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Innovative Scouring Spacer Applied in Liners Cementation Enhanced Zonal Isolation & Cement Bond Logs: Case Studies from the UAE

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Abstract
Achieving superior wellbore zonal isolation requires several critical factors, including efficient fluid displacement and effective mud removal. A fluid system pumped ahead of the cement slurry that creates a physical scouring and scrubbing action from the fluid can enhance the effectiveness of the gelled mud removal. Field data will illustrate the success of an innovative scouring fluid technology in wells where removing oil-based muds is challenging. This technology facilitates complete and effective cement placement, setting, and bonding, thereby achieving zonal isolation.

It is well known that effective mud removal is crucial for proper cement placement. Various solutions, including pre-flushes design, casing accessories, drilling fluid adjustments, and distinctive operational procedures before and during cementing operations, have been explored in this context. However, it is often impractical to implement all best practices for mud removal, potentially compromising zonal isolation. This paper focuses on the design, laboratory testing, and deployment of scouring spacer technology to enhance mud removal prior to the introduction of cement. This novel, one-sack solution is used as a fluid to facilitate the cleaning of wellbore surfaces, effectively removing drilling fluids and ensuring the wellbore annulus is ready for optimal cement bonding.

The scouring spacer under study demonstrated superior performance in the laboratory-modified rotor test, achieving a cleaning efficiency above 90 percent, while other conventional spacer systems did not surpass 62 percent. The primary cementing operations covered in this paper were completed successfully as per design and safely pumped through small restrictions (e.g., liner hangers). Cement bond logs from these field applications demonstrated consistent superior results. The scouring spacer can be utilized in cementing operations involving difficult-to-remove drilling fluid to enhance mud removal and fluid displacement efficiency, optimizing cement slurry placement, minimizing the formation of micro-annuli, and reducing the likelihood of annular pressure build-up.

Introduction
Achieving zonal isolation is crucial during primary cementing operations, as failure to do so can compromise planned hydrocarbon production. In such cases, remedial cementing may be required to establish a hydraulic seal across the targeted formation(s). Poor cementing can also lead to unwanted consequences, including casing corrosion, subsurface annular flow, unintended zone stimulation, and potential annular surface pressure. One of the primary causes of inadequate zonal isolation during primary cementing is insufficient mud removal.

Mud Removal Best Practices
Effective mud removal is achieved through a combination of engineered solutions and field best practices. These include pre-cementing mud circulation, the use of washers and weighted spacers, proper tubular centralization, casing reciprocation and rotation, as well as the application of scratchers/scrapers and high displacement rates. This study introduces an engineered scouring spacer, demonstrating its significance in mud removal strategies for non-aqueous fluids based on laboratory testing and field applications.

Wellbore Condition
Wellbore construction is a critical consideration from a cementing perspective, with the objective of maintaining a gauge open hole as close as possible to the drill bit size. This approach optimizes fluid displacement, mud removal, cement placement, and overall zonal isolation. Enlarged holes can create pockets of non-displaced mud, leading to micro-annuli, unwanted fluid migration, and challenges in achieving adequate tubular standoff. In these sections, low annular velocity during cementing may result in poor displacement. To mitigate these risks, running caliper logs is recommended to determine the actual hole size, aiding in fluid volume estimation (spacer and

cement slurry), centralization placement, and mud displacement efficiency. The raw caliper data can also be integrated into cementing software to enhance job design accuracy.

Drilling Fluid Circulation

While the tubular to be cemented is being run in the hole (RIH), the drilling fluid remains in a static condition. It is a field practice to circulate the drilling fluid to establish circulation once the tubular reaches the previous casing shoe and the casing joints filled while RIH to reduce the buoyancy force. The drilling fluid removal process starts when the tubular reaches its designed final depth and fluid circulation starts. The aim of this mud circulation is to remove all the unwanted solids (formation cuttings) that may be suspended in the wellbore to facilitate the mud removal process. It starts at low pumping rate of 2-3 bpm to slowly break the mud gels that developed during the static period until it reaches the maximum circulation rate or expected equivalent circulating density (ECD) during the cementing operation. A common practice is to circulate at least two bottom-ups the annular volume or until the returns to surface are clear of solids (<6%) and fluid density pumped-in is equal to the fluid density coming out of the wellbore. A low viscosity mud is also recommended to be pumped ahead of the cement pre-flushes to facilitate the mud removal process.

Cementing pre-flushes

During cementing operations, a pre-flush fluid is pumped to separate the mud from the cement, as oil-based mud (OBM) and cement are incompatible. Without proper separation, the fluid interface can form a viscous mixture that may be difficult or even impossible to displace. The cementing pre-flush can be a Newtonian fluid or a weighted spacer; both pre-flush fluids design must be compatible with the drilling fluid to be removed. The weighted spacer system must have higher rheological properties than the mud but lower than the cement, at both surface and downhole conditions to facilitate the mud removal. Failure to achieve this may lead to an intermixing of the fluids, leaving mud on the surfaces (casing and formation) of the annulus space. As a best practice, the volume of spacer to be used must have at least 10 minutes contact time and at have the density at least 10% above the density of the fluid to be displaced. Newtonian fluids may also be used if the ECD during the cementing operation is sufficient for the wellbore to remain overbalance and avoid formation fluids from entering the wellbore. This type of fluids can be aqueous, or oil based mixed with surfactants and/or solvents. Their purpose is to dilute the mud to facilitate its removal and often used in combination with a weighted spacer. Newtonian fluids can achieve turbulent flow at much lower rates when compared to Bingham, Power Law or Herschel-Bulkley fluids and its effectiveness is highly dependent on a good stand-off of the tubular. The cementing pre-flushes may include surfactant and/or solvents when the mud to be removed is OBM to change the wettability of the annulus surfaces from oil-wet to water-wet to facilitate the cement bonding with the casing and formation surfaces.

Centralization

Tubular centralization is key to achieving homogeneous fluid flow across the annulus space. To achieve centralization of the casing or liner in the open hole (OH) and casing-casing, centralizers are placed in the tubular joints. Centralizers can be flexible or rigid/solids, depending on the hole deviation. Flexible centralizers are recommended in vertical or not-highly deviated wellbores while rigid/solids centralizers are recommended in highly deviated or horizontal sections. The reason for not using flexible centralizers in highly deviated / horizontal is because the weight of the tubular in a deviated section can deform the centralizers, decreasing its efficiency. API RP 10D-2 recommends a minimum stand-off of 67% for bow-string (flexible) centralizers. An industry standard recommended for tubular centralization is above 70% stand-off, while other operators depending on the section to be cemented and wellbore conditions require centralizations tally to achieve 80-90% stand-off. The higher the centralization or casing stand-off, the more homogeneous annular flow, improved mud removal and cement coverage.

Other techniques

Reciprocation and rotation of the tubular during cementing are recommended practices, as these movements aid in the cleaning of cuttings from the wellbore. While rotating the tubular (typically 10 – 40 rpm), it starts to have an orbital or whirling movement in addition to the rotation around its axis, as can be observed in Figure 1. While reciprocating in an inclined section, the pipe has an alternating up and down or lateral movement in a section of the well in addition to the axial movement (Well Cementing, Second Edition).

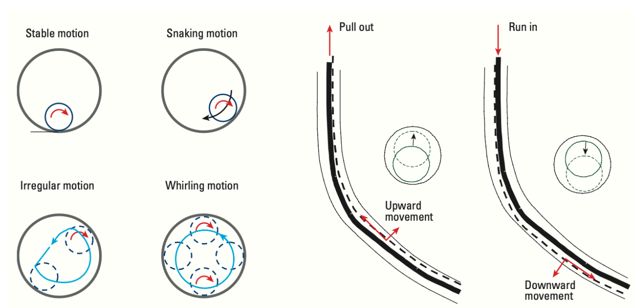

Figure 1 – Tubular rotation effect on the hole (right) and reciprocation effect on the wellbore while reciprocating up and down.

Casing accessories such as scratchers, scrapers and cable wipers mechanically erodes the mud filter cake and improve the mud removal process when they are performed in combination with the reciprocation and rotation of the tubular.

OBM contains non-polar molecules, which do not readily interact with the polar molecules in spacers. As a result, they tend to segregate and attach to the face of the formation and casing. To enhance cleaning properties, an engineered scrubbing material is added to the cement spacer, creating a scrubbing effect that removes the difficult to remove gelled mud from the casing and the formation. The engineered scrubbing material attracts the non-aqueous compounds via hydrophobic-hydrophobic interaction.

Scouring Spacer Technology Introduction

Industry best practices for drilling fluid removal include the engineering and field techniques outlined in the previous section. Non-aqueous fluids (NAF) pose the greatest challenge in mud removal, requiring a combination of chemical interaction (aided by surfactants and solvents when necessary), fluid flow optimization, and friction hierarchy principles.

This newly introduced scouring spacer enhances these methods by incorporating scouring particles within the spacer mix, creating a mechanical interaction with the annular surfaces. This scouring and scratching effect effectively aids in dislodging and removing gelled mud, which is often difficult to clear. Key advantages of the scouring spacer include:

- The scouring spacer is compatible with surfactants and solvent packages.
- This novel spacer system can also be used in conjunction with other spacers or chemical washers.
- Maintains performance when mixed with seawater or highly saturated brines.
- Rheology can be easily adjusted to preserve the friction hierarchy of fluids, optimizing the mud removal process.
- Effectively removes various OBM formulations from annulus surfaces.
- Can be used to displace other fluids from the wellbore.
- A single sack solution that can be mixed with conventional cementing surface mixing equipment.
- Performance remains unaffected by mud or cement contamination.

Technology Validation

To validate the scouring spacer, various laboratory tests were performed as per API RP10B-2 included rheological behavior on surface and downhole, fluids compatibility test, static stability test, free fluid test, dynamic stability test and reverse emulsion test. Additionally, an alternative to the API tests was introduced to monitor the cleaning efficiency of the scouring spacer. The results were then compared with a standard spacer system.

Rheological Properties

The rheological properties of the scouring spacer were measured in the laboratory at surface and at downhole conditions, using a FANN-35 viscometer. In Table 1 the 12.5 lb/gal scouring spacer formulation used in this study.

The rheology tests were performed at room temperature and at 170 F after conditioning for 30 min under atmospheric conditions. The test results can be observed in Table 2, the spacer sample showed good fluidity and mixability as well pouring at surface and downhole conditions achieving a Plastic Viscosity (PV) of 42 cP and Yield Point (YP) of 24 lb/100ft^2 at room temperature and 116 cP PV and YP of 17 lb/100ft^2 at 170 F.

Table 1 – Components of a typical 12.5 lb/gal scouring spacer

Description	Unit of Measurement	Concentration
Fresh Water	gal/bbl	33.56
Defoamer	gal/bbl	0.02
Scrubbing Concentrate	lb/bbl	20
Weighting Agent	lb/bbl	217.62
Surfactant	gal/bbl	1.0

Table 2 – Room temperature and downhole rheologies readings

	RPM	3	6	30	60	100	200	300
Surface Temp.	Reading -up	16	19	34	45	55	73	89
	Reading -down	15	19	34	44	54	71	89
170F	Reading -up	9	11	31	44	68	99	123
	Reading -down	9	11	29	42	66	96	123

Fluids Compatibility Test

While performing the cementing operations, the drilling fluid, pre-flushes and cement slurry get intermixed while been pumped downhole through the casing, or if mechanical separators are utilized, such as cement plugs, the intermixing will occur in the annular space. It is of most importance to ensure the fluids are compatible when NAF drilling fluids are present. Fluid incompatibility can result in a fluid mixture of high viscosity that can jeopardize the cement slurry placement.

To test the compatibility, the fluids are intermixed at different ratios and conditioned at downhole temperature and rheological properties are measured. In Table 3 compatibility can be observed between a 11.7 lb/gal OBM drilling fluid, a 12.5 lb/gal scouring spacer and a 15.8 lb/gal cement slurry.

Table 3 – Compatibility test between the drilling fluid (NAF), scouring spacer and the cement slurry

Fluid Mixture (% By vol)	3	6	30	60	100	200	300	PV	YP
100% Mud	6	8	21	29	36	42	58	48	14
95% Mud 5% Spacer	10	13	22	34	45	63	95	82	14
75% Mud 25% Spacer	9	11	21	35	40	48	69	56	15
50% Mud 50% Spacer	10	11	21	31	40	48	69	56	15
25% Mud 75% Spacer	9	12	27	40	59	94	110	105	16
5% Mud 95% Spacer	10	12	28	41	63	91	118	109	16
100% Spacer	9	11	31	44	68	99	123	116	17
5% Cement 95% Spacer	10	13	28	41	64	92	128	117	16
75% Cement 25% Spacer	10	12	30	43	68	95	134	123	16
50% Cement 50% Spacer	11	13	33	50	73	100	145	131	18
25% Cement 75% Spacer	10	11	26	52	70	105	140	133	16
95% Cement 5% Spacer	10	13	32	61	80	104	160	143	19
100% Cement	9	13	32	62	84	114	150	140	20

Dynamic and Static Stability Test

To test the scouring spacer stability, a dynamic and static stability test is performed. A laboratory sample of scouring spacer is prepared in the laboratory as per Table 1 composition. The prepared scouring spacer is placed in the slurry cup of an HPHT consistometer under the field application downhole conditions. Once the fluid is under downhole condition, the motor is switched off for 1 – 2 hrs and switched on again to continue the test under downhole dynamic conditions. This procedure will detect any potential hi-gels or settling behavior in the spacer system. This test has an average duration of 3-4 hrs. for the intended field application. Once the test is completed, the consistency chart is revised for any decrease on the consistency of the spacer under downhole condition, also the slurry cup paddle and the bottom of the cup are visually inspected to ensure there is no agglomeration or settling of the scrubbing particles contained in the spacer mix, as observed in Figure 2.

The density of the fluid tested in the HPHT consistometer is taken and placed in a 250-ml graduated cylinder and into water bath for 2 hrs. Once this is completed, the sample is visually observed to ensure there is no free fluid on top the sample. Spacer samples are taken from top, middle and bottom with a syringe and the densities are measured to ensure there are no considerable variations between the initial density of the fluid and after the completion of the test from top / middle and bottom of the graduated cylinder.

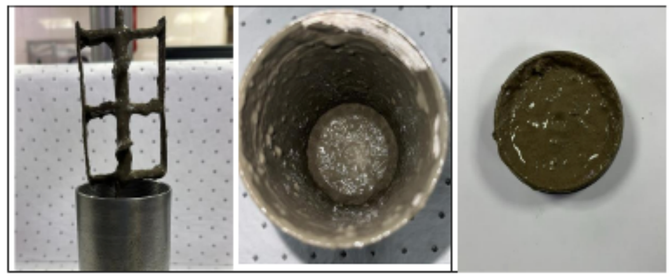

Figure 2 – Slurry cup paddles and cup bottom visual inspection of 12.5 lb/gal scouring spacer sample

Spacer Surfactant Screening Test (SSST)

When using oil-based mud, the wellbore surfaces are oil-wet; this condition will have to be converted to water-wet to allow the cement slurry to bond with the casing and formation surfaces. While most of the mud removal when using the scouring spacer occurs by the mechanical interaction between the scouring particles of the spacer and the difficult-to-remove gelled mud, a surfactant is required to convert the wellbore surfaces from oil-wet to water-wet. A SSST or Water Wetting Capability Test (WWCT) is performed as per the API RP10B-2 to measure the change in conductivity. Samples of the oil-based mud and the scouring spacer are conditioned at 170 F in the atmospheric consistometer, in a pre-heated wettability tester, the heated scouring spacer is added, and the conductivity is adjusted at 1.25 mAh. The mixing jug cleaned and 200 ml of the oil-based is added at 2,500 - 3,500 RPM at the desired temperature (Expected bottom hole circulating temperature (BHCT) for the field application). Scouring spacer is added slowly into the oil-based mud sample until the conductivity reaches 1.25 mAh and remains stable. The volume of spacer required is documented. In the Table 4 it can be observed the results of the RET for a 12.5 lb/gal scouring spacer into a 11.7 lb/gal NAF performed at 170 F with a volume of 200 ml OBM sample.

Table 4 – Reverse Emulsion Test results for a 12.5 lb/gal scouring spacer in a 11.7 lb/gal oil-base mud field sample

Spacer Volume (ml)		Conductivity (mAh)
0	0	0
100	33	0
120	38	0.5
140	41	0.9

160	44	1.25
180	47	1.25
200	50	1.25

Modified Rotor Mud Removal Efficiency Test

To evaluate the performance of the scouring spacer, a non-API test was developed. A modified rotor that can fit into the standard rheometers, with the bottom part closed is used. The modified rotor has a sandblasted surface to simulate the non-polish casing external surface and facilitates the mud adherence to the rotor. To perform the scouring spacer mud removal efficiency test, a pre-weighed rotor is submerged into a pre-conditioned sample of fluid to be tested (NAF) at 170 F, the bottom part wiped clean and the rotor weight measured. A pre-conditioned scouring spacer sample is poured into a test cup. The coated NAF rotor is tightened to the rheometer and is submerged in this scouring spacer sample and rotated at 100 rpm for 10 min. to simulate the mud removal best practice of 10 min. pre-flush contact time. Once completed, the test cup is removed, and the scouring spacer is replaced with fresh water. Submerged the rotor in the water and set the viscometer to rotate at 100 RPM for 5 min to remove any scouring spacer that may be attached to the rotor walls. After completion, the modified rotor is detached from the rheometer and the bottom part of the rotor is dried, then the rotor is weighted. The difference of the initial and final weight after the completion of the test is used to calculate the mud removal efficiency, the Eq.1- Eq3 formulas are used to calculate the test results:

$$\%\,\boldsymbol{NAF\ removed} = \frac{\boldsymbol{Mass\ of\ mud\ initially\ on\ rotor\ (g) - Mass\ remaining\ on\ rotor\ (g)}}{\boldsymbol{Mass\ of\ mud\ initially\ on\ rotor\ (g)}} \times \mathbf{100} \quad \text{(Eq. 1)}$$

Where:

$$\boldsymbol{Mass\ of\ mud\ initially\ on\ rotor\ (g) = Initial\ rotor\ weight\ sumerged\ in\ mud\ (g) - Initial\ rotor\ weight\ (g)} \quad \text{(Eq. 2)}$$

$$\boldsymbol{Mass\ remaining\ on\ rotor\ (g) = End\ rotor\ weight\ (after\ sumerged\ in\ the\ scouring\ spacer)\ (g) - Initial\ rotor\ weight\ (g)} \quad \text{(Eq. 3)}$$

In Figure 3 can be observed the results of a 12.5 lb/gal scouring spacer mud removal efficiency test on a 11.7 lb/gal field sample of an OBM with an efficiency of 99.30 percent. In this test, the initial rotor weight was 129.78 grams and after being submerged as per the described test procedure in the tested OBM, the weight of the rotor was 131.25 grams. The final weight of the rotor after being rinsed in water was 129.79 grams, obtaining the previous mentioned result.

Figure 3a Figure 3b Figure 3c

Figure 3 – Modified rotor coated in the 11.7 lb/gal OBM field sample (3a). Rotor after 10 min submersion into the scouring spacer (3b). Rotor after being submerged in water (3c).

An additional test was performed with the same 11.7 lb/gal field OBM sample at 20 RPM to simulate slower fluid flow conditions. In this test, the initial rotor weight was 129.80 grams, and after being submerged into the oil-based mud sample, the weight of the rotor was 131.05 grams and after being rinsed with fresh water, the weight was 129.87 grams, resulting in a mud removal efficiency of 93.6 percent. The rotor after being submerged in OBM can be observed in Figure 4a, after being submerged 10 minutes at 100 rpm in the scouring spacer in Figure 4b and after rinsing the excess scouring spacer with fresh water in Figure 4c.

Figure 4a Figure 4b Figure 4c

Figure 4 – Modified rotor coated in a field OBM sample (4a). Rotor after being submerged in scouring spacer (4b). Rotor after being submerged in water (4c).

To compare the mud removal efficiency of the scouring spacer with conventional spacers, the modified rotor mud removal efficiency test was performed by submerging the rotor coated in the same oil-based mud sample in a 12.5 lb/gal conventional spacer with surfactant and with similar rheological properties. The initial weight of the rotor was 129.76 grams and once coated with the OBM, the reported weight was 131.02 grams and after being rinsed in fresh water the weight was 130.26 grams, resulting in 60.31 percent mud removal efficiency. On Figure 5a we can observe the rotor after the conclusion of the test, the residual mud can be observed on the surface of the rotor.

Figure 5a Figure 5b Figure 5c

Figure 5 – Final rotor condition tested with conventional spacer (5a). Final rotor condition after performing the 24 hrs. aging test for a conventional spacer (5b). Final rotor condition after performing the 24 hrs. aging test with the scouring spacer (5C).

Additional tests were performed for both the conventional and the scouring spacers with similar rheological properties. In these tests, the rotor was left submerged for 24 hrs inside the OBM mud sample. Once the time was completed, the rotor was exposed under test conditions. The initial rotor weight for the test done with the conventional spacer sample was 129.62 grams, and once coated in the OBM field sample after 24 hrs, the weight was 130.33 grams. Once the test was completed after rinsing the weight of the rotor was 130.01 grams and the calculated mud cleaning efficiency was 45 percent. The rotor surface after the completion of the test can be observed in Figure 5b. The conventional spacer cleaning efficiency was reduced from 60.31 (without aging) to 45 percent (with aging). For the scouring spacer mud removal efficiency test, the initial rotor weight was 129.66 grams, and the reported weight after coating the rotor for 24 hrs. with the same OBM sample was 131.46 grams. The mud removal efficiency was performed at testing condition and the final rotor had a weight of 129.71 grams, resulting in a cleaning efficiency of 97.22 percent. Both the aged and non-aged mud removal efficiency results show acceptable result for a 99.30 percent cleaning efficiency without soaking, dropping to 97.22 percent for the test where the rotor was submerged in mud for 24 hrs.

Technology Deployment

Case Study #1

A long, extended horizontal open-hole (OH) completion oil well was planned for drilling. The last cased section was a highly deviated 8½-in drilled hole and the casing point was set on top of the reservoir section, a 7-in liner was called to be cemented. The cementing operation in the highly deviated section presented a challenge. A 11.7 lb/gal OBM was used to drill this section, and due to the highly deviated geometry, with the liner shoe landing at 89 degrees, centralization was a challenge due to the highly deviated wellbore and the absence of a caliper log, making difficult the analysis of the hole condition, casing stand-off and fluid flow regime. Poor stand-off might cause differences in the fluid's annular velocity and fluid flow, which could lead to incomplete cement coverage. To mitigate the absence of the caliper log and ensure fluids contact time and cement coverage 20% OH fluids volume excess was included in the cementing simulations and final design, in addition the introduction of the engineered scrubbing spacer with a minimum volume of 100 bbl to ensure the OBM removal. Achieving zonal isolation was critical to avoid unwanted fluid flow through the cemented annular space, which could lead to annular build-up pressure (ABP), potential decrease in production and hydrocarbon migration to shallow underground aquifers reservoirs.

The scouring spacer was proposed to be pumped ahead of the cement slurry to remove gelled mud from the casing and formation walls. It was used in combination with a surfactant to water-wet the annular surfaces, followed by a 15.8 lb/gal lead slurry and a 16.7 lb/gal tail slurry, both formulated with expansion properties to mitigate chemical shrinkage during cement setting. In total, 100 bbl of 12.5 lb/gal scouring spacer was pumped, followed by 72 bbl of lead slurry and 55 bbl of tail slurry to cement the 7-in liner. The cement slurries were displaced using 11.7 lb/gal oil-based mud. The plug bumped in the float collar with 3,000 psi, and the float valves were checked to ensure they were holding pressure. Followed up by setting the top packer and POOH the liner running tool.

The cementing operation was successfully completed, with pumping pressures and fluid densities aligning with the cementing design. After setting the liner top packer, stinging out, and reverse circulating, spacer and good cement were observed at the surface. Setting time was allowed for the cement, and good cement was drilled in the shoe track. After the horizontal section was drilled successfully, the cement bond evaluation for the 12¼-in. and 8½-in. sections were completed together. A successful cement bond log (CBL) was obtained for the 8½-in. section, as shown in the CBL and ultrasonic cement bond log (USIT) in Figure 6. There is a complete cement coverage in the cemented 8½-in x 7-in section as well as in the casing-casing section, demonstrating good zonal isolation was achieved.

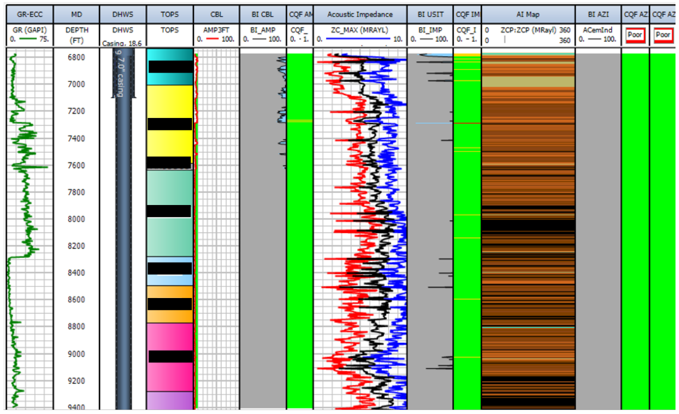

Figure 6 – Cement bond log (CBL & USIT) results on a field case study where the scouring spacer was deployed

Case study #2

In this case, an 8 ½-in highly deviated section, with maximum deviation of 89 degrees, required to be cemented to isolate the OH formations. This well drilled was to be a water injection well, zonal isolation is required in this section to ensure that the injected water is directed into the target reservoir to be drilled in the next section and does not migrate behind the casing to another unwanted formation. While drilling this section, a diesel based OBM at 11.5 lb/gal was used with PV of 25 cP and YP of 22 lbf/100ft^2.

A caliper log was not performed in this well section, making centralization and fluid placement simulations more challenging. To compensate, the final cementing design included a 20% excess of open-hole fluid volume and incorporated a scouring spacer with a minimum of 100 bbl in the mud removal strategy. A train of pre-flushes was recommended, including 200 bbl of low viscous mud, followed by 30 bbl of diesel, 50 bbl of 12.5 lb/gal scouring spacer, 20 bbl unweighted water-based spacer (chemical wash) and 50 bbl of scouring spacer. The diesel and water-based pre-flushes were paired with a surfactant. Two expandable slurries followed, with a 15.8 lb/gal lead and a 16.7 lb/gal tail slurry.

As this section was highly deviated, solid centralizers were recommended, centralization simulation was run with 20% OH excess, achieving optimum centralization with two centralizers per joint. There was no risk of losses as the ECD's during the cementing were within the operating window and did not surpass any of the formations fracture gradients.

The 7-in liner was run to TD as per plan, and the rig started to slowly break circulation and pumped a full cycle while reciprocating the liner. An additional bottom-up was performed while rotating the liner, then proceeded to connect the cementing lines, cement head and completed the pressure test at 5,000 psi. Dropped the ball and successfully set the liner hanger, released the running tool and sheared the ball seat. Started pumping 200 bbl low-vis pill while circulating the hole up to maximum of 5 bpm, without losses observed. Conducted pre-job safety meeting and started pumping the pre-flushes and the cement slurries, dropped the dart and commenced displacement. The dart latched in the plug and liner displacement continued till the plug bumped at the landing collar. The liner was pressure tested to 3,000 psi for 10 minutes, and the float equipment held. No returns were observed, and the line was bled off. Proceeded to set the liner top packer and started 1.5 times string volume reverse circulation, receiving on surface 15 bbl of good cement. POOH 1 stand dropped a foam ball and proceeded to direct circulate a full cycle volume to ensure the working pipe was clean.

After waiting on cement (WOC), RIH cleaning BHA, tagged cement at the top of the landing collar, and continued to drill the liner shoe track with 2-3Klbs weight on bit (WOB) and 2-3 Klbs of torque. While drilling the shoe track, started displacing the hole with 8.7 lb/gal non-damaging fluid (NDF), drilled 5 feet of new formation and performed flow check with the well static. Started drilling inside the reservoir horizontal section. Once drilling was completed, the rig proceeded to log the 8 ½-in and the 12 ¼-in sections. CBL and USIT were run, observing good cement across the 8 ½-in section as can be observed from the cement log in Figure 7. As per the operator standard operating procedure and the bond log results, good zonal isolation was achieved across the 7-in liner cementing operation.

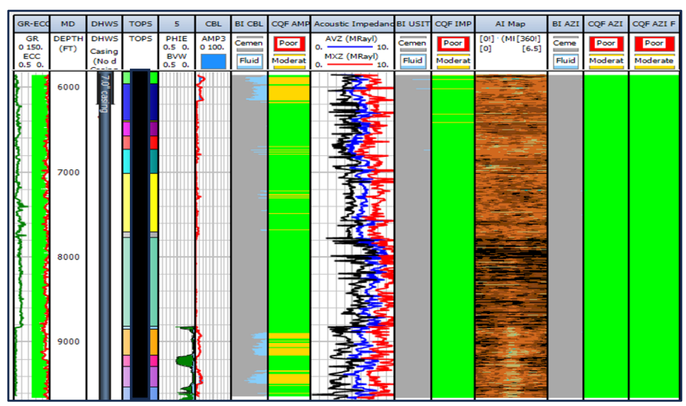

Figure 7 – Cement bond log results for case study #2 where the scouring spacer was deployed while cementing

Conclusions

The scouring spacer has been successfully tested in the laboratory, demonstrating enhanced mud removal, particularly in OBM drilling fluids. Compared to conventional spacer systems, the scouring spacer consistently achieves efficiency above 90%, whereas conventional spacers typically perform below 60%.

The scouring spacer has been proven to enhance water wetting of the casing and formation faces, improve mud removal, and strengthen cement bonding to both the casing and formation. This enables the operator to achieve effective zonal isolation while eliminating the need for costly remedial cementing operations, which can increase overall construction costs and delay hydrocarbon production. Given the continued success in cementing liner sections, scrubbing spacer technology has become a best practice for OBM sections and is now a standard procedure for the operator.

Building on the continued success in cementing liner sections, the adoption of scrubbing spacer technology has become a best practice for OBM sections, with over 16 successful jobs completed to date.

Acknowledgments

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Nomenclature

API = American Petroleum Institute
Bbl = Barrels
cP = Centipoise
ECD = Equivalent Circulating Density
HPHT = High-Pressure / High- Temperature
F = Degrees Fahrenheit
mAh = Milliamperes
min = minutes
NAF = Non-Aqueous Fluid
NDF = Non-Damaging Fluid
NRV = Non-Return Valve
OBM = Oil Based Mud
POOH = Pull Out of Hole
PV = Plastic Viscosity
RET = Reverse Emulsion Test
RIH = Running in Hole
RPM = Revolutions Per Minute
SSST = Spacer Surfactant Screening Test
WOC = Waiting on Cement
WWCT = Water Wetting Capability Test
YP = Yield Point

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