimal technical and economic results.

An offshore drilling platform is a hydrotechnical construction intended to support needed equipment for the drilling in the offshore oilfields and which, while in function, has its legs fixed on the seabed or floats on the surface. The platform is composed of two main parts:

- the basic structure which allows the platform, according to its type, to be connected to the seabed, to sit on the seabed or to float;
- the platform body, secured to or supported by the base structure, on which the rig equipment and the auxiliary equipment are installed. [1]

The offshore rigs, built in a variety of types and variants of construction, are usually classified by the possibility for changing their location during their working time. Thus there are:

- islands for drilling;
- stationary offshore rigs : fixed and gravity;
- mobile rigs: Submersible jack ups, drillships.

The narrow pressure margin while drilling, arising from the smaller tolerance between pore pressure and fracture pressure gradient, is, by far, one of the most recognized deepwater challenges. Unlike their continental shelf and onshore counterparts, deep waters are characterized by young depositional formations that lead to a narrow window between pore pressures and fracture gradient. Low fracture gradients can necessitate lighter drilling fluids and lighter cement slurry, while rising pore pressures can often upset the delicate fracture gradient, destabilizing the wellbore and jeopardizing the section, if not the entire well. Basically, fracture pressure gradient is defined as the pressure gradient that will cause fracture of the formation. In other words, if the formation is exposed to a pressure higher than its fracture pressure limit, the formation will break, often resulting in severe lost circulation. Thus, the drilling process in deep water and ultra deep water, there are a number of economic and operational complications. It requires a large number of casings, but must also be blamed for the inability to reach total depth and formation fracturing operations during eruptive manifestation.

The practical implication is severe restrictions on one or more of the following variables: fluid type, fluid density, circulating rates, and trip speeds. Given that the pressure requirements have to be met while achieving efficient hole cleaning and operationally acceptable trip rates, designing a well plan in these circumstances can be a difficult action. For example, drill cuttings must be removed from the borehole, at the same time keeping the drilling fluid density managed to keep the borehole open without fracturing the formation. Further, circulation must be maintained even when fluid is lost to the formation. A number of direct and indirect methods are employed for estimating the fracture pressure gradient. Direct methods rely on measuring the pressure required to fracture the rock and the pressure required to propagate the resulting fracture. These methods are generally based on a leak off test (LOT), which uses mud to pressurize the well until formation fracture is initiated. An LOT is a normal procedure in vertical wildcat wells where the formation fracture gradient is not well established.

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While highly reactive shale formations are encountered in a variety of drilling environments, they are more or less innate to the young offshore sedimentary basins. Dealing with highly reactive shales requires both chemical and mechanical solutions to avoid wellbore instability, which is blamed for nearly half of all non productive time. Clearly, considering the exorbitant costs associated with deepwater, the resulting problems of wellbore instability, including severe lost circulation, stuck pipe, flows, kicks, sloughing shales and even wellbore collapse, have made dealing with reactive shales a hotly debated issue in the literature

Perhaps no single distinction of the deepwater poses more direct and indirect risks to drilling fluid performance than cold water temperatures that decrease in proportion with increasing depth. Surveys in the more tepid Gulf of Mexico and West Africa have revealed mid mud line water temperatures of less than 40°F (4.4°C) at 4,000 ft - 1219m. Conversely, in the deep waters of the outer Norwegian North Sea, temperatures at the mud line can dip to as low as -4°C. Ironically, although water temperature at the mud line in the North Sea is lower, flowline temperatures are higher than 60° so 65°F (16° to 18°C) than those in the Gulf of Mexico that average 55° to 65°F (13° to 18°C).

Basically, flowline temperatures are a function of how long the return mud in the riser has been exposed to the cold water. Accordingly, the lower flowline temperature in the Gulf of Mexico is directly related to the deeper water depth. Deepwater wells in the Gulf of Mexico vary from 1500 ft to more than 7700 ft (457 to 2347 m), while the maximum water depth in the North Sea is about 1097 m. Elsewhere, Malaysia considers deepwater wells as those drilled in waters between 762 to 1067 m, while prospective deepwater wells off New Zealand are drilled in more than 2134 m (7000 ft) of water.

The drilling fluid becomes an integrat element when planning a drilling location identified as a risk area of shallow water (gas kicks / water). Usually in these areas, wells are drilled without returns on the surface, using seawater and volumes of bentonite pills until the information about pressure during drilling (PWD) or other monitoring equipment installation confirms the risks. In this situation, there is a comon practice to utilize brine or drilling fluid with high mud weight, prepared and having 150 kg/m^3 up to 200 kg/m^3 than normal mud weights. Before the displacemnt , the drilling fluids are reduced in denisty with seawater until the mud weight is sufficient to control the formations pressure and fluids pressure, also during drilling and while running the casing.[2]

2. Riserless Drilling

As it is well known, the design and implementation of deepwater wells, obviously differs from wells in much lower water. The differences start at the upper part of the hole, where the practice has shown to be drilled without riser, usually to a conductor depth, and using sea water based fluids that are discharged to the seabed. The reason for drilling riserless, in the first part,is due to superficial surface formations with very low fracture resistance.

In the riserless drilling operation, the structural conductor in normal mode is run through washing process, using the weight of the casing and its rotation. With this process, the casing is pushed at the required depth for ensuring the upcoming frictions, sufficient to support well casing strings together with the wellhead and the BOP's stack.

In some areas, the presence of some stones on the sea floor do not allow the casing to be run by washing, while in other parts of the world, the information about field strength is limited. In these cases, the operator companies can choose to run the casing and set the structural casing by drilling at the required depth and then run the casing and cementing job. Once the structural casing is fixed at the right depth, the well will be drilled riserless until to the next casing point, depending on the local pore pressures. As we have mentioned, the drilling fluid – the seawater is used for this section due to the fact that it is accepted from an environmental point of view and is found in abundance. By pumping and dumping the drilling fluid continuously on the seabed, huge cuttings amounts will accumulate around the wellhead but can be spread usually with ease.

After the section without riser was drilled, the conductor casing is run in the open hole. Due to the high diameter of the casing and to the involved cement volumes, these casings are cemented with the inner string device. Once the casing was set and cemented, the BOP's stack and the riser are run and set on top of the wellhead. Again, the drilling will go through surface formations until it reaches a sufficient depth for setting conductor casing. Appropriate depth is defined as that on which the formations are considered to be strong enough to withstand the drilling fluid column, after the Bop's stack and the riser casing was set. Generally, formations begin to be more resistant after the conductor casing was set. One of the main advantages of the riserless drilling is the cost efficiency, due to the fact that seawater, which is relative without cost, is used as drilling fluid in an open circulation system that simply has the returns of the cuttings on the seabed.

The tools for opening hole logs, are recorded equipments for using during drilling (LWD) and also for measuring while drilling (MWD), this tools are recommended during drilling the riserless section. Using an investigation equipment, will ensure a real time interpretation on the formations drilled. Other equipment, which is recommended when drilling the riserless section, is power while drilling tool (PWD).The PWD tool provides a constant read-out of the actual pressures in the hole while drilling. PWD tools also measure the ECD of the fluid in the annulus. This knowledge allows the operator to avoid exceeding the estimated formation fracture pressure. [1, 3]

The ROV is an important tool while drilling the riserless section. The ROV camera is focused on the wellhead while drilling riserless and the images are transmitted to the rig where they are monitored by the shallow hazard expert and the drilling foreman. The ROV application can be supplemented with various accessories, such as devices for checking the pH or closing devices for valves of the annular after the cementing operation. This equipment, ROV, can be equipped to pump corrosion inhibitors and hydrates inhibitors at the wellhead.

The basics guide can be permanent or temporary, but it is run with the same assembly. Such a guide device will be set when the structural casing is also run, the basic guide is fixed up to the BOP's. This basic guide assists in centering the BOP stack above of wellhead. This operation will prevent the huge horizontal movement of the BOP's stacks, while running in the hole or pulling out of the hole the drilling strings, which can affect the wellhead connections.

The most common method for riserless drilling or washing the structural conductor (36 in or 30 in) is using mud motors with high-speed and low-torque.The mud motor in general is made of its 9 5/8 in body with attached 26-in. stabilizer blades and a 26-in bit.The jetting process toghether with weight of the casing, easily penetrates the soft surface formations. It is very important that this structural conductor stay as close to vertical as possible while advancing through sediments. The wellhead connectors have an operating limit angle and most manufacturers set limits of 1 degree or less, for the verticality of the conductor. If the angle exceeds this limit, the contractor must approve the exception or another conductor must be run again through the washing process. Measuring devices are provided by the structural conductor before the conductor being introduced to bottom. Figure 1 shows the way to fix the guide base using ROV's guide.

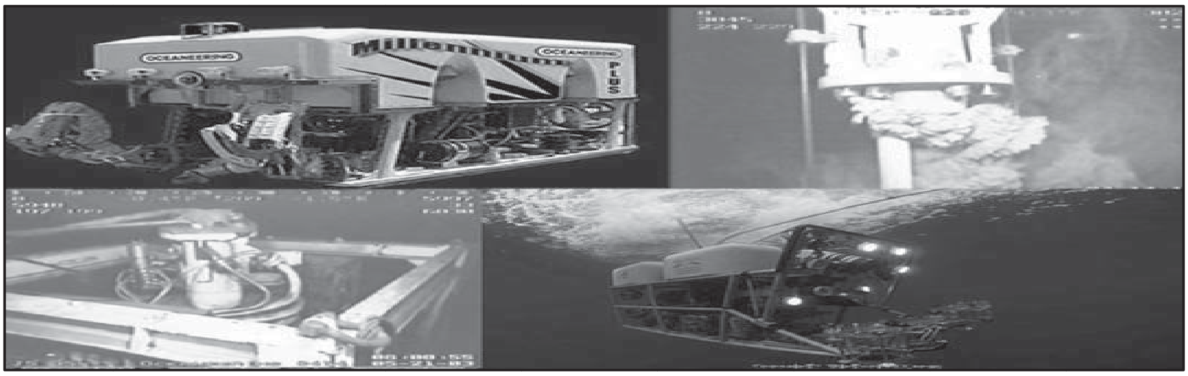

Fig.1. *Setting the base guide using the ROV*

It is very important to control weight of the casing which is applied during the washing operation, so to ensure that the conductor will remain vertical and prevent bending of the drill strings. A maximum of 80% of the weight of the column, applied during the washing operation, will be held at the neutral point of the drill string, while keeping vertical structural conductor and preventing buckling of the drill string. While the conductor casing continues to advance into the sediments, during the washing operation, the friction factor will continuu to increase as the area between the conductor and the contact surface of the formation increase. If the friction factor increased to a point where the conductor will continue to advance in formation and 80% of the limit is reached, the conductor will be raised to reduce friction factor and allow further advancement. During the washing process, the laterals forces absorb much of the weight of the casing. The laterals forces consisting of friction factor of the earth, which resist at the downword movement of the casing.The structural conductor is made by a predetermined length,based on casing weight and wellhead equipment, necessary for well construction and the anticipated friction factor.This structural conductor is run for allowing a sticking up with 3-5 m (10 -15 feet).

The washing process involves pumping seawater through the drill bit. The drill bit is rotated by the mud motor, this wash the formation which is located below of the structural conductor and allowing the casing to gradually advance as solids are removed and circulated over structural conductor, where cuttings is deposited on the seabed.

If the friction factor increases before reaching the proposed advancing, it is important to reduce friction to allow the casing to go down to the final depth. Increasing the friction factor is controlled by tripping and / or pumping prehidratated bentonite pills.First method is to pick up the structural conductor for reducing the friction factor. The measure of lifting must be kept to a minimum to minimize the disruption of soil around the casing. If the structural conductor will not continue to go down after this pick up, a bentonite pill can be pumped on bottom. During pumping the pill the casing should be moved, doing so the friction factor will decrease.

The wetting time is the time expected after washing to allow the friction factor to be restored. Wetting time may vary depending on specific preferences of the operator company and by the drilling program, it is generally considered for two to six hours to fully restore friction factor.

Some operators will use a drill-ahead tool, such as the Cam Actuated Drilling Assembly (CADA), to eliminate the need for a trip to pick up the drilling assembly to begin making new hole, immediately after the structural conductor develop enough friction factor. Sometimes the soak timp is suplimentar taken for allowing the friction factor to build back and the earth to come back, because the drilling operation will begin immediately below structural casing and will remove from his resistance. There have been instances in which the drilling started to early and the structural conductor has moved down. Drilling operation had to stop and the structural conductor pulled out of hole and washed again or a new structural conductor was run. Some operators choose to wash structural conductor with a washer assembly and then be extracted from the hole and form a normal drilling assembly.

With a remoted operated vehicles or CADA equipment, the drilling string is suspended inside of the structural conductor. The bottom hol assembly is released when the friction factor is sufficient and the casing will remain in place without filing trend. As we mentioned whend CADA tool isn't in place, it is necessary a trip for the bottom hole assembly during the soak time. [1,3]

Exceptional technical requirements associated with the technologies of drilling fluid systems for deepwater environment, have been well documented in the speciality literature. Regardless of location, the new wells in water depths exceeding 458m (1500 ft) presents a range of separate issues to be addressed in the initial planning stage and constantly monitored during the drilling operation. If this are not checked, this phenomenon causing problems, make serious safety risks, economic and environment and may even endangers the project itself. Among the most dangerous aspects of drilling fluid in deepwater operations, are constant risk of losing circulation, the low pores pressure compared by differentials of fracture gradient, cleaning improper hole cleaning during drilling trough gumbo shale sections, unique considerations in terms of logistics and environmental, wellbore stability, fluid density and potentially disastrous formation of gas hydrates in the cold water, among others.

3. Cold temperature impact

The selection of inhibitive drilling fluids with low dilution and consumption rates are of considerable benefit, not only for minimizing logistics and supply issues, but improving solids control efficiency as well. With typical riser volumes from 160 to 500 m^3 (1,000 to 3,000 bbl) and circulating volumes from 400 to 800 m3 (2,500 to 5,000 bbl), any requirement for massive dilution volumes must be avoided. Consequently, solids control efficiency is paramount to controlling low gravity solids (LGS) and minimizing dilution volume. Furthermore, solids control considerations differ between water-based and synthetic-based drilling fluids, thereby requiring different courses of action depending on the mud selected.

While the definition and causes of what constitutes the loss of whole mud to a formation differ little between offshore and land applications, in deepwater drilling the incidents are more prevalent and the ramifications potentially much more severe. Lost-circulation problems in deepwater are exacerbated by low fracture gradients, tight casing/hole clearances, and muds made denser and more viscous by low fluid temperatures. In ultra-deepwater, shallow formations cannot support the weight of the mud column and may prevent use of a riser.

In deepwater operations , the lost circulations effect can be profound after the riser was set. So, many operators will choose to drill without riser if posibil.One of the main concerns about losing circulation in deepwater drilling, is the potential for gas hydrate formation. A sudden drop inthe hydrostatic pressure due to loss of circulation of drilling fluid may allow natural gas to penetrate rapidly into the borehole. Subsequently, the gas can migrate upward direction in the borehole where the low temperature at the bottom allows water to form hydrates in the blowout preventer.[3]

4. Gas Hydrates

The combination of extremely cold water at the mud line and hydrostatic pressures in the 1600 psi range are ideal for the formation of extremely dangerous gas hydrates. If allowed to form unabated, gas hydrates can seriously threaten the drilling process by plugging the upper annulus, the subsea BOP stacks and choke/kill lines.Given the right combination of temperature, pressure, time, gas and water, hydrates can form quickly. At one atmosphere of pressure (14.7 psi), fresh water freezes at 0^0 C (32 deg F). The addition of compounds such as ethylene glycol (antifreeze) or salts can lower the temperature where ice commences to form. The addition of other compounds (mostly gases) under high pressure can raise the "freezing" temperature of water higher than 21^0C (70^0F). Hydrate zones and the associated gas and water sands usually can be identified from shallow seismic data before drilling commences. Seismic velocities are as much as three times faster in hydrates than in water saturated or gas bearing formations. These velocities produce a characteristic "bright spot" on seismic. Immediately beneath the hydrates the velocities decrease especially in gas zones, creating a clear marker at the base of the hydrates, called a "Bottom Simulating Reflector" or "BSR," which is illustrated in Fig.2.

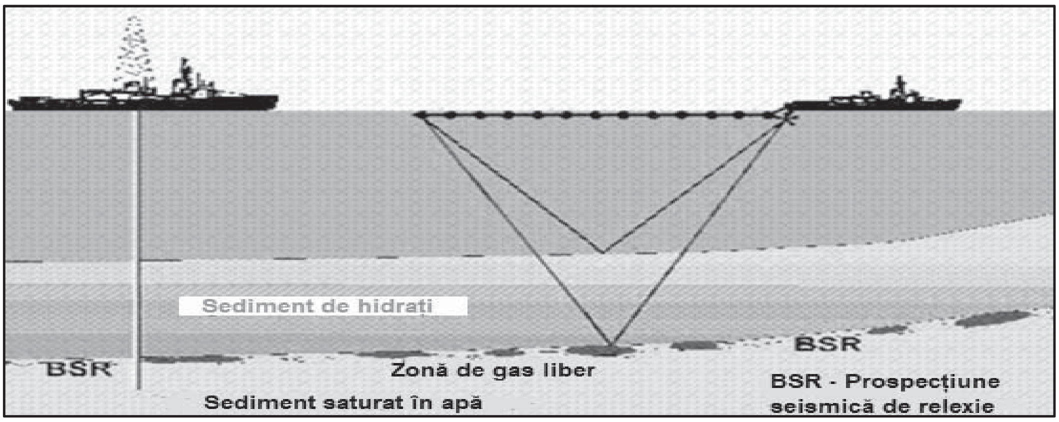

Fig.2. *Shallow seismic hydrate survey*

5. Hydrate Inhibitive Drilling Fluids

When discussing drilling fluid treatments to mitigate the impact of hydrate formation, the operative word is inhibition, which does not necessarily mean prevention. Rather, inhibition refers to the suppression of hydrate formation temperature to a level where hydrates will not form at the anticipated temperature and pressures. Further, inhibition is used to indicate that the mud has been treated to delay hydrate formation or treated to keep the hydrates from forming a solid mass or plug when they form.

The application of the various types of hydrate inhibitors can be explained in terms of a normal deep water drilling operation. The coldest temperature the mud will be exposed to will be at the mud line. Hydrates will not be a problem during any operation, unless gas is present. When a kick is taken, the gas cut mud has to cool to a temperature where hydrates will form under the hydrostatic pressure or hydrostatic plus shut-in pressure. After the mud has cooled to a temperature favorable for hydrate formation, a period of time up to several hours will elapse before there will be any indication of hydrates forming. During this time, water is crystallizing (nucleation) around gas and hydrocarbon molecules to form hydrate crystals. Given sufficient time, the hydrate crystals will grow together or agglomerate and form a mass or plug.

6. Drilling fluids water based

When drilling in deepwater with water based muds where hydrate formation is a potential problem, limiting the mud additives to those that do not actively promote hydrate formation will not provide sufficient protection. To provide a desirable level of inhibition, the mud must be formulated to prevent hydrate formation at the lowest temperature and highest pressure it will be exposed to at this lowest temperature point. Unfortunately, it is not always possible to avoid or even know every additive that will promote and stabilize hydrates to some degree. Even products as common as clay, lignite, lignosulfonate, and polymers can promote and stabilize gas hydrates. To make matters worse, the activity of many additives, such as glycol and other thermodynamic inhibitors, is concentration-dependent. Adequate hydrate inhibition using glycols may require concentrations of 30 to 40% by volume of the liquid phase. The dilemma is that the low molecular weight glycol is more effective at suppressing hydrate formation than a higher molecular weight glycol. Unfortunately, low molecular weight glycols are more toxic than higher weight glycols as is alcohol, which is both toxic and corrosive, making it rarely recommended as a hydrate inhibitor. Salt and glycol can be used together if the glycol does not "cloud out." The glycol must remain in solution to act as a hydrate inhibitor.

On a pound for pound basis, sodium chloride (NaCl) is the most efficient salt for suppressing hydrate formation. Hydrate inhibition with sodium chloride requires chloride concentrations ranging from 100,000 mg/l to saturation. Because of their solubility, other salts can deliver higher inhibitive characteristics, but have limited applications in drilling fluids because of their effect on rheology. Since the solubility of salts decreases with temperature, salt-based inhibition must be based on its solubility at the mud line temperature.

The mud line temperature and the fracture gradient at the casing shoe represents the most extreme case of pressure and temperature for hydrate formation that will be encountered before the next casing string is set. If the temperature where hydrates will form can be suppressed a few degrees below the anticipated worst case well conditions, it should be possible to shut the well in for an extended period if necessary. It is important to note that the maximum level of hydrate inhibition that may be needed can be predicted as soon as the fracture gradient has been determined. [3]

7. Combating barite sag

Hole cleaning and barite sag are related in concept and often discussed together, as they are here. More often than not, actions taken to enhance one are concurrently beneficial to the other, even though the actions may be at odds with other concerns. For example:

- Flow rates and rheological properties required to minimize hole-cleaning and barite-sag problems can cause excessive pressures while drilling, tripping, and running casing;
- Efforts to offset low-temperature effects on rheology can exacerbate barite sag.

Today, many field procedures in use for hole cleaning and barite sag are the results of extensive flow-loop testing by the industry and correlations with field results. For hole cleaning, analytical models developed over the years have been complemented by practical field guidelines. For barite sag, the major hurdle was overcome when the issues was identified as a dynamic settling problem. Later Joint Industry Projects (JIP) has reinforced the major roles of pipe rotation, pipe eccentricity, angle, and sag-bed characteristics. [3]

8. Environmental solutions

It goes without saying, but the geographic expansion of deepwater drilling activities coupled with ever-increasingly distances from shore has made environmental issues even more predominant.Many of those issues center squarely on the drilling, reservoir drill-in and completion fluids used in the deep and ultra-deepwater environments. Obviously, the toxicity of fluids used in deepwater E&P activities is of primary concern. Consequently, many deepwater jurisdictions have enacted strict zero discharge regulations pertaining to any waste, including drill cuttings, generated through drilling operations. Others, like the Gulf of Mexico, allow the controlled overboard discharge of cuttings produced by synthetic-based drilling fluids, providing the treated material complies with strictly enforced toxicity and oil retention on cuttings (OOC) limitations. [3]

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