AGH DRILLING, OIL, GAS • Vol. 35 • No. 1 • 2018

http://dx.doi.org/10.7494/drill.2018.35.1.283

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DRILL STRING ROTARY SPEED INFLUENCE ON EQUIVALENT CIRCULATING DENSITY VALUE

1. INTRODUCTION

Nowadays, since the middle of 2014 oil & gas industry a faces major disruptions and undergoes pivotal modernization due to the growth of renewables and governments policy to reduce carbon dioxide emissions. Nevertheless, according to BP Energy Outlook 2018, CEO Bob Dudley BP and presented forecasts, oil demand is supposed to grow for the next two decades, rising by additional 15 million barrels per day (mb/d). The peak shall be reached in the mid-2030s at about 110 mb/d with consumption plateauing and declining through 2040s and beyond [1]. For that reason petroleum stay and will remain as one of the most important commodities, which plays a major role in energy and transportation industries. With aim of meeting this demand for oil & gas, there is a necessity to replace mature, ageing hydrocarbon fields. But while modern ultra-deep, projects become far more technically advanced there is a need to develop new technologies to successfully reach the reservoirs. During this complex operations, drilling problems tend to occur more frequently, therefore avoiding complications plays a increasingly vital role. One of the conditions and ways to reduce failures and non-productive time is to maintain a proper mud pressure during all operations. For this reason ECD management is one of the most crucial aspects and optimization of the parameter is very important. On this account drill string rotary speed impact on ECD value was investigated as a new solution for reducing ECD value and optimize the parameter during drilling operations.

2. THEORETICAL INTRODUCTION

Before heading to main topic of this paper it is vital to present an insight about Equivalent Circulating Density parameter. Under dynamic conditions, when mud pumps

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are on, drilling fluid circulating in wellbore annulus exerts higher pressure on formations than hydraulic – static pressure. Equivalent Circulating Density (ECD) then is a effective mud density exerted against the formation that takes into account the influence of pressure losses of the fluid flowing up the annulus as well as changes of the fluid's average density due to rock cuttings load and combines it with initial mud weight. ECD parameter represents the additional superficial "mud weight" increase caused by pressure losses of fluid in the annulus. In other words ECD is the density a static fluid needs to have in order to create the same pressure the actual fluid creates while circulating in the annulus at a certain depth [2]. Because ECD is a density parameter, it is commonly expressed in ppg or kg/m^3. The most basic equation used to calculate ECD value in SI system is presented below [3]:

$$\mathrm{ECD} = \mathrm{MW} + \frac{\Delta P}{0.0981 \cdot \mathrm{TVD}} \tag{1}$$

where*:*

MW – mud weight/density [kg/m^3]
TVD – true vertical depth [m]
ΔP – pressure loss [Pa]

ΔP describes only pressure losses in annulus between drill string and borehole without pressure losses inside drill string. It is vital to highlight that according to Wójcikowski A. (2007) [14], ΔP value is calculated by different equations, depending on selected part of the annulus [14]:

a) open hole section:

$$\Delta P = 0.824 \cdot 10^{-6} \cdot \frac{\eta^{0.14} \cdot \mathrm{MW}^{0.86} \cdot Q^{1.86} \cdot \mathrm{MD}}{(d_1 - d_2)^{0.86} \cdot \left(d_1^2 - d_2^2\right)^2} \tag{2}$$

b) casing section:

$$\Delta P = 0.771 \cdot 10^{-6} \cdot \frac{\eta^{0.14} \cdot MW^{0.86} \cdot Q^{1.86} \cdot \mathrm{MD}}{(d_1 - d_2)^{0.86} \cdot \left(d_1^2 - d_2^2\right)^2} \tag{3}$$

where:

η – plastic viscosity [Pa·s],
Q – flow rate [m^3/s],
MD – measured depth or wellbore length [m],
d_1 – wellbore diameter [m],
d_2 – drill pipe outside diameter [m].

Therefore combination of above mentioned equations (1), (2) and (3) may present full ECD formula:

a) open hole section:

$$\mathrm{ECD} = \mathrm{MW} + (0.0981 \cdot \mathrm{TVD})^{-1} \cdot 0.824 \cdot 10^{-6} \cdot \frac{{}^{0.14} \cdot \mathrm{MW}^{0.86} \cdot Q^{1.86} \cdot \mathrm{MD}}{(d_1 - d_2)^{0.86} \cdot \left(d_1^2 - d_2^2\right)^2} \tag{4}$$

b) casing section:

$$\mathrm{ECD} = \mathrm{MW} + (0.0981 \cdot \mathrm{TVD})^{-1} \cdot 0.771 \cdot 10^{-6} \cdot \frac{\eta^{0.14} \cdot \mathrm{MW}^{0.86} \cdot Q^{1.6} \cdot \mathrm{MD}}{(d_1 - d_2)^{0.86} \cdot \left(d_1^2 - d_2^2\right)^2} \tag{5}$$

The full formula is relatively elaborate and presents several parameters which impact ECD. By analyzing this equation it is easy to notice not only which, but also how particular factors affect ECD. For instance it is clear that mud weight is the most crucial element and its shifts will cause the strongest impact on ECD value. Additionally, despite that the equation presents series of parameters such as [2]:

- wellbore geometry – annular clearances,
- true vertical depth (TVD), measured depth (MD),
- rheology, mud properties: plastic viscosity,
- flow rate.

It is necessary to remember that they are more coefficients which impact ECD value like:

- rhelogoy, mud properties: yield point,
- rate of penetration (ROP),
- drill sting rotary speed,
- wellbore trajectory,
- hole cleaning process.

Despite the fact that drill string rotary speed is not directly included in presented equations it is crucial to remember that rotation can impact mud viscosity, hole cleaning process thus fluid weight and wellbore clearances affected by formation of cuttings bed, especially in deviated wellbore sections. For this reason authors investigated DSRS indirect impact on ECD value in displayed paper.

3. RESEARCH METHODOLOGY

Presented research is based on actual, field data gained from two already existing wells. The wellbores were chosen in a way to have similar design, trajectory, completion, drilling and hydraulics parameters. Additionally the wells were matched in a way to present differences between DSRS impact on straight and deviated wells, therefore wellbore A is horizontal and wellbore B is vertical. Both wells were drilled in Lublin Basin (Poland) in order to estimate potential of shale hydrocarbons accumulations in this area. The main goal was to collect high-quality formation evaluation data from LWD logs or coring samples, necessary to determine lithology, hydrocarbon content and geomechanical parameters the formations, in order to plan hydraulic fracturing program. Both wellbores have also similar lithology with targeted, most perspective formations located in Lower Silurian, Upper Ordovician and Cambrian shales [2].

Wellbore A – Horizontal: vertical section consist of 20" conductor casing, 13 3/8" surface casing and intermediate 9 5/8" casing. The shoe of last section was set in Silurian formation at 2240 m MD/2237 m TVD and Inc 15 deg. After running the 9 5/8" casing there was drilled 8 1/2" hole with planned horizontal section. KOP was targeted at 2054 m MD/TVD before reaching 9 5/8" casing shoe. EOC is located at 2879 m MD/2562 m TVD with Inc 91 deg. The lateral section of this well with Inc angle 91 deg have approximately 922 m length. In this section there was performed advanced Logging While Drilling for hydraulic fracturing purpose. Total displacement from wellhead is approximately 1500 meters due to West direction and 50 meters North.

Wellbore B – Vertical: consists of four sections, 18 5/8? conductor casing, 13 3/8" surface casing, 9 5/8" intermediate casing and 8 1/2" part along with coring section from 3690 to 3990 meters in Silurian formation with well TD at 4020 m TVD. In this section there was planned to take approximately 200 m core ±10%. Coring ought to be performed until the reaching the top of Cambrian formation. Finally the coring point was established at 3478 m TVD. After reaching Cambrian drilling operations proceeded until reaching TD at 3850 m TVD in order to estimate potential of this formation. The well was suspended for analysis of wireline and coring data.

Each of above mentioned wellbore's components were designed in Halliburton's Landmark Drilling Software [5, 13]. Pore and fracture pressure gradients were also applied with regard to accomplished geological surveys and then ECD values were calculated for each part of the wellbores. ECD values are presented in pounds per gallon [PPG] units, because it has bigger nominal values that static gravity [SG], which enables to present differences between particular simulations results more plainly and vividly. In order to verify the programs results accuracy, the outcomes were compared with pressure while drilling (PWD) equipment surveys' results made during drilling operations. Analyzes indicate that there appeared some differences. The results from Landmark

Software grow in stable, continuous way along wellbores length. On the other hand in "PWD" outcomes increase or drop erratically without any noticeable or repeatable scheme. This situation appears due to a fact that even Landmark Software takes into account various, crucial factors it still uses mathematical equations and computer science which produce "linear" results. Wellbore environment instead, is very harsh, unpredictable and unstable ambient, especially for measurement equipment sensors. Nevertheless the differences in results do not exceed 5% of their total values. For that reason it is permissible and logical to assume that not only ECD values but also conducted simulations, included in this paper are correct and present a proper scientific value [2].

4. LITERATURE OVERVIEW

Even though correlation between drill string rotary speed and ECD parameter has been investigated by several different authors since early 1990's, still there are many different conclusions and opinions. Therefore, below are presented references to few researches in order to give a larger foundation to understand the complexity of the topic.

With regard to Charlez et al. (1998) [6] and collected field data from the North Sea wellbores, an higher ECD will be seen with increased drill string rotation speed especially in slimhole sections. Additionally the authors claim that flow rate does not affect the trend from the first test. This theory was supported by Bertin et al. (1998) [7] who claimed to find almost linear relationship between ECD and pipe revolutions per minute (RPM) of around 10 kg/m^3 for every 60 RPM growth. Furthermore with increased the availability of downhole pressure tools, drill string rotation effect was investigated. The tools were used to measure the circulating pressure drop in a cased hole (without any cuttings) with only axial flow. Later the drill string rotation speed was ramped up and changes in circulating pressure drop were measured. In nearly all cases the effect of drill pipe rotation served to increase pressure drop.

On the other hand, with the growing attention given to slim hole drilling projects in the 1990s, many researchers investigated similar topic as it was known that in small diameter wells, rotation of the drill string could significantly increase downhole pressure losses and also initiate turbulent flow conditions. Nevertheless, their work showed contrary results, presenting opposite outcomes. Additionally, according to T. Hemphill and K. Ravi (2011) [8], over the years several notable papers have predicted that circulating pressure drop will decrease with increasing drill pipe rotation and researches have attributed this to the shear thinning nature of pseudoplastic drilling fluids in which the fluid viscosity drops as a result of increasing shear rate.

Recently in 2008 a combined theoretical and experimental study was performed by Ahmed and Miska [9]. Presented data shows fluid pressure drop increasing and decreasing with drill pipe rotation in a circulating annulus due to different eccentricity of particular wellbore sections. The inertial effects could be generated either from eccentricity and geometric irregularities or combinations of these.

5. NUMERICAL SIMULATIONS

The literature overview leads to a conclusion that DSRS impacts ECD in several different ways. It may cause turbulent flow of drilling fluids thus increase pressure losses in the annulus. But meanwhile, in deviated wellbore sections mechanical agitation created by rotary movement is necessary to provide sufficient cuttings removal, which causes reduction of solids concentration and overall mud density. Therefore simulations were made in order to investigate drill string rotary speed effect on hole cleaning process, pressure losses and test its overall impact on ECD management. As it was previously mentioned, there were chosen two wellbores, horizontal and vertical, with the aim of examination differences between those two types.

The calculations made in Landmark Drilling Software [5] were executed for a situation when the last 8 1/2" open hole section was drilled and target depth was reached. This wellbore section is usually the most challenging one, where appear many problems or complications and ECD management is extremely vital there. All parameters values, applied in the simulations were designed with regard to particular wellbores characteristics and conditions presented in Chapter 3 and Table 1 (see Appendix). Obtained results directly met with prior assumptions, correspond with literature overview and also plainly present the differences between deviated wellbore A and vertical wellbore B. The research was divided in two sections [2].

In the first part there was applied small flowrate (1550 l/min for well A and 1300 l/min for well B) with normal and very high ROP (14/30 m/h for well A and 30/50 m/h for well B) in order to create poor hole cleaning conditions and also formation of cuttings bed in deviated well sections. In each of simulations were used low (60 RPM) and very high (180 RPM) DSRS to check its influence on hole cleaning process and pressure management, thus ECD value as well. As expected the results were different in lateral and straight well (Tab. 2 and 3 – see Appendix).

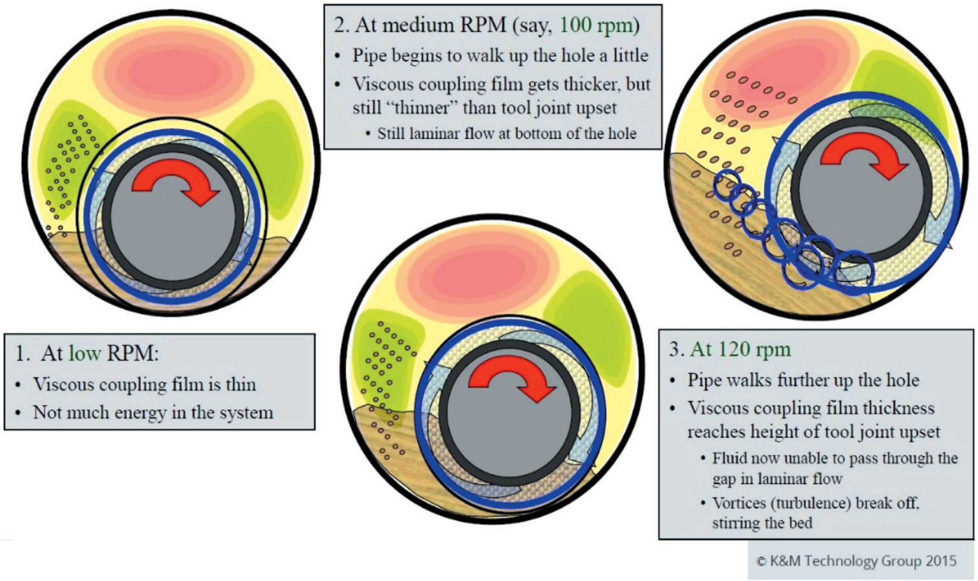
In simulations for vertical wellbore B the ECD outcomes were stable throughout all sections and almost do not vary between DSRS of 60 RPM and 180 RPM even for increased rate of penetration values up to 50 m/h. In essence conducted test does not indicate DSRS as a key impact on pressure losses or hole cleaning process in straight sections, despite of applied conditions. This results also meet with expectations, because as it was mentioned before cuttings removal is much more easy in vertical sections and usually do not require additional, mechanical agitation.

Additionally as presented by Skalle (2010) [11, 15], drillpipe rotation in a laminar flow will lead to an additional shear velocity component. Basically drilling fluids are shear thinning, and rotation would cause an increase in overall shear stress, with a reduction of the viscosity, leading to a decrease of the pressure drop and bottomhole pressure. During drill pipe rotation, the effective strain rate is increased, the effective viscosity decreased, with a reduction of the axial pressure drop as a result. In laminar developed flows of Newtonian fluids, viscosity is independent of shear rate, and the described effects could not take place.

Contrary to well B in horizontal wellbore A, DSRS played very important role. The differences between low and high DSRS are huge and varied to even 5 PPG. In those poor hole cleaning conditions, when also low rotary movement was applied, ECD value raised significantly for both normal and high ROP. This situation was caused by insufficient cuttings removal from deviated sections. It lead to formation of massive cuttings bed and severe mud density increase, due to higher solids concentration. Moreover, this situation could certainly lead to stuck pipe, formation fracturing, lost circulation or other drilling problems and complications. What is very compelling, in the same conditions increase of DSRS to 180 RPM was a great remedial for extensive ECD. Because of high rotary movement, ECD value was stable and very similar to primary conditions. There appear a conclusion that mechanical agitation redeemed lacks of flow rate, stirring the cuttings bed, thus providing proper solids removal and stable ECD management.

This process is explained more closely by I. Kjøsens, G. Løklingholm et al. (2003) [10]. According to the author's research, it is important to create a sufficiently high shear stress onto the cuttings bed in deviated sections to be able to remove particles from the bed. Since low viscosity systems are generally favorable, it is necessary to increase pumping volume or drill string rotation speed in order to enhance shear stress. Furthermore, in deviated sections it is preferable to have the turbulent flow, which correlates to the shear stress onto cuttings bed. Turbulent or unstable flow in annulus with rotating drill strings is common. The flow is vulnerable for instabilities named Taylor vortices. Those vortices add to the flow like a weak turbulence even in absence of flow. According to Skalle (2010) [11, 15], drill string rotation and the forming of those vortices would lead to an axial-radial mixing, and this would have the same effect on momentum transport as turbulent mixing. This turbulence-like motion is shear thickening it makes the frictional pressure loss increase, resulting in an increased shear stress on the cuttings bed surface.

In essence, the higher rotation rate becomes, the bigger the impact on turbulence intensity and thereby, hole cleaning will be. This phenomenon is also demonstrated by K&M Technology in Figure 1 [12].



2. At medium RPM (say, 100 rpm)
- Pipe begins to walk up the hole a little
- Viscous coupling film gets thicker, but still "thinner" than tool joint upset
  - Still laminar flow at bottom of the hole

1. At low RPM:
- Viscous coupling film is thin
- Not much energy in the system

3. At 120 rpm
- Pipe walks further up the hole
- Viscous coupling film thickness reaches height of tool joint upset
  - Fluid now unable to pass through the gap in laminar flow
  - Vortices (turbulence) break off, stirring the bed

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Fig. 1

The second part of the simulations has the same form as the first one, with only difference in flow rate value, which is very high reaching 2500 l/min for both wells. This time results are corresponding with each other both in vertical and horizontal wellbores and does not indicate any impact of DSRS on ECD. The extensive flow rate created turbulent flow in the annulus, resulting in increased pressure drop as well as provided sufficient cuttings removal. Even in horizontal wellbore A DSRS at 180 RPM did not enhance hole cleaning process at all. Therefore mechanical agitation caused by ramped up DSRS did not affect overall ECD value. This conclusion is contrary to observations presented by Charles et. al. [6], therefore it should be given under more investigation in following researches.

6. CONCLUSIONS

To sum up, both the conducted simulations and scientific researches highlight the importance of drill string rotary speed in ECD management. The parameter can simultaneously reduce and increase pressure losses in the annulus, hence it may influence ECD management in different manners at the same time. Simulations results indicate that DSRS causes turbulent flow in the annulus thus increasing pressure losses. In the same time, rotary movement creates mechanical agitation which is necessary to lift up and remove cuttings, enhancing hole cleaning process, reducing cuttings bed and decreasing overall ECD value. This appearance is extremely crucial in deviated and horizontal wellbores to prevent stuck pipe or formation fracturing problems. Nevertheless, as it was mentioned at the beginning, drill string rotary speed impact on pressure losses is very complex issue which consists of several, different aspects. During drilling operations all of them should be taken into consideration and optimized due to existing field conditions.

REFERENCES

[1] https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/energy-outlook/bp-energy-outlook-2018.pdf [access: February 2018].

[2] Kiebzak P.: *Equivalent circulating density (ECD) value impact on optimization of drill string elements selection process in oil wells*. Master Thesis, Wydział Wiertnictwa, Nafty i Gazu AGH, Kraków 2016.

[3] http://www.iwcf.org/images/pdfs/formula_sheets/drilling/QA-RD7CE-V8_English_Metric_0.0981_Formula_Sheet.pdf [access: February 2016].

[4] http://www.drillingformulas.com/calcuate-annular-pressure-loss/ [February 2018]

[5] Halliburton Landmark Software Manual, Faculty of Drilling, Oil and Gas at AGH UST License; Quotation no.: 22159269.

[6] Charlez A., Easton M., Morrice G. et al.: *Validation of Advanced Hydraulic Modeling using PWD Data.* Paper OTC 8804, 1998.

[7] Isambourg P., Brangetto M., Bertin D.L.: *Field Hydraulic Tests Improve HPHT Drilling Safety and Performance.* Paper SPE 59527, 1998.

[8] Hemphill T., Ravi K.: *Improved Prediction of ECD with Drill Pipe Rotation.* International Petroleum Technology Conference, 2011.

[9] Ahmed R., Miska S.: *Experimental Study and Modeling of Yield Power-Law Fluid Flow in Annuli with Pipe Rotation.* Paper IADC/SPE 112604, 2008.

[10] Kjøsens G. Løklingholm et al.: *Successful Water Based Drilling Fluid Design for Optimizing Hole Cleaning and Hole Stability*. Paper SPE/IADC, 2003.

[11] Thorbjorn Lejon Skjold: *Drillpipe Rotation Effects on Pressure losses.* Norwegian UST Department of Petroleum Engineering and Applied Geophysics, 2012.

[12] K&M Technology Group. Training Materials, 2015.

[13] Wiśniowski R.: *Wybrane aspekty projektowania konstrukcji otworów kierunkowych z wykorzystaniem technik numerycznych.* AGH, Kraków 2002.

[14] Wójcikowski A.: *Wykonywanie pomiarów płuczki wiertniczej i specjalnej 311[40].Z2.0.* Instytut Technologii Eksploatacji – Państwowy Instytut Badawczy, Radom 2007.

[15] Skalle P.: *Drilling Fluid Engineering.* Pål Skalle & Ventus Publishing ApS, 2010.

APPENDIX

Table 1

Primary drilling mud properties

Drilling mud properties		
Properties	Wellbore A	Wellbore B
Density [PPG]	11.85	14.35
PV [mPa·s]	15	35
YP [Pa]	9.58	10.53

Below are presented numerical simulations results prepared in Landmark Drilling Software. In order to read the data properly, in undermentioned description are consecutively explained meanings of all titles and abbreviations used in included Tables 2 and 3.

The first column (counting from the left) include particular survey points, which were vital from ECD management point of view. Numbers indicate wellbore measured depth (MD) in meters while words and abbreviations present selected part of well. Hence "0 Casing" means that measurement was made at 0 m MD in 9 5/8" casing string. "Shoe" always refers to casing shoe of 9 5/8" intermediate section. "OH" stands for open hole 8 1/2" section. "3900 Horizontal" means that survey was made in horizontal part of open hole section at 3900 m of MD. "BHA" regards to wellbore section with bottom hole assembly part of drill string. "TD" indicates that the last measurement point is located in drill bit position at target depth.

In "PWD" column are presented real data surveys from pressure while drilling equipment. X regard to the points where PWD measurements were not made, because this tool was used only in horizontal sections.

"Primary Condition" columns include results from Landmark Drilling Software which present ECD values in primary well conditions for mud rheology presented in Table 1, without changes or optimizations in any parameter whatsoever. As it was mentioned at the beginning, results from this column were compared with PWD data in order to check the software's accuracy. Additionally as pointed earlier on, ECD values are presented in pounds per gallon [PPG] units, because it has bigger nominal values that static gravity [SG], which enables to present differences between particular simulations results more plainly and vividly.

The rest of columns present simulations results, which include isochronal shifts in drill string rotary speed (DSRS), flowrate and rate of penetration parameters to their possible, terminal values. Pararell changes of the parameters enabled to simulate poor and good hole cleaning conditions in order to check how DSRS may impact pressure losses, rock cuttings removal process, thus ECD management as well. Consecutive parameters are is expressed in: drill string rotary speed (DSRS) – [RPM], flowrate (*Q*) – [l/min], rate of penetration (ROP) [m/h] units.

Table 2

Wellbore A simulations results

Wellbore A											
MD [m] / Section	Inc [deg]	Equivalent Circulating Density [PPG]									
		Primary conditions*	PWD	*Q* 1550, ROP 14		*Q* 1550, ROP 30		*Q* 2500, ROP 14		*Q* 2500, ROP 30	
				DSRS 60	DSRS 180	DSRS 60	DSRS 180	DSRS 60	DSRS 180	DSRS 60	DSRS 180
1. 0 Casing	0	12.44	x	12.43	12.43	12.49	12.49	12.43	12.43	12.47	12.47
2. 2082 Casing	4	12.44	x	12.43	12.43	12.49	12.49	12.43	12.43	12.47	12.47
3. 2241 Shoe	15	12.45	x	12.44	12.44	12.50	12.50	12.44	12.44	12.48	12.48
4. 2568 OH	60	12.47	x	12.46	12.46	12.55	12.52	12.46	12.46	12.50	12.50
5. 2879 OH	90	12.52	12.94	12.75	12.51	12.86	12.57	12.53	12.53	12.57	12.57
6. 3500 Horizontal	90	12.67	12.88	13.51	12.65	13.45	12.70	12.69	12.69	12.73	12.73
7. 3610 BHA	90	12.70	12.78	13.63	12,67	13.57	12.73	12.73	12.73	12.77	12.77
8. 3700 BHA	90	12.76	12.75	13.67	12.71	15.22	12.77	12.82	12.82	12.86	12.86
9. 3801 TD	90	12.83	12.62	14.47	12.76	17.65	12.82	12.92	12.92	12.96	12.96

* Primary parameters	
MW 11.85 [PPG]	*Q* 2 000 [l/min]
PV 15 [mPa·s]	ROP 14 [m/h]
YP 9.58 [Pa]	DSRS 90 [RPM]

Table 3

Wellbore B simulations results

Wellbore B									
MD [m] / Section	Equivalent Circulating Density [PPG]								
	Primary conditions*	*Q* 1300, ROP 30		*Q* 1300, ROP 50		*Q* 2500, ROP 30		*Q* 2500, ROP 50	
		DSRS 60	DSRS 180	DSRS 60	DSRS 180	DSRS 60	DSRS 180	DSRS 60	DSRS 180
1. 0 Casing	15.45	15.35	15.36	15.42	15.42	15.93	15.93	15.97	15.97
2. 2700 Shoe	15.45	15.35	15.36	15.42	15.42	15.93	15.93	15.97	15.97
3. 3100 OH	15.47	15.37	15.38	15.44	15.44	15.98	15.98	16.04	16.04
4. 3530 OH	15.48	15.36	15.37	15.43	15.43	15.97	15.97	16.03	16.03
5. 3600 BHA	15.48	15.54	15.55	15.61	15.61	16.56	16.56	16.60	16.60
6. 3650 BHA	15.86	15.54	15.55	15.61	15.61	16.56	16.56	16.60	16.60
7. 3761 TD	15.90	15.56	15.57	15.63	15.63	16.62	16.62	16.66	16.66

* Primary parameters	
MW 14.35 [PPG]	*Q* 2 000 [l/min]
PV 35 [mPa·s]	ROP 30 [m/h]
YP 10.53 [Pa]	DSRS 90 [RPM]