APPLICATION OF A UNIQUE LOSS CIRCULATION CURING CEMENT SPACER DURING CEMENT PLACEMENT IN GEOTHERMAL WELLS

Abraham S. Samuel (Consultant) Kenya , **Chike Uchendu** , **Francis Okoto** (Consultant), **Johnstone Maleche, Abraham Khaemba, Lawrence Murungi** – (GDC), Kenya and **David Kulakofsky** (Impact Fluid Solutions),
Email Address: Abrahamsamsamuel@yahoo.com

1. INTRODUCTION

As with oil and gas wells, maintaining well integrity is critical in geothermal applications. Typically, wellbore stability is achieved by replacing the drilling fluid in the annulus with cement, thereby providing effective zonal isolation. Achieving effective zonal isolation usually requires pumping a spacer system to replace the mud prior to the introduction of cement to the annulus. It is imperative that the spacer generate sufficient downhole force to overcome the yield stress of the mud, enabling it to be successfully displaced. Prior to cementing, the mud in the well is conditioned through circulation to ensure it maintains a uniform rheological profile in and out of the well to more easily enable displacement with the spacer. However, downhole losses occasionally prohibit circulation. While lost circulation material (LCM) is commonly used to cure losses encountered prior to cementing, the severity may be such that remediation with LCM is ineffective. Thus, proper mud conditioning could then further break down of the formation, leading to even more severe losses. This paper details the unique nature of a uniquely engineered wellbore shielding (WBS) spacer, which has demonstrated its capacity to cure losses with a mechanism that delivers a sealing effect in permeable and fractured formations. The authors will describe in a case study how the spacer has been used in remediating moderate to total losses experienced in both a low fracture gradient formation and an induced fractured geothermal well in Kenya.

2. PROBLEM AND SOLUTION

Unconsolidated formations and depleted reservoirs are two of the primary causes for lost circulation during drilling and cementing operations, often resulting in poor cement bond logs and failed top of cement (TOC) requirements. A common practice to address these well integrity problems is the application of lost-circulation materials and/or low-density cementing systems designed with densities of 10.5 to 11.0 lb/gal. Specialized low density cement systems, however, are not only difficult to work with, they tend to increase the overall slurry cost. Moreover, this approach does not consistently achieve the desired results, usually requiring remedial cement squeezes for many primary cement jobs in the targeted geothermal drilling location. To overcome these challenges, an innovative cement WBS spacer system was engineered and applied. This environmentally preferred spacer system contains a biopolymer that helps mitigate lost circulation issues during cementing. Furthermore, it strengthens the wellbore wall by forming an effective shield (seal) along the formation surfaces, thereby minimizing losses while preventing cement fallback after placement (Anugrah, et al. 2014).

The unique space was employed to meet the severe lost-circulation challenge encountered in the operator's wells in Kenya. Prior to cementing, conditioning the well showed total losses and subsequent remediation attempts with LCM proved unsuccessful. Consequently, the unique WBS cement spacer was used, owing to its dual-ability to form a seal across the loss zones and maintain good rheological properties that could be fine-tuned to enhance the displacement of unconditioned mud.

Delivering cement to surface is of particular importance in geothermal wells, especially in the annular spaces between casings. Without cement to surface, water trapped between casing may result in casing failure during the discharging period when the well is heated. Thus, putting these wells on production required the operator make sure cement gets back to the surface in both the 20-in. and 13 3/8-in. casing annuli. Well conditioning, likewise, is strikingly difficult in geothermal wells, because of their associated low fracture gradient. As a result, most operators refrain from required pre-job mud conditioning, which normally aids the capability of the cement and spacer to more easily push out the mud. In the targeted well, it was found that returning cement to surface during primary cementing was extremely difficult. Accordingly, top-out cement jobs were needed to achieve well integrity, but early results were so unsuccessful that, as many as 16 top-out cement jobs were required to completely fill the annulus.

3. DESIGN AND SEALING MECHANISM

The WBS cement spacer system helps mitigate lost circulation issues while cementing. As well as preventing induced losses the protective shield laid down by the WBS spacer also can minimize filtrate invasion and formation damage. Based on its ultra-low invasion fluid technology, the system forms a protective barrier (shield)_on the inside surface of the wellbore wall to effectively strengthen the wellbore. However, the system does not claim to increase the formation's fracture gradient, but rather, the formation can retain its integrity and permeability for optimized production because of the near 100% return permeability property of the WBS spacer.

After placement, the WBS spacer reduces slurry fallback to minimize lower-than-expected cement tops and reduce or eliminate costly remedial cement jobs. In wells with critical fracture gradients, the WBS spacer helps strengthen the wellbore, allowing the equivalent circulating density (ECD) during the cement job to exceed the fracture gradient without losses or reduced losses. This minimizes the need to compromise on thickening times and compressive strength and, in some cases, can eliminate the need for a stage collar.

The WBS cement spacer system can be used in high-temperature, high-permeability formations; formations with low fracture gradients; fragile, unconsolidated, and fractured formations. As shown in Figures 1a.-1d, the WBS spacer achieves its sealing properties in both fractured and high permeability formations.

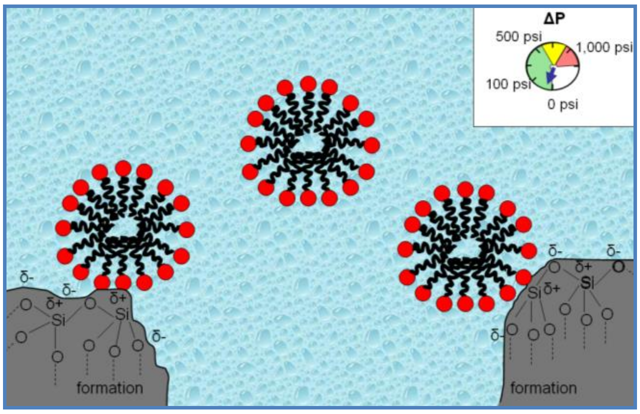

Figure 1a: Initially the WBS micelles are free floating in the fluid

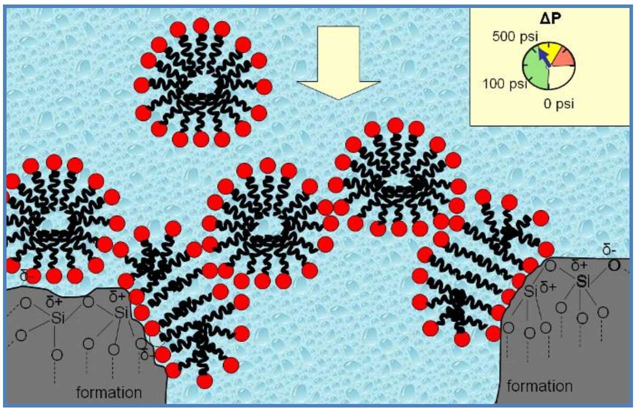

Figure 1b: As differential pressure increase the WBS micelles migrate towards the formation, are adsorbed, break apart and form a protective barrier

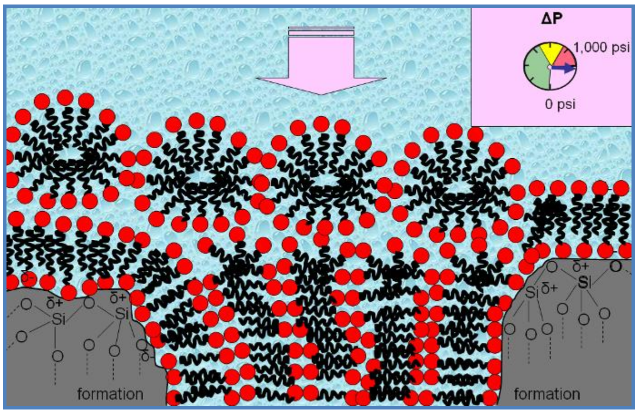

Figure 1c: At max differential pressure micelles form an nearly impenetrable surface layer

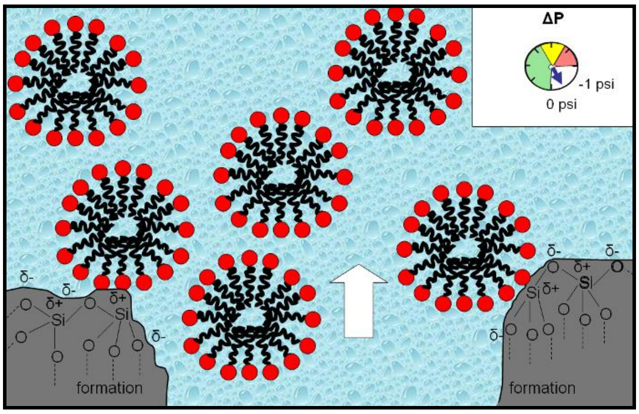

Figure 1d: As differential pressure is released micelles return to the flowing fluid leaving the formation permeability with essentially no damage

4. CEMENTING AND BEST PRACTICES

Merely incorporating a WBS spacer into the cementing program, without also employing good cementing practices will not provide optimal results. As lost circulation is more apt to occur during cementing operations, producing poor cement jobs, poor zonal isolation, increasing casing corrosion and mandating costly remedial cementing. Thermally stable mud properties and the micronized cellulose, in conjunction with the foamed cement, can be one of the effective methods of obtaining quality cement jobs (Rickard, et al 2010). As part of the effort to provide the best possible cementing results for these geothermal wells, focus is placed on standard cementing best practices. To obtain an effective annular seal a number of steps must be taken:

- **Pre-job mud conditioning** – During the static period between reaching section total depth (TD) and when the bottom hole assembly (BHA) is tripped out of the well and the casing or liner string run to bottom, the mud, which was designed as a dynamic system, has remained stagnant in the wellbore. Hence, the drilling fluid is potentially developing static gel strengths far in excess of that normally observed during the drilling process. To overcome this phenomena, it is critical every effort be made to return the mud system to its design properties, through physical circulation down through the casing or liner and back up the annulus. Bottoms-up twice is recommended.

- **Centralization** – If the pipe is not centralized in the well-bore it will create a wide side and a narrow side to the annulus. Since fluids follow the path of least resistance, the mud will differentially flow through the wide side with its greatly reduced frictional forces. As the eccentricity increases, the difference between the wide-side narrow-side flow rates also increase. In the worst case, the frictional force in the narrow side becomes so great that zero flow could actually result and the casing ends up not completely surrounded by a cement sheath. In the best case, good cement surrounds the lower portion of the pipe, but the desired top of cement (TOC) will fall short in the narrow side, unless sufficient excess cement is pumped to get the required narrow side TOC. However, to achieve the desired narrow side TOC, the TOC on the wide side will be substantially higher. With the new moulded centralizers built directly onto the pipe the lingering concerns of lost in hole no longer an issue. A standoff of 70-80% is recommended.

- **Spacer volume** – The most common rule of thumb for spacer volume is 10 min. of contact time or enough volume to cover 1000-1500 ft of open hole length. Contact time being simply the spacer volume divided by the displacement rate planned for the point in time that the spacer is across from the key zone in the annulus. While these are acceptable general rules, they ignore well specific conditions, such as hole size, mud condition and open hole length. Larger holes obviously require more spacer, and 1500 ft of 22-in. hole will be more spacer than normally desired. If the mud is not well conditioned or the job is dealing with a long open hole section, to achieve optimal results, the spacer volume must be increased. As the spacer is pumped, the leading edge mixes with the mud system, while the trailing edge mixes with the cement. As the open hole length increases these intermixing lengths also grow. If the spacer volume is insufficient, the contaminated volumes can grow together, leaving no spacer left to separate the mud and cement. Some zones with bad bond logs have been successfully converted to good cementing results simply by increasing spacer volume.

- **Pump rate** – The mixing rate for cement and spacer are not particularly important. Rather, the displacement and pre-job conditioning rates are what will significantly affect job results. These rates should always be as high as the equipment can handle without compromising the safety of personnel or the integrity of the formation and equipment. Even though higher rates will enhance hole cleaning, exceeding the fracture gradient can result in loss of bulk cement.

- **Hole Size** – The difference between the ideal hole to casing size diameter is 1.5 – 3 in. With smaller annular clearances, slight eccentricities can lead to high enough frictional pressure drops to prevent flow up the narrow side. Larger gaps, on the other hand, result in low annular velocities making hole cleaning less effective.

- **Rheological hierarchies** – To aid in the displacement process it is important that each successive fluid have a higher frictional pressure drop. Thinner fluids can channel up through the fluid it is supposed to be displacing.

- **<u>Density hierarchies</u> -** To aid in the displacement process it also is important that each successive fluid be heavier than the previous one. Under static conditions, higher density fluids can fall through lighter fluids, after the plug lands.

5. SPACER DESIGN AND STRATEGY

A quality spacer design will include volume sufficient to effectively maintain separation between the mud and cement systems, with rheological properties sufficient to push any non-mobile mud out of the annulus. The most effective spacer systems also include specialized lost circulation characteristics that can both prevent losses caused by the increased ECD often associated with the later portions of cement jobs and help stop losses already encountered. The subject WBS spacer discussed herein can handle both of these common cementing problems. This spacer includes special wellbore shielding components that lay down a very thin permeability barrier membrane that can shield the formation from the effects of excessive pressure. The mechanism, as illustrated in Fig. 1a-d, is a shield that allows cement to circulate under conditions that otherwise would result in fracturing and loss of cement resulting in a lower than desired TOC.

Additionally, a synergistic LCM was designed specifically for use in conjunction with the WBS spacer. This combination is used in jobs where losses are present even before the wellbore is exposed to the higher ECD associated with cement jobs. In geothermal wells, this specialized LCM should be mixed into the WBS spacer. When the synergistic LCM is incorporated into the spacer, it helps control any existing losses prior to cement entering the annulus. As in the targeted Kenya wells, this system allows heavier cement to be circulated in instances when the mud in the well is not circulated out due to the losses experienced during the drilling phase.

6. EXECUTION

As the operator was preparing to drill its third geothermal well on Well Pad A, it was decided an alternative strategy for the cementing design was required to avoid the problems experienced, not only with the previous two wells on this pad but also with two offset wells. During the cementing of the 20-in. and 13 3/8-in. casing in previous wells on the pad, uncontrolled severe losses were experienced during the drilling phase, thereby resulting in a severe TOC shortfall. Multiple top-out jobs were carried out to return cement to surface. In order to avoid, or at least minimize, these problems the operator decided to try the WBS spacer system in tandem with the synergistic LCM product. As with the previous wells, during drilling of the fifth well, total losses were encountered once the casings were run to bottom. However, while full circulation was not completely achieved, the assistance delivered by the specialized WBS spacer system, in the fifth well, brought TOC much closer to the surface on the A2 well, as documented in Tables 1 & 2.

Well	Well A	Well A1	Well A2
TD (m)	50.3	72	72
Casing Depth (m)	47.2	69.2	69.2
Number top-jobs	16	7	2
Top-job volumes (m^3)	166	167	22

Table 1. Cement top-job requirements for the 20 inch casing for the three A pad wells

Well	Well A	Well A1	Well A2
Number top-jobs	9	7	2
Top-job volumes (m^3)	81	137	38

Table 2. Cement top-job requirements for the A pad wells – 13 3/8 inch casing

For the 20-in. casing jobs the number of top jobs reduced from an average of 11.5 to 2, for an appreciable savings in both costs and time. Additionally, the extra cement required to finish filling the annulus was reduced from 166.5 m^3 to 22 m^3. Comparative analysis of the 13 3/8-in. cementing jobs show a similar improvement as the top jobs decreased from 8 to 2 and the required cement volumes from 108 m^3 to 39 m^3. Both of these jobs used 65 bbl of the WBS spacer with a slurry density of 9.1 lb/gal. The system was mixed with a concentration of 15 lb/bbl of spacer concentrate and 30 lb/bbl LCM.

While the WBS spacer will slightly increase the cost of the initial primary cementing job, if the more conventional spacers do not work, the WBS spacer system can drastically reduce the overall well cost. In Well A2, two WBS spacers, plus four top-out jobs cost $199,640. In wells A & A1 the average cost of the 15.5 top-out jobs was $529,144. The resulting initial cost savings generated, after taking into account the additional cost of the spacer with the enhanced features of the WBS spacer, was $329,504. Additional future savings may be generated during the life of the wellbore resulting from the better initial cement jobs achieved with the WBS spacer. Remedial top-out jobs rarely provide as good a cement bond as that achieved with the primary cement job.

7. CONCLUSIONS

- A properly designed cement job can yield better results.
- The use of an optimized WBS spacer system can improve results when used in wells with a narrow mud-weight windows and/or mud losses ranging from minor to total.
- The costs required to do a cement job properly at the onset will often reduce the overall well costs, especially when taking short-cuts compromise the wellbore integrity. In the discussed case study, the premium solution provided a clear economic and technical advantage.

REFERENCE

Anugrah, A., Budiawan, A., Indro Pratomo, D., Brandl, A., & Shahabadi Farahani, H. (2014, August 25). Innovative Cement Spacer Improves Well Cementing Integrity - 60 Case Histories Reviewed. Society of Petroleum Engineers. doi:10.2118/170545-MS

Rickard, B., **Samuel, A. S.,** Spielman, P., Otto, M., & Nickels, N. (2010). Successfully Applying Micronized Cellulose to Minimize Lost Circulation on the PUNA Geothermal Venture Wells. Geothermal Resources Council Transactions, 34, 253-260. Retrieved from ISSN: 0193-5933; ISBN: 0-934412-95-2.