AADE-22-FTCE-048

Field Case Study: Application of Microemulsion Technology in Displacement in the Colombian Foothills

Sebastian Mesa G, Felipe Quissak and Carlos F Toro, Baker Hughes

Abstract

The wells located in the foothills in Colombia, are characterized by their high complexity from the geological point of view, due to complex geology, the well was drilled in five different diameters and completed with three wide and long annular sections before completion operations. The first goal was to use microemulsion based technology to do a Wellbore Clean Out operation (WBCO) to change the surface from oil to water wet in different annular spaces through the well to prevent the contamination of the completion fluids and the formation damage associated with emulsions or solids from the oil base mud.. The second objective was minimize the filtration and circulation time to reduce the cost associated to rig and disposal.

For this application, it was necessary to do different simulations in a specialized software to evaluate the interaction between the microemulsion pills with the oil base mud used in the well, in terms of pressure, contact time and annular velocity in all the sections. Lab work was developed to validate the fluid/fluid compatibility and hole cleaning efficiency.

The WBCO operation was developed under the design parameters: Annular velocities, pill volumes, and contact times of the pills. Generating a reduction in circulation time close to 40% after the circulated the microemulsion pill train.

The operation was developed in a single stage, taking into account that in similar wells drilled in the past, it was required to carry out the displacement indirectly, increasing surface volumes, drilling times and costs associated with both aspects. The use of the microemulsion pill with ultra-low interfacial tension, self-diffusion and high cleaning efficiency helps to solubilize the oil and change the wettability of the surface to water-wet in complex wells drilled with oil base muds.

Introduction

As the industrial growth around the globe expands, the demand for energy from hydrocarbons correspondingly increases. As a result of increasing demand and as the cost of drilling and completion operations rises in a complex wells, measures to minimize formation damage during the completion phase has become a major focus during well planning (Jones, 2011).

The Eastern Cordillera Fold Belt covers an area of about 60,000 km2. It is located between the Magdalena River Valley and the Llanos Cenozoic Foreland Basin. During the Triassic-Jurassic and late Cretaceous, tensional/transtensional stresses, produced a system of asymmetric half-graben basins filled continuously with alternate marine and near shore to continental deposits. The deformation of these deposits occurred as a succession of events. The first event of late Eocene Early Oligocene age generated an imbricated system. The imbricated system was eroded and covered by upper Oligocene deposits. A subsequent transpressional event during Miocene to Pleistocene reactivated pre-existing thrust faults and re-folded the structures concomitant with the uplift of the Cordillera. See figure 1. Lithology – Stratigraphic Unit (ANH, 2007).

The most important petroleum reservoir rocks were deposited during Albian and Cenomanian time and Paleogene siliciclastic units with a wide range of petrophysical properties: average porosities between 5-10 % and permeabilities in the order of 4-100 md. (ANH, 2007). This type of formation are very susceptible to formation damage associated to solid particles invasions from drilling and completion fluids.

The wells drilled in the Colombian foothills are recognized as the major complex wells in Colombia, because their end depth, the pressure and temperature profile and the geological issues affect the project during the drilling phases. See figure 2 Common wellbore schematic in the Colombian foothills

The well involved in this paper was drilled with OBM and was completed with three annular spaces: casing of 11 ¾” and 9 5/8” and Liner of 7”x 5”. The well was drilled to a depth of 19,750 ft with a maximum angle of 23.38° and a BHT of 245 °F.

The big challenge in this job was to remove the oil base mud and change the wettability of the steels to guarantee the quality of the completion brines before the perforating to prevent the migration of particles to the reservoir and reduce the permeability in the near wellbore.

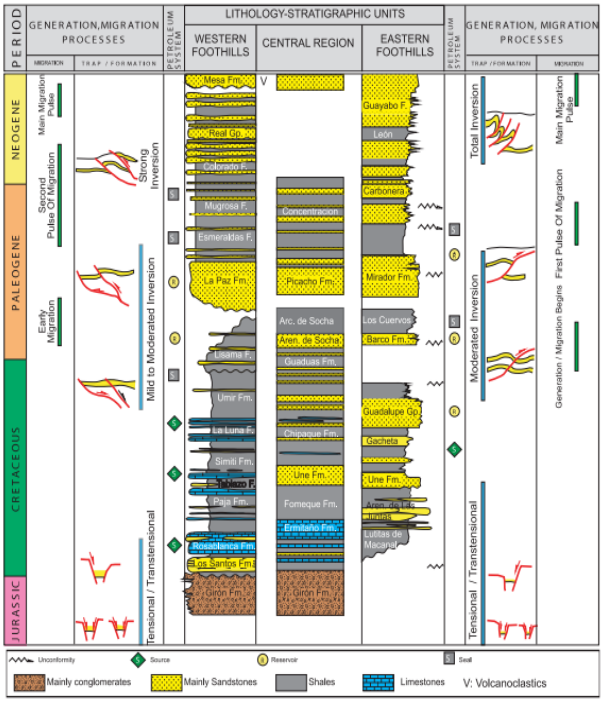


Figure 1. Lithology-Stratigraphic Unit, Eastern Cordillera (ANH, 2007)

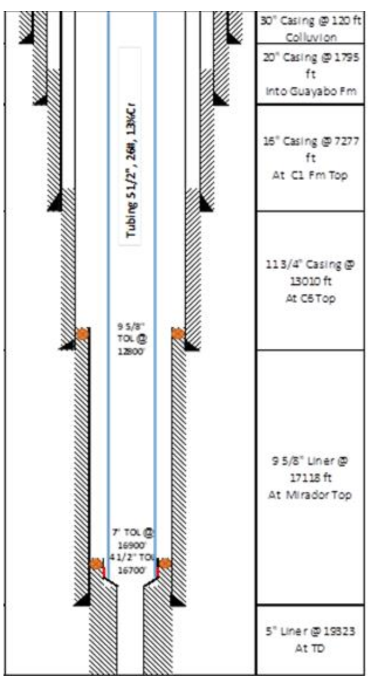


Figure 2. Common wellbore schematic in the Colombian foothills

Microemulsion technology was selected as an alternative to cleaning pills for its ultra-low interfacial tension properties, self-diffusivity and water wetting characteristics to help clean oil-wet surfaces. A microemulsion is defined as a thermodynamically stable clear fluid typically composed of a non-polar oil phase, a water phase, and surfactants. In some cases, additional components, such as co-surfactants and electrolytes are used to formulate microemulsions (Olsson, 1990).

For this job different software simulations, lab testing and field validations were developed. The next section describe the procedure to obtain a successful application in the field.

WBCO Pills Design

WBCO pill was designed to remove the OBM from the wellbore, clean all residue from metal surface and leave surfaces water-wet before clear brine displacement, the KPIs for this job were:

- Minimize pumping time
- Minimize filtration time
- Minimize contamination of OBM and Clear Brine
- Minimize waste volumes
- No HS&E issues

The WBCO pill design parameters are shown in table 1 below.

Table 1. WBCO Pills parameters design

BASE OIL SPACER	
Density, ppg	7.2
Length, ft	500
PUSH SPACER	
Density, ppg	10.5
Length, ft	1500
YP, lb/100ft^2	>45
Contact time, min	>10
Flow regimen	Laminar
CLEAN SPACER	
Density, ppg	8.4
Length, ft	1500
Contact time, min	>10
Flow regimen	Turbulent

The displacement in the field was pumped as shown in figure 3 to optimize the displacement (Javora, 2011).

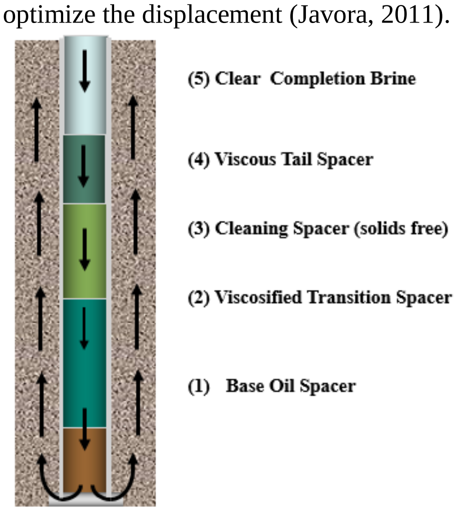


Figure 3. Sequence of pills pumped

Lab test

Laboratory tests were performed to

- Prove **Cleaning Spacer** is sufficient to clean well
- Prove that **Cleaning Spacer** can handle estimated OBM contamination
- Prove **Transition Spacer** is compatible with OBM

% of Cleaning Test

The cleaning test is performed using a FANN 35, which has been in contact with the OBM from the well for 30 minutes. The weight of the jacket is recorded with the addition of the OBM. The spacer is evaluated by putting it in contact for 1, 2, 4, 6 and 10 minutes, see figure 4.

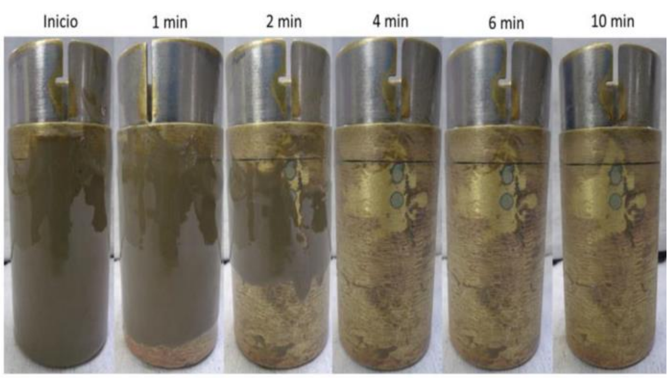


Figure 4. Cleaning spacer vs Contact time

Taking the weight of the jacket and the photographic record. To finish, the same procedure is carried out generating contamination with the OBM fluid with 5, 10, 15 and 20% to the clean spacer

Table 2. % Cleaning of Clean spacer vs % Contamination

Contact Time (minutes)	100% Clean Spacer 0% OBM	95% Clean Spacer 5% OBM
1	55.06	17.3
2	72.67	57.7
4	96.96	92.0
6	97.40	92.6
10	99.19	94.1

Table 3. % Cleaning of Clean spacer vs % Contamination

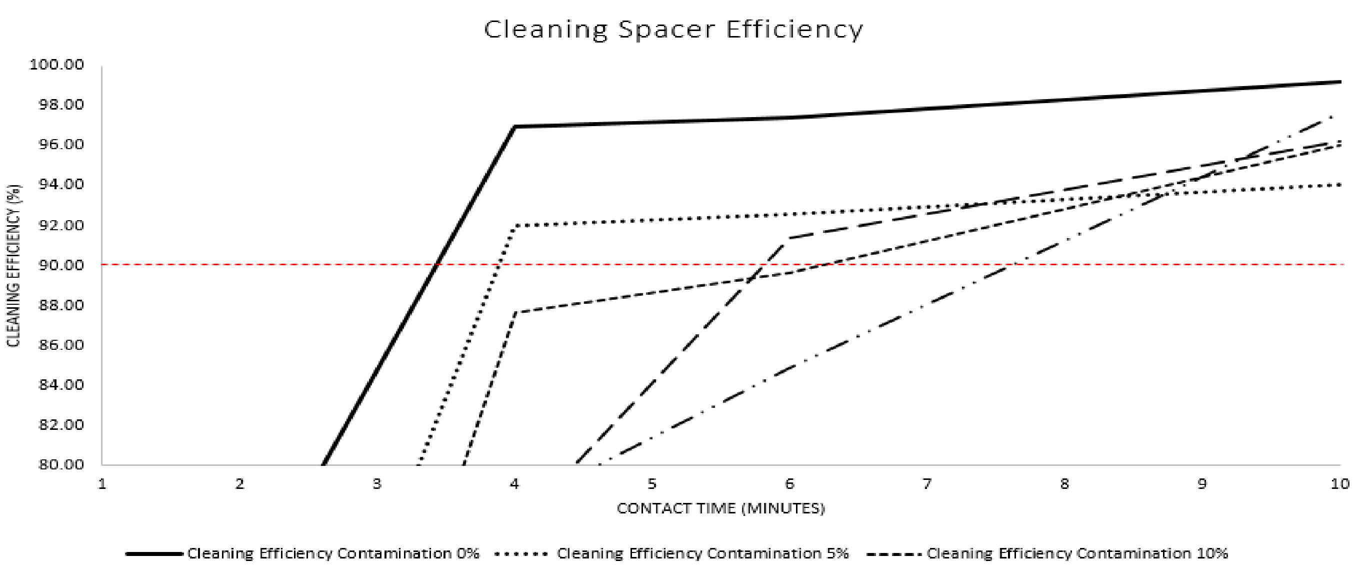
Contact Time (minutes)	85% Clean Spacer 15% OBM	80% Clean Spacer 20% OBM
1	24.3	19.4
2	49.6	46.6
4	76.9	77.9
6	91.4	84.9
10	96.2	97.6

Tables 2 and 3 shows the range of contamination that the microemulsion technology can tolerate without losing their cleaning properties. This test was developed to simulate and evaluate some issue through the displacement and prevent an additional displacement in the well.

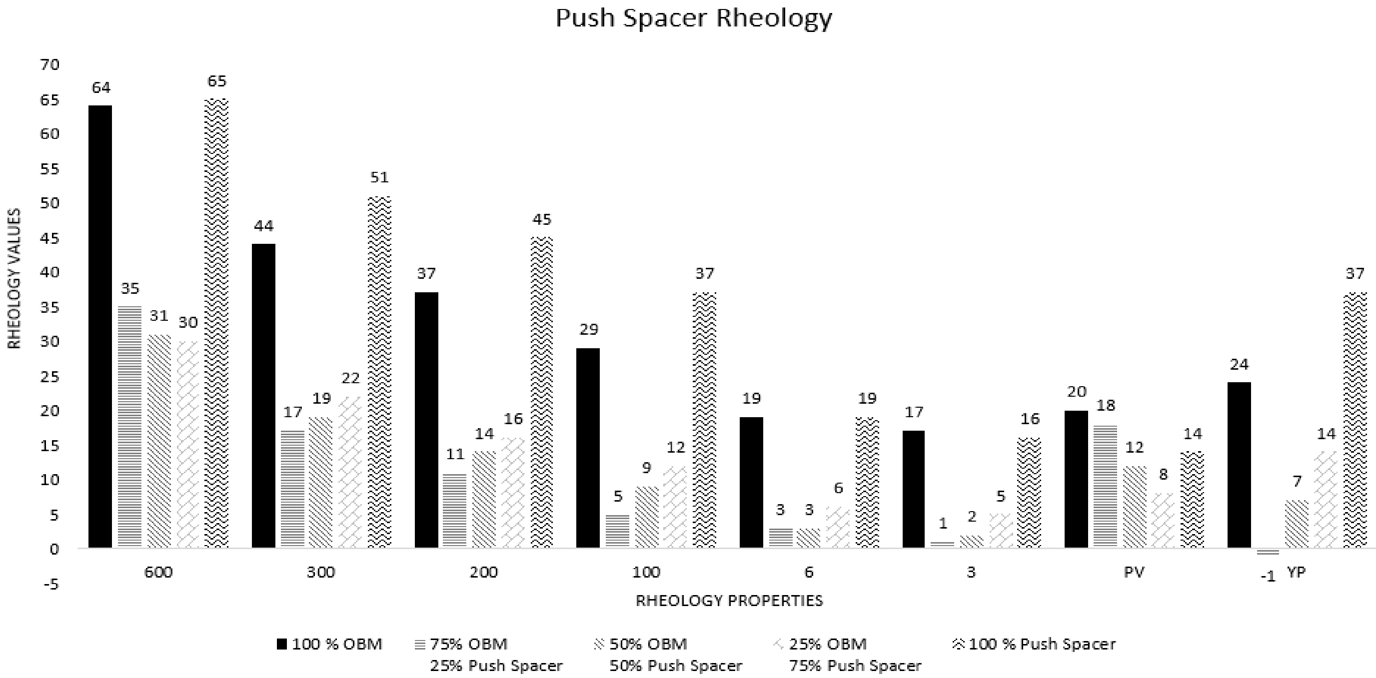
After the test, the cleaning spacer showed cleaning efficiency > 90% after 8 minutes of contact time. (see graph 1) with a 20% of contamination with OBM

Compatibility Test Push spacer vs OBM

The compatibility of the push spacer with the OBM drilling fluid in concentrations of 75% OBM – 25% Push Spacer, 50% OBM – 50% Push Spacer and 25% OBM – 75% Push Spacer is validated. This is to ensure that rheological behaviors do not occur that may require higher capacities in the pump and worsen displacement operations. Rheology tests are performed at 150°F.



Graph 1. Cleaning spacer efficiency



Graph 2 Push Spacer Rheology

Table 4. Rheology profile 100% OBM and 75/25 Mix

RPM	100% OBM	75% OBM 25% Push Spacer
600	64	35
300	44	17
200	37	11
100	29	5
6	19	3
3	17	1
PV, cP	20	18
YP, lb/100ft^2	24	-1

Table 5. Rheology profile 50/50 and 25/75 and 100% push spacer

RPM	50% OBM 50% Push Spacer	25% OBM 75% Push Spacer	100% Push Spacer
600	31	30	65
300	19	22	51
200	14	16	45
100	9	12	37
6	3	6	19
3	2	5	16
PV, cP	12	8	14
YP, lb/100ft^2	7	14	37

Tables 4 and 5 show how the rheology properties change when the ratio between OBM / Push spacer is increased. This test determined that the OBM and the push spacer are fully compatible, (see graph 2)

WBCO Pills Efficiency

The test was performed with the pills and contact time simulated in the software to have the specification of each pill at 150 °F

Table 6. Contact time pills

Pill	Contact time (minutes)
Base Oil	5
Push Spacer	8
Clean Spacer	8
High Vis Pill	6
Brine	10

Figure 5. WBCO Pill Efficiency

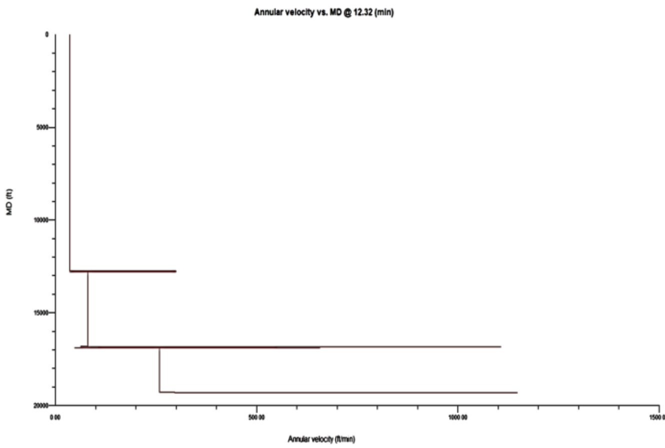
After the test, the percentage of cleaning was 99% and the steel surface water wet

Software simulation analysis

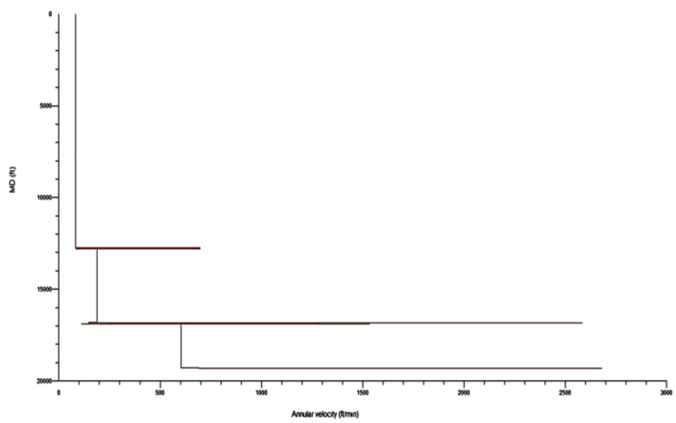
All simulation was performed in a hydraulic specialized software to calculate annular velocity, contact time, pressure on the pumps and ECD. For the analysis, wellbore schematic, BHA, pumps, BHT and BHP were considered

Annular Velocity

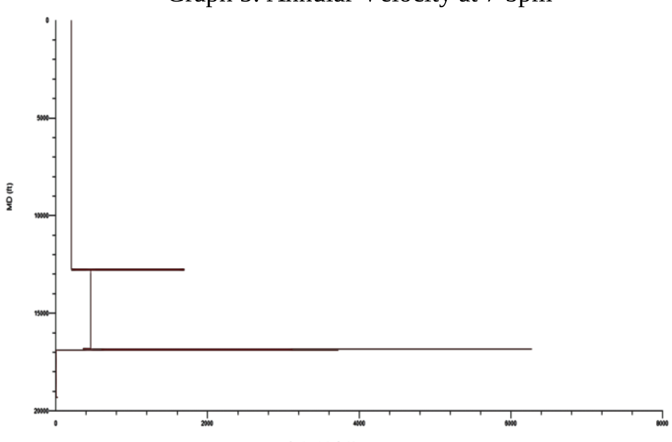
According to hydraulic analysis the displacement was performed to three different rates: 3, 7, 17 bpm (see graph 3)



Graph 4. Annular Velocity at 3 bpm



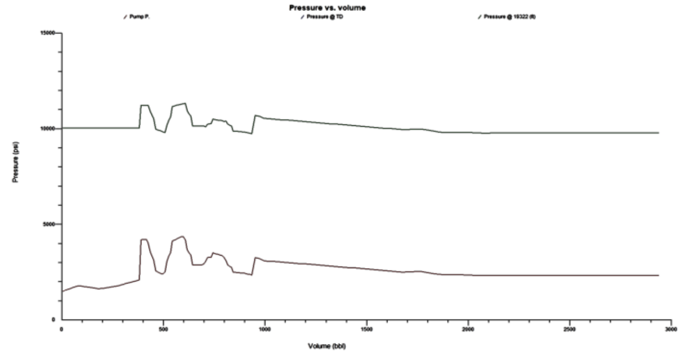
Graph 5. Annular Velocity at 7 bpm



Graph 6. Annular Velocity at 17 bpm

Pressure Analysis

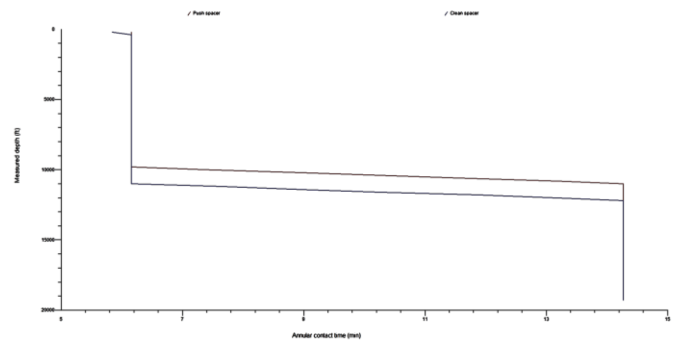
The simulation consider a circulation sub to increased the flow rate according the annular velocity analysis



Graph 7. Pump Pressure profile

The analysis show a maximum pressure on the pumps close to 4300 psi

Contact Time


Graph 8. Contact Time

According the simulation the micro emulsion pills have a contact time profile, and show a minimum contact time of 6 minutes when the well have the major annular space.

Field application

A quality control on the field was developed to validate the properties about each pill after mixed. API procedure for rheology properties and density was used.

Figure 6. WBCO Pills

The WBCO chemical operation was developed according to the procedures and technical assurances carried out by Baker

Hughes during the planning phase. The operation did not present operational inconveniences, reducing the planned circulation times from 8 to 5 hours. After removing it from the cleaning BHA pipeline, water-wet surfaces and parameters of the packing brine are observed according to Customer's operational guidelines. The annular velocities achieved throughout the entire well were as planned, which allowed to guarantee the effectiveness of the proposed microemulsion pills

Key performance Measures indicator			
Reference Indicator	**How to Measure**	**Target**	**Achieve**
Interface Volumes	Measure Interface volumes	<50 bbls	<15 bbls
Clean Return	Circulating Time	8 hours	4 hours
Waste Volume	Volume of Disposal waste	<100 bbls	<90 bbls
Tool Joints	Visual Inspection and photos	Free from mud residue	All tool joints clean
Brine Filtration	STT measurement	< 0.050%	<0.0023%
Clean Returns	Measure return volumes	< 100 bls	<50 bbls
Residual Solids recovered from well bore	Visual inspection of debris collections tools, filtration media	<70% solid recovery in the basket tool	<40% solid recovery baker tool
Water wet surface	No oil on the string during the first 10 stand	100% string water wet	100% string water wet

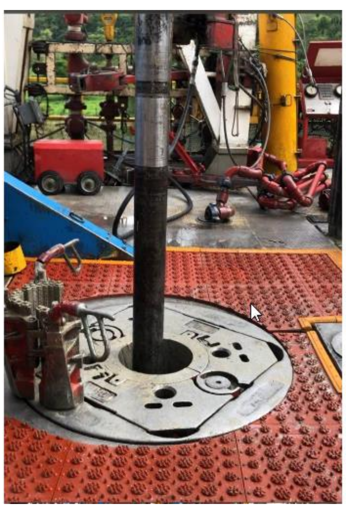


Figure 7. BHA after displacement

Figure 8. BHA after displacement

Figure 9 BHA After displacement

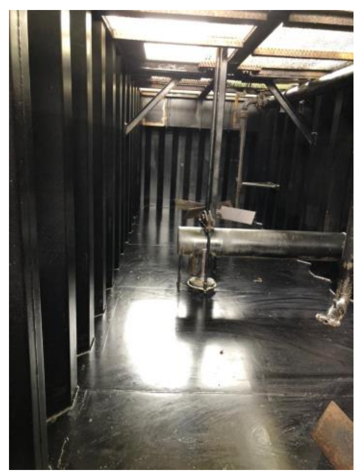


Figure 10 Mixing Tank before Cleaning with microemulsion pills

Conclusions

According to the results obtained during the simulation of the Clean Spacer pill contamination scenario with drilling fluid (up to 20% by volume), it is observed that the pill has a cleaning efficiency percentage of > 90% with a contact time greater than or equal to 8 minutes.

During the interaction with the OBM drilling fluid with the push spacer cleaning pill, there is no sudden increase in rheological properties that may indicate a possible incompatibility between the fluids.

After evaluating the pill train with the calculated contact time, a cleaning percentage of the rheometer jacket > 99% is observed, in addition to surfaces wetted by water.

According to the experience of past wells, the WBCO of the study well was achieved in a single run, optimizing drilling times and circulation times in addition to the costs associated with these times. Any additional volume or pre displacement by water was necessary in this applications.

The WBCO operation was developed under the design parameters: Annular velocities, pill volumes, contact times. Generating a reduction in circulation time from 8 to 4 hours after the cleaning pill train, additionally the operation was developed in a single stage, taking into account that in similar wells drilled in the past, it was required to carry out the displacement indirectly, increasing surface volumes, drilling times and costs associated with both aspects. After completion of the operation, water-wett surfaces are observed, both from the drill pipe and from the WBCO tools. The use of two filtration units in parallel made it possible to handle adequate surface circulation gallons, helping to reduce times.

Acknowledgments

We thank the management of Baker Hughes for allowing us to publish this paper. Special thanks to E. Luna, L.Olivella, A.Morales, Field personnel and the laboratory personnel in Bogota for their support in the field trial and the generation of laboratory data.

Nomenclature

OBM = Oil Base Mud
BHT = Bottom hole Temperature
BHP = Bottom Hole Pressure
BHA = Bottom Hole Assembly
°F = Temperature Fahrenheit
WBCO = Wellbore Clean Out
KPI = key performance indicator
ft = feet
% = percentage
" = inches
YP = Yield point
PV = Plastic Viscosity
Ppg = pounds per gallon
Lb/100 ft^2 = pounds per 100 hundred feet squared
ECD = Equivalent circulating Density
Bpm = barrels per minute

References

1. Quintero, L., Jones, T., Pietrangeli, G., "Phase Boundaries of Microemulsion Systems Help to Increase Productivity", SPE 144209, SPE European Formation Damage Conference held in Noordwijk, The Netherlands, June 7–10, 2011.
2. Quintero, L., Jones, T. A., Clark, D. E., and Twynam, A., "NAF Filter Cake Removal Using Microemulsion Technology".SPE-107499 presented at the European Formation Damage Conference held in Scheveningen, The Netherlands, 30 May–1 June 2007.
3. Olsson, U. Lindman B., "Uni and Bicontinous Microemulsions", in The Structure, Dynamic and Equilibrium Properties of Colloid Systems, ed by D.M. Bloor and E. Wyn-Jones, Kluver Acad Publishers, The Netherlands (1990) 233-242.
4. Barrero,D., Pardo, A ., Vargas, C., "Colombian Sedimentary Basins", ANH, 2007
5. Javora, P, Adkins, M., "Optimizing the Displacement Desing – Mud to brine" SPE 144212 presented at the SPE European Formation Damage Conference, June 7–10, 2011