A NOVEL INVERT EMULSION SYSTEM USING A POLYGLYCEROL INTERNAL PHASE

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ABSTRACT

Invert-emulsion systems, which have been used since the 1950's, consist of a continuous oil phase and an aqueous internal phase. The aqueous internal phase typically consists of a calcium chloride brine solution. In this paper it was found that a polyglycerol additive led to consistent trends of increased rates of penetration (ROP), reduced stick-slip, and improved wellbore stability. This paper verifies that the novel polyglycerol acts as a water-activity control agent and functions better than a calcium chloride invert-emulsion drilling fluid.

This water activity control agent is a proprietary blend of polyglycerols with low alkalinity and is completely soluble in water and brines. This innovative additive minimizes wellbore shale hydration by optimizing the water phase's activity. The additive strengthens the wellbore and inhibits fluid interactions with formation clays. The additive also reduces the coefficient of friction, which increases ROP and reduces torque and drag in high-angle wellbores. Reducing axial and rotational stick-slip allows for prolonged bit and tool life, resulting in more time on bottom drilling and less time tripping. The cumulative performance improvements reduce total well costs.

This paper discusses an on-going, seven-year, field application in the Rocky Mountains of this novel invert-emulsion drilling fluid system. Results improved over time and led to optimized operational efficiencies.

INTRODUCTION

The Pinedale Anticline of Wyoming is known to be technically challenging with stacked lenticular sands, high pore pressures, and unexpected lost circulation zones. All of these factors negatively impact the drilling operation, particularly the drilling fluid. According to the U.S. Energy Information Administration the Pinedale Anticline is among the top five largest natural gas fields in the U.S. It contains more than 5,000 feet (1,524 m) of vertical pay zone, which is an estimated supply of 10 million U.S. homes for the next 30 years[1].

The use of oil-based invert emulsion drilling fluid is quite prevalent. Depending on environmental concerns the fluid can be modified by selecting from multiple base oils. There are economic benefits of invert emulsions; this is usually expressed by the wellbore's stability[2]. This paper discusses a unique internal phase comprised of a proprietary blend of polyglycerols used to control water activity in diesel or synthetic-based drilling fluids. It is an environmentally-preferred alternative [3,4,5] to calcium chloride or other salts, and provides precise control of drilling fluid activity.

Work began with Ultra Petroleum using a conventional invert emulsion drilling fluid with diesel as the continuous phase and brine as the internal phase. Over 600 wells were completed with a conventional oil-based drilling fluid. Nearly 300 wells were completed using the polyglycerol internal phase fluid. Issues with stick-slip were encountered and minimized with the novel fluid.

DISCUSSION

The novel alternative developed after initial testing as a likely replacement for calcium chloride to control water activity of the fluid was tested with various low aromatic oils and diesel. Drilling fluid properties were tested using several formulations of the novel invert emulsion system using a polyglycerol internal phase. These tests included resistance to common oil-base contaminants. Observations of shale inhibition of the fluid in question were compared to a calcium chloride brine using the Downhole Simulation Cell (DSC) operated by Newpark Drilling Fluids Laboratory in Houston. Additionally, seepage characteristics of the two systems were analysed using a Particle Plugging Test (PPT) apparatus. DSC and PPT results were very satisfactory illustrating the environmentally-friendly polyglycerol internal phase protected the shale from hydration and therefore degradation[4].

Further testing examined the proposed system with various oil/water ratios. This included rheology, electrical stability (which was indicative of contaminants such as drilled solids and water) and the fluids' water activity was compared to calcium chloride brine and other alternatives. The fluids' density may be adjusted as with any oil based fluid. The test results of the ultra-deep drilling fluid used by the operator are presented in the appendix section of this paper.

STICK-SLIP

Stick-slip occurs when the bit momentarily stops while the rotary table or top drive continues to turn. At this moment, the energy that is in the string builds up and leads to a powerful release of torsional oscillation. It has been reported that this force can be up to twice the magnitude of the average rotational force. This not only causes an increase in tool failure but can also lead to a disruption of the fluid flow regime[6]. Stick-slip occurs when the downhole RPM is not consistent, but undergoes large and even violent movements which can harm the drill string. For the downhole tools used in the operations the cumulative maximum downhole RPM must not exceed 220 rpm. If the RPM exceeds 220, holding a tool face becomes difficult, bearing filter housings could back off, or complete tool failure can occur. Below in Fig. **1** results can be seen based on collar RPM where stick-slip is encountered.

Stick-slip results in poor performance, not allowing for a good tool face and poor weight transfer from the bottom hole assembly to the formation being drilled. The lubricating effects of the drilling fluid become even more important while slide drilling to alleviate some of the drag forces experienced[7]. Generally oil based drilling fluids are the conventional option to reduce stick-slip due to the lubricating characteristic of the fluid. To further reduce friction a combination of additional downhole tools and the application of polyglycerol to the drilling fluid was implemented.

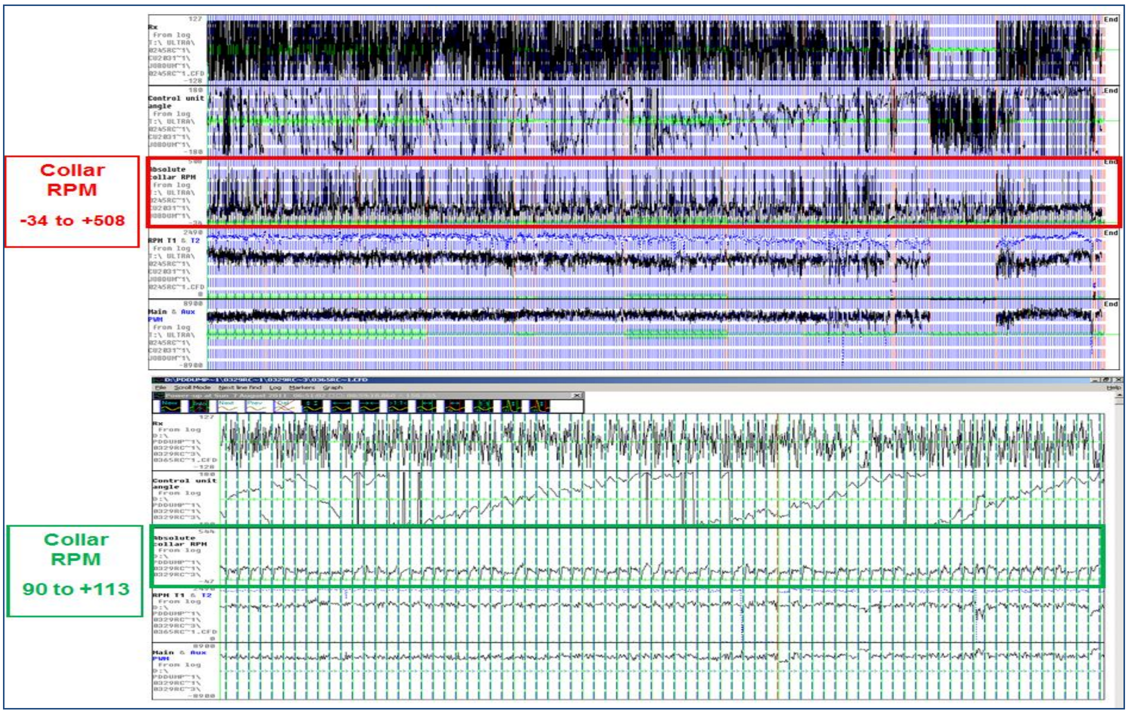

Fig. 1: Stick-slip Results due to RPM

BOTTOM HOLE ASSEMBLY MODIFCATION

In early 2011, decreased tool life was experienced while drilling. The operator underwent a higher rate of failure with mud motors and measurement while drilling (MWD) tools. This commenced an investigation where a discovery of elevated vibrations (see figure 2) was noted. In August 2011 a drilling on gauge (DOG) sub was added to reduce the stick-slip with the following results, (see figure 3).

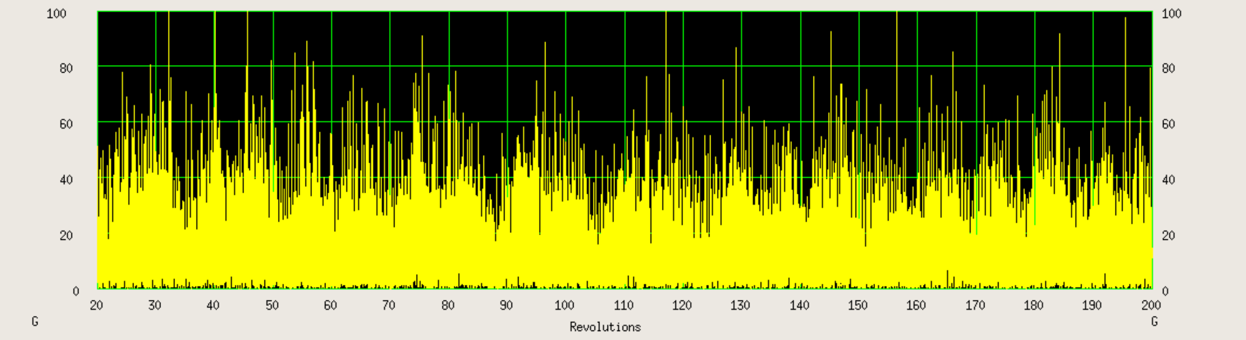

Fig. 2: Vibration without Dog Sub

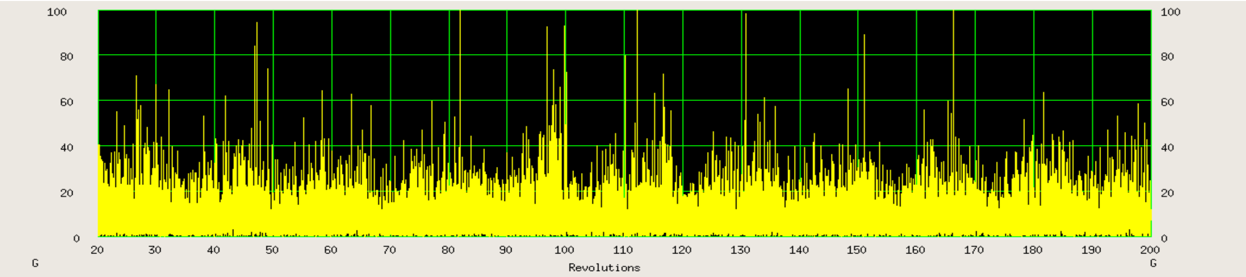

Fig. 3: Vibration with Dog Sub

WYOMING ANTICLINE DRILLING FLUID IMPROVEMENT

The surface section with a 12 ¼ inch hole used a water-based spud drilling fluid. After the surface interval was drilled and cased, the oil-based invert emulsion system displaced the cement.The invert emulsion drilling fluid was utilized along with a bit size of 8 ½ inches for the intermediate interval. Generally, intermediate casing would be set into the M Lance A formation and then continue with the same drilling fluid to total depth with a 6.0 inch bit. Initially, the invert drilling fluid consisted of an 80/20 oil/water ratio with mud weights ranging from 10.5-13.5 ppg (1.26-1.62 s.g.).

To further improve the stick-slip conditions it was recommended in September of 2011 to increase the oil to 90% with 3% of the polyglycerol additive, but maintain chlorides levels for inhibition. General reductions in stick-slip were seen. The stick-slip rotary torque was measured both before (figure 4 & 5) and after (figure 6 & 7) the addition of the 3% polyglycerol additive. The changes made to the drilling fluid represents a reduction in friction as reemphasized by table 1. This correlation had very beneficial results on the time drilled, (see Fig. 8).

Drilling torque was also examined. The operators identified friction as the number one culprit to effectively drilling their wells. There are four main areas where wellbore friction hindered their operations: drilling torque, sliding friction in their laterals, flowing fluid pressures and wear. Friction is the function of the reactive forces that are a result of two objects rubbing against each other. The rubbing entities include the components at the surface of the rig, the sliding and rotation of drill string components, casing against other casings or formation, and the flowing of drilling fluid in the wellbore.

The drilling fluid serves a multitude of functions and assumedly has a complex chemistry. An immense amount of research and development has been done on changing the internal phase of an invert drilling fluid so that it can properly interact with problematic shale[8]. Optimizing drilling operations is tremendously dependent on incorporating efficiencies for the unique challenging environments in drilling a specific well.

The drilling fluid development went from an 80/20 diesel/water emulsion with 250,000- 320,000 mg/L chlorides to a 90/10 diesel/water invert fluid with the same level of chlorides but with a 3%

addition of the aforementioned polyglycerol additive. Due to the improvements in vibration and rotary torque, the use of the diesel invert with 3% polyglycerol in the internal phase continues.

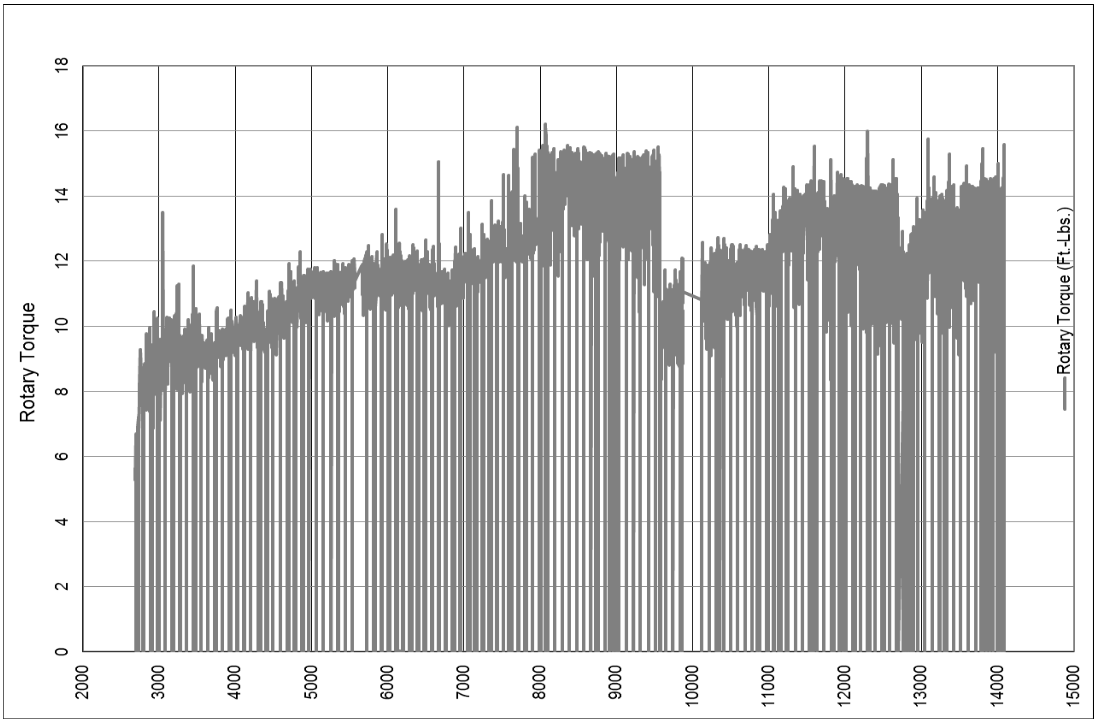

Fig. 4: Rotary Torque with use of Dog Sub and Conventional Invert

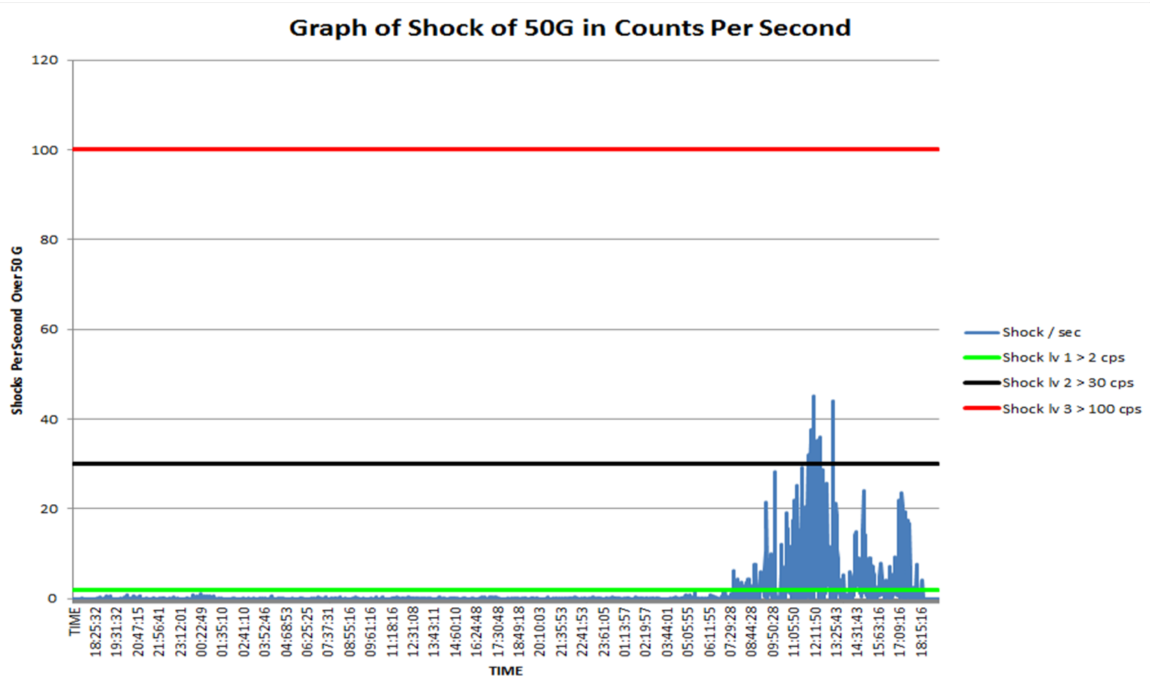

Fig. 5: Shock of 50G with use of Dog Sub and Conventional Invert

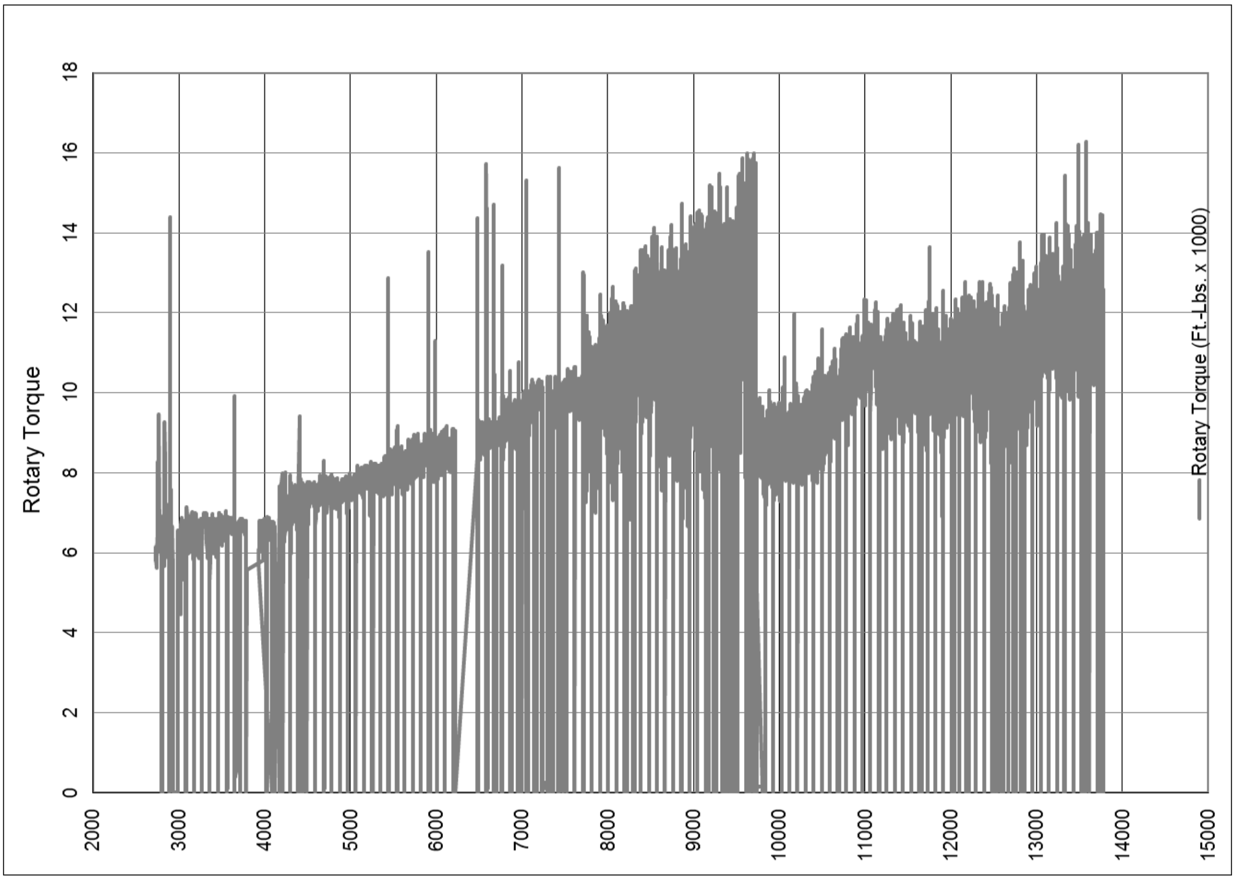

Fig. 6: Rotary Torque with use of Dog Sub and Polyglycerol Internal Phase Invert

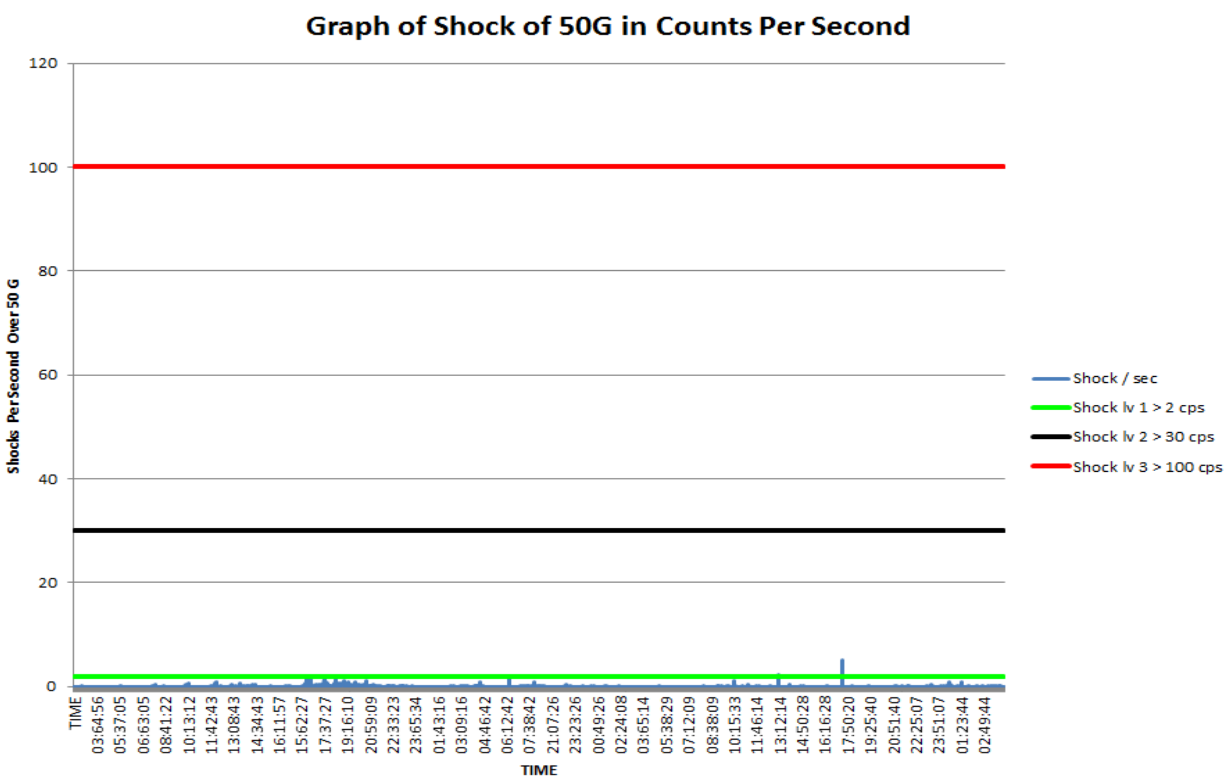

Fig. 7: Shock of 50G with use of Dog Sub and Polyglycerol Internal Phase Invert

Tab. 1: Stick-slip with use of Dog Sub and Polyglycerol Internal Phase

BR WELL September 2011						
	Beginning Run 1	**End Run 1**	**Beginning Run 2**	**End Run 2**	**Beginning Run 3**	**End Run 3**
Fluid Used	90/10 OBM	90/10 OBM	90/10 OBM with 3% Polyglycerol blend	90/10 OBM with 3% Polyglycerol blend	90/10 OBM with 3% Polyglycerol blend	90/10 OBM with 3% Polyglycerol blend
RPM Variance	65-172	32-417	75-154	50-214	35-186	59-195
Stick-Slip	45%	187%	33%	68%	63%	57%

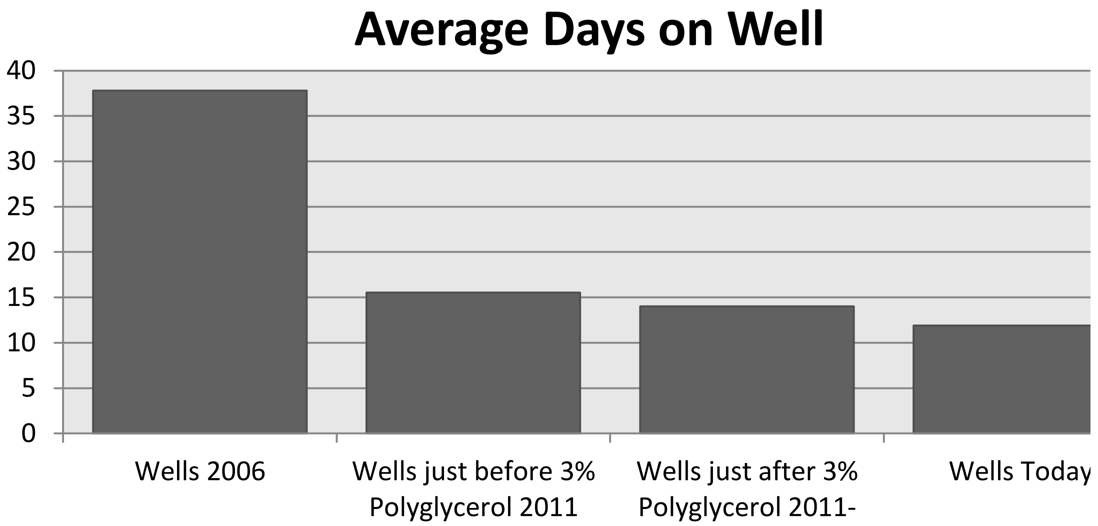

Fig. 8: Days on well performance throughout project

CONCLUSIONS

1. The study presented the benefits of using a polyglycerol additive incorporated into an invert-emulsion drilling fluid. These effects can be quite significant and lead to a reduction in friction and therefore an increase in tool life.
2. The proposed drilling fluid minimized stick-slip situations.
3. These advances in technology resulted in definite cost savings.
4. Further testing would be focused on dynamic and static friction differences using the polyglycerol internal phase drilling fluid.

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REFERENCES

1. *www.eia.gov*. (2014, December 4). Tratto il giorno 1 2015, January da EIA: http://www.eia.gov/pub/oil_gas/natural_gas/data_publications/crude_oil_natural_gas_reserves/current/pdf/top100fields.pdf
2. Chenevert, M. (1970). “Shale Control with Balanced-Activity Oil-Continuous Muds”. *SPE paper 2559* (p. pp 1309-1316). Journal of Petroleum Technology.
3. David Jeanson B.Sc, P. M. (2003). Design and Performance Review of New-100, a Calcium Chloride Free Invert Drilling Fluid. *CADE/CAODC Drilling Conference.* Calgery Alberta Canada: Paper No 2003-030.
4. Tony Harlan, P. C. (2006). Salt-Free Internal Phase Oil Mud Provides Improved Performance. *AADE Drilling Fluids Technical Conference.* Houston, Texas,: AADE-06-DF-HO-08.
5. Simpson, J. P. (May 1979). “A New Approach for Oil-Base Muds for Lower Cost Drilling”. *SPE Paper 7500* (p. pp 643-650). Journal of Petroleum Technology.
6. C.D. Marken, X. H. (1992). The influence of Drilling Conditions on Annular Pressure Losses SPE 24598. *Society of Petroleum Engineers 67th Annual Technical Conference and Exhibition.* Washington, DC: Society of Petroleum Engineers.
7. R.G. Bland, J. R. (2001). Rotary Steerable Drilling Fluid SPE 68670. *SPE Asia Pacific Oil and Gas Conference and.* Jakarta, Indonesia,: Society of Petroleum Engineers Inc.
8. H.L. Dearing, J. S. (2000). Effects of Drilling Fluid/Shale Interactions on Shale hydration and Instability. *GRI 99/0213.*

APPENDIX

INITIAL DRILLING FLUID RESULTS on an 18.0 ppg (2.16 s.g.) Polyglycerol Internal Phase

Tests were performed on an 18.0 ppg (2.16 s.g.) fluid used in an ultra-deep well. Below are the results:

Table 2: Rheologies of Polyglycerol Drilling Fluid

18.0 ppg (2.16 s.g.) Polyglycerol Internal Phase w/ 7% Solids	
Hot roll @ 151ºF (66^{o}C) for 16 hr	
600 rpm / 300 rpm	105 / 59
200 rpm / 100 rpm	45 / 29
6 rpm / 3 rpm	12 / 11
Plastic viscosity, @ 150ºF, cP	46
Yield point, lb/100 ft^2 (g/100cm^2)	13 (6)
Gel strengths - 10s/10min, lb/100 ft^2 (g/100cm^2)	14 / 17 (7/8)
Electrical Stability, volts	584
Alkalinity, mL N/10 Sulfuric Acid	0.8

Run Date: August 10, 2006
Sample Rec'd: August 10, 2006
Sample ID: 18.0 ppg Polyglycerol internal phase (Hot-rolled)
Mud Weight: 18.0 ppg (2.16 s.g.)

Table 3: Fann 75 Results

Sequence Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Temperature, ^{o}F	80	150	150	200	200	250	283	300
Temperature, ^{o}C	27	66	66	93	93	121	139	149
Pressure, psig	0	0	2,500	5,000	7,500	10,000	15,000	17,500
Apparent Viscosity, cp	93	41	50	40.5	48.5	41	47.5	49.5
Equivalent Dial Reading @:								
600 rpm	186	82	100	81	97	82	95	99
300 rpm	98	44	52	43	50	44	50	53
200 rpm	70	32	38	31	37	32	37	39
100 rpm	43	21	25	22	25	22	26	27
6 rpm	12	10	10	9	10	9	9	10
3 rpm	11	9	9	8	9	8	8	9
Plastic Viscosity, *cp*	88	38	48	38	47	38	45	46
Yield Point, lb/100 ft^2 (g/100cm^2)	10 (5)	6 (3)	4 (2)	5 (2)	3 (1)	6 (3)	5 (2)	7 (3)
10 sec gel, lb/100 ft^2 (g/100cm^2)	11 (5)	9 (4)	10 (5)	9 (4)	10 (5)	8 (4)	8 (4)	9 (4)
10 minute gel, lb/100 ft^2 (g/100cm^2)	14 (7)	12 (6)	13 (6)	10 (5)	12 (6)	10 (5)	9 (4)	9 (4)