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Case Histories Demonstrate Sustained Performance by Clay-free Invert Emulsion Fluid during Hurricane Evacuation and as Packer Fluid

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Abstract

The approach of Hurricane Ivan demanded a 160-hour rig evacuation and the operator had concerns about maintaining wellbore stability and good drilling fluid properties during the week-long shutdown. The well had reached 16,195 ft MD and had a maximum angle of 43°. The 15.0 ppg clay-free invert emulsion fluid in the hole at the time of the evacuation was treated with 0.07 ppb of liquid viscosifier designed to maintain desired rheological properties and support emulsion stability. After the operator re-entered the well and tested the blowout preventers, the drillpipe went straight to bottom. The mud in the pits weighed 15.0 ppg throughout the system despite having no agitation for 160 hours. Although the original plan called for conditioning the mud 4-6 hours prior to tripping for a new bottomhole assembly, the time actually required was a little over two hours to get bottoms up. Approximately 12 hours of rig time was saved overall.

The high performance clay-free invert emulsion system demonstrated similar reliable performance when left in the hole as a packer fluid on a series of wells in Green Canyon. The case history presented here involves a 20,165 ft MD well with a maximum deviation of 37.5°. Prior to temporary abandonment, the mud system was tested to determine optimal properties and then treated with 1.0 ppb of the liquid viscosifier. The 15.4 ppg clay-free system remained in the well for 19 months. When the well was re-entered, the mud system density was carefully monitored at the flow line. There was no evidence of barite sag and the operator was able to reduce circulating and conditioning time by approximately nine hours. Based on the performance of the system in the initial well, the operator was able to modify the operational plan on subsequent wells, resulting in significant savings in rig time (Figure 1).

Introduction

Short- and long-term abandonment requires a stable drilling fluid that retains its suspension characteristics until re-entry. The same is true when using a drilling fluid as a packer fluid. With conventional drilling fluids, the risk of sag increases as the depth, temperature and angle increase. The objective is to prepare the fluid sufficiently to prevent settling in the pits, retain suspension properties, and minimize the risk of hole closure so that upon re-entry, minimal conditioning and rig time is required to return the well to its pre-abandonment condition.

Conventional synthetic- or oil-based invert emulsion fluids tend to thin with increased temperatures. However, the clay-free invert emulsion system described in this paper is designed to maintain desirable rheological properties over the wide range of temperatures typically encountered in deepwater operations. The capacity to maintain stable rheological properties in temperatures ranging from 40°F to 325+°F helps prevent the occurrence of barite sag.

Clay-free System Used in Hurricane Abandonment

Prior to shutting down operations on a Gulf of Mexico shelf well in preparation for Hurricane Ivan, there were concerns about maintaining wellbore stability and good drilling fluid conditions for the duration of the evacuation. Maximum fluid testing parameters do not usually exceed 72 hours, and the length of the Ivan evacuation eventually reached 160 hours.

Before the operator initiated the shutdown, a 6x7" bi-center hole was being drilled with a 15.0 ppg clay-free invert emulsion fluid at a measured depth of 16,195 ft (15,225 TVD) in approximately 150 ft of water with a bottom hole temperature of 255°F. The well was an "S" shaped well with a maximum angle of 43°. The mud properties at the time of shut down are shown below:

MW, lb/gal	15.0
PV, cP	53
YP, lb/100ft^2	19
Tau0, lb/100ft^2	6.72
S/W Ratio	79/21
ES, mV	793

The active mud system was treated with 0.07 ppb liquid viscosifier prior to shutdown. Upon returning to the rig after the storm and testing the blowout preventers, the operator was able to run the drillstring straight to bottom with no problems. The original plan was to circulate and condition the mud for 4-6 hours prior to tripping for a new assembly. This was an aggressive plan, as it usually takes at least 12 hours of washing, reaming and conditioning as had been the case on the other rigs in the area.. The mud was circulated for less than three hours prior to pumping a slug, saving at least 12 hours of rig time on a $75K day rate. Additional savings were achieved because the clay-free invert emulsion fluid required only minimal conditioning and showed no signs of barite sag.

The surface volume of clay-free invert emulsion fluid had not been agitated for approximately 160 hours, yet retained its pre-evacuation density of 15.0 ppg throughout all active pits when operations resumed.

A small volume of light mud (-0.6 ppg) was observed immediately after pumping started and was attributed to the water used to wash the stack prior to evacuating. The slug in the drillstring accounted for a small amount of heavy mud (+0.9 ppg) observed just after bottoms up. The bottoms up mud properties were as follows:

MW, lb/gal	15.2
PV, cP	59
YP, lb/100ft2	15
Tau0, lb/100ft2	6.06
S/W Ratio	79/21
ES, mV	451

Subsequent hurricane evacuations in the GOM also produced similar results with the clay-free invert emulsion system. For example, the drilling operations from a semi-submersible were shutdown for 384 cumulative hours during Hurricanes Dennis, Emily and Katrina with no opportunities to circulate bottoms up. The water depth at the location was 2,000 ft and the well depth was approximately 16,000 ft with an 8.5” hole at a 50° angle. When operations resumed, the 15.0 ppg clay-free invert emulsion fluid required only 16.5 hours of circulating time for bottoms up and conditioning and exhibited no evidence of barite sag.

Clay-free System Used as a Packer Fluid

The clay-free invert emulsion system demonstrated similar reliable performance when left in the hole as a packer fluid on eight deepwater wells in Green Canyon. In early 2003, the operator made the decision to temporarily abandon these wells using a series of three cement plugs. The first case well, located in approximately 3,400 ft of water, had an anticipated PBTD of 20,165 ft MD / 19,217 ft TVD. The maximum well deviation was 35.7º. The challenge was to minimize barite sag during the abandonment period by properly conditioning the fluid.

This case history is representative of the results typically achieved on all eight wells.

The operator left a 14.6 ppg clay-free invert emulsion fluid in the hole as a packer fluid. To prepare the 14.6 ppg clay-free drilling fluid for its function as a packer fluid between each cement plug, the system was pre-treated with an additional 0.5 ppb of liquid viscosifier. The successful outcome of using clay-free drilling fluid as a packer fluid is partly related to its having been sheared through the bit. This helps ensure that the desired properties will be maintained over a long static interval. Several mud samples from each wellsite were sent to the lab for a High Angle Sag Test (HAST) at a 45° angle to ensure the proposed treatment would minimize any potential for sag.

The 14.6 ppg example well described above was not re-entered until 4Q 2005, approximately two years later. When operations resumed, the properties of the mud system left in the well for over two years were observed to be very close to the original properties (Table 1).

During cleanout, a minimal amount of emulsion stabilizer was used to maintain electrical stability and rheological properties. No additional circulating time was required other than the standard industry practice of circulating bottoms up before proceeding further in the hole from each circulating depth. There were no indications of barite sag and no significant pressure spikes were experienced during the conditioning process.

Prior to using the clay-free invert emulsion system, the operator had used a conventional clay-based SBM in a number of wells with similar wellbore conditions. The conventional SBM used resulted in severe sag in at least one case (from 15.0 ppg down to 11.0 ppg).

Performing extensive field and lab tests on the clay-free system prior to plugging the well allowed the operator and drilling fluids technical personnel to determine the optimal formulation without the addition of any organophilic clay. The clay-free invert emulsion fluid served as an excellent packer fluid able to sustain long term suspension with minimal evidence of barite sag.

With conventional packer fluids, upon re-entry the operator generally has to plan for additional rig time and chemicals to condition the fluid for shipment, displacement or drilling ahead operations. By contrast the clay-free invert emulsion packer fluid requires very little chemical treatment or circulation time.

While all of the wells were successful, the following data is representative of the minimal mud weight fluctuations when re-entering the wells (Table 2, Figure 2).

Cost Comparison

The treatment costs per barrel to prepare a 14.0 ppg conventional clay-based oil- or synthetic-based packer

fluid would have been approximately 12 times higher than the cost per barrel to treat the clay-free invert emulsion fluid. This does not include additional circulating time needed to prepare conventional SBMs that also increase rig time and associated costs. The decision to use the clay-free invert emulsion fluid as the packer fluid also saved nine hours of rig time normally allocated to circulating and conditioning.

Conclusion

After the addition of approximately 0.5 ppb of a unique liquid viscosifier designed to work with the clay-free invert emulsion drilling fluid, the fluid was used successfully to maintain wellbore stability and the desired mud properties in temporarily abandoned wells over both the short and long term.

The clay-free fluid was found to have retained its properties after more than 300 hours of static time resulting from hurricane evacuations. Minimal conditioning time was required prior to resuming normal operations.

The clay-free system has also demonstrated reliable performance over the long term by serving as a packer fluid in several deepwater wells. Upon re-entering these wells after two or more years, the operator was able to return to bottom with significantly reduced circulating and conditioning time when compared to previous experience with conventional clay-based invert emulsion fluids.

As a result, rig time and associated spreadcosts were lower than expected. Because the system required significantly less treatment, total drilling fluid costs were also lower than expected.

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Nomenclature

ES = *electrical stability*
MD = *measured depth (ft)*
MW = *mud weight (lb/gal)*
PBTD = *plug back total depth (ft)*
PPB = *pounds per barrel*
PPG = *pounds per gallon*
SBM = *synthetic-based mud*
S/W = *synthetic/water ratio*
YP = *yield point*

TABLE 1 Original vs Re-entry Properties 14.6 ppg Clay-free Invert Emulsion Fluid

14.6 ppg packer fluid properties at time well was plugged (April 2003)

Date	Time	Circ Depth	Previous Circ Depth	Original Mud Wt.	Mud Wt In	Highest FL Mud Wt	Lowest FL Mud Wt	Total SPM	Pump Pressure	Max FL Funnel Vis	Gel Strengths	Yield Point	Tau 0
4/16/03	10:00 PM	22,439		14.6	14.6	14.6	14.6	93	2800	140	23-43-48	50	11.23

14.6 ppg packer fluid properties at time well was re-entered (Oct 2005)

Date	Time	Circ Depth	Previous Circ Depth	Original Mud Wt.	Mud Wt In	Highest FL Mud Wt	Lowest FL Mud Wt	Total SPM	Pump Pressure	Max FL Funnel Vis	Gel Strengths	Yield Point	Tau 0
10/15/05	11:00 PM	11,725	3,717	14.6	14.6	14.7	14.5	121	390	300+	17-35-39	28	10.01
10/18/05	1:00 AM	18,136	11,725	14.6	14.4	14.4	12.8*	121	5450	350+	25-52-61	33	12.06
10/18/05	7:00 AM	19,251	18,136	14.6	14.2	14.8	13.9	119	5500	350+	33-70-80	38	15.03
10/27/05	6:00 AM	22,197	19251	14.6	14.3	14.6	14.3	85	5100	280	20-48-54	20	10.09

* Encountered 100+bbl cement spacer

Table 2 Circulating Depths & Mud Weights for Case History Well								
Date	Time	Circ Depth	Previous Depth	Original Mud Wt.	Mud Wt In	Average Mud Wt Out	Total SPM	Pump Pressure
1/4/05	1600 hrs	3,790	3687	13.4	13.2	13.2	155	2300
1/4/05	1700 hrs	3,985	3790	13.4	13.2	13.2	155	2300
1/4/05	2200 hrs	5,514	3985	13.4	13.2	13.1	140	2500
1/5/05	0315 hrs	7,501	5514	13.4	13.3	13.2	140	3200
1/5/05	1020 hrs	9,514	7501	13.4	13.3	13.2	140	3700
1/5/05	1500 hrs	10,450	9514	13.4	13.3	13.3	140	4000
1/5/05	2030 hrs	11,862	10,450	13.4	13.3	13.3	140	4150
1/6/05	0130 hrs	13,220	11,862	13.4	13.3	13.2	140	4580
1/6/05	0455 hrs	13,613	13,220	13.4	13.3	13.3	140	4800
1/6/05	0830 hrs	14,432	13,613	13.4	13.3	13.3	140	5200
1/9/05	1130 hrs	16,569	14,432	13.4	13.3	13.5	96	3400
1/9/05	1700 hrs	18,297	16,569	13.4	13.5	13.6	96	3400
1/10/05	0900 hrs	18,449	18,297	13.4	13.5	13.7	92	3400
1/12/05	0300 hrs	20,865	18,449	13.4	13.4	13.5	92	3900

Figure 1: This chart illustrates the average circulating depths and mud weights for the 15.4 ppg example well.

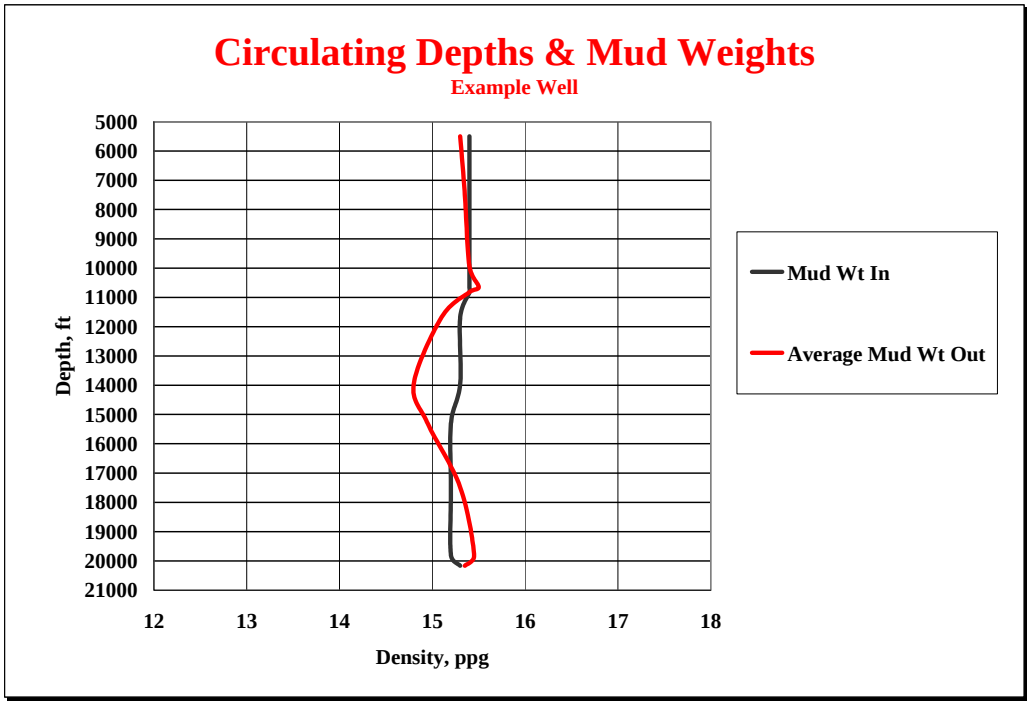

Figure 2: The average mud weight in for all eight wells was 13.3 and the mud weights at the flowline were 13.3. This chart shows the hydrostatic at the bottom of the well was the same. There was no barite plug or settling at the bottom.