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Reverse Circulation Foamed Latex Cementing Method and Application In Geothermal Wells

Abraham Samuel
3000 N Sam Houston Pkwy E, Houston, TX-77385, USA
Samuel.abraham@halliburton.com

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ABSTRACT

Several challenges are encountered while geothermal well casings are cemented because of high temperature, presence of carbon dioxide, and lost circulation. To address lost circulation, one method is to pump the cement job in the reverse path down the annulus while taking returns through the casing or drill pipe. This reduces the bottom hole circulating pressure and the chance of formation breakdown, which minimizes the need for top out jobs. The presence of carbon dioxide in some of the wells can lead to corrosion, and well integrity can be comprised. To deal with this issue, a foamed latex cement blend was used for proper zonal isolation instead of the conventional Class G cement mix. The successful execution of this cementing process is based on proper cementing design, appropriate equipment for cement pumping, detailed planning of the job, and flawless execution of the plan.

1 INTRODUCTION

In many of the geothermal wells, multiple loss circulation zones are encountered while drilling which may range from partial to total losses, and these loss zones need to be sealed. After a particular hole section has been drilled, the casing must be run and cemented in place with the annulus filled with cement to provide support and protection for the casing, Rickard et al. (2011). The primary cement job must be performed effectively to maintain well bore integrity, with minimal losses while pumping the primary job to reduce top jobs. In conventional cementing procedures, the cement is pumped down the casing or drill pipe, and it flows up the annulus space to fill the casing by open hole and casing-by-casing annular space. This is the commonly used method for pumping cement slurries in the well, but may not work in all the geothermal wells which have fractured formations. When the cement is lifted into the annulus, the high pressure (equivalent circulating density) tends to cause the formation to break down, and the cement is lost to the formation preventing full annular coverage of cement to surface, which may require remedial cementing operations. The pumping of cement down the casing string or drill pipe requires cement retarders to be added to the formulations to prevent the cement from setting up quickly. Reverse circulation is an alternative method to effectively place cement. The cement slurry is pumped through the side outlet valves into the annular space (Fig. 1), while returns are taken up the casing or drill pipe. This can reduce the high pressures needed to lift the cement slurry up the annulus and eliminate the need for some additives due to minimal displacement required.

The carbon dioxide in the formation when combined with formation water becomes carbonic acid and causes corrosion and affects the cement in the annulus. Latex cement formulations with ultra-low permeabilities can provide acid resistance, reduce the permeability of the cement, improve zonal isolation and have excellent fluid loss properties. The latex cement can be foamed to form an improved cement sheath which has a lower cement density, adequate compressive strength, low permeability, improved placement across fractured and weak zones, along with enhanced displacement efficiency.

2 REVERSE CIRCULATION FOAMED LATEX CEMENTING

The reverse circulation cementing process provides a viable method to fill the entire annulus around the casing by lowering the equivalent circulating density (ECD), reducing the risk of the formation breaking down and cement returns being lost. The exposure time of the cement to the higher formation temperature is lower than the conventional placement method especially when the casing setting depth is relatively deeper and excess cement volumes can be pumped to account for the bigger hole sizes drilled in weaker formations. Other advantages of this method are gravity-assist placement, possible customization of setting order of cements, reduction and customization of transition times and slurry design of waiting on cement (WOC) time at various temperatures in the annulus, Spielman, et al. (2006). The disadvantages of this method could be the cement

channeling if drilling mud has not been properly conditioned, contaminated cement inside the casing, and the proper placement of cement around the casing shoe. While using the inner string method, the operation must be carefully planned and coordinated during the execution as different valves need to be opened and closed at various stages of the cement job.

2.1 Reverse Circulation Cementing – Planning and Execution

The selection of cement density is based on the result of the formation integrity test (FIT) or leak off test (LOT) that was performed in the geothermal well and/or correlating the case histories of nearby wells if available. The simulation of the cement job execution provides anticipated pumping pressures and the maximum ECD's at various depths along the wellbore. The objective of the simulation is to stay below the LOT pressure or density by using a lighter weight cement slurry or varying pump rate. High pumping pressures can cause the undesirable effect of inadvertently "floating" the casing string upward, Hernandez and Nguyen (2010).

2.1.1 Cementing Design

The latex cement slurry was designed by Halliburton as a preventive measure to help resist corrosion from naturally occurring brines, and carbon dioxide, have good fluid-loss control, low viscosity and high temperature solid suspension properties, Hernandez and Nguyen (2010). By adding foam to the latex cement, the cement slurry density is reduced to improve cement placement in formations with low fracture gradients. The compressible property of the slurry increases and protects against gas that could invade into the annular space. Foamed cement is also a more ductile set cement and can tolerate expansion and shrinking without losing its sealing capabilities, Spielman et al (2006) (Fig. 2).

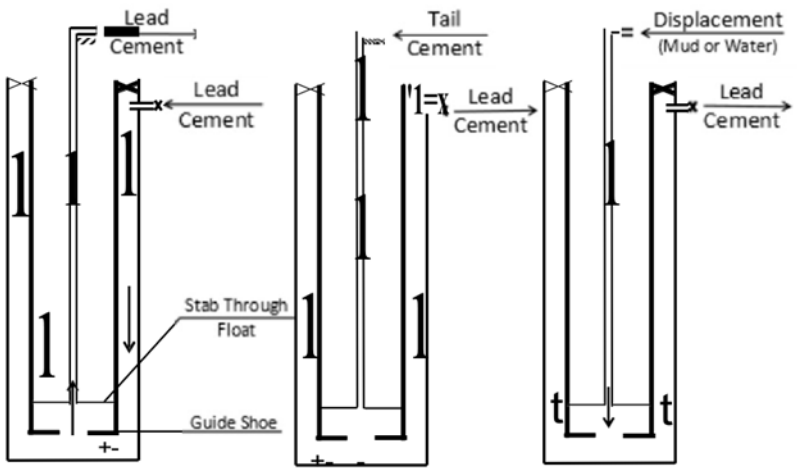


Figure 1: Stab Through Case Lead (Foamed) to Surface, Rickard et al. (2010).

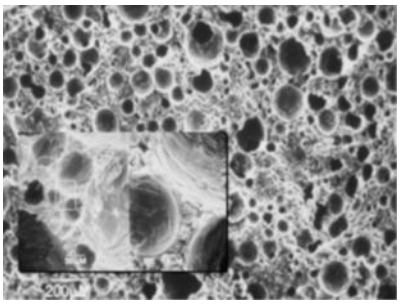


Figure 2: Microphotographs of a foamed cement sample, Niggemann et al. (2010).

The slurries selected for the reverse circulation cement job consisted of freshwater spacer, a scavenger slurry, foamed latex lighter lead slurry, unfoamed tail slurry with 40% silica flour, and an unfoamed latex cement as the cap. These cement slurries were planned to be mixed and pumped on the fly into the annulus, and the returns of the drilling mud taken back into the pits. Hernandez and Nguyen (2010). To ensure good cement around the shoe, the tail cement is pumped in a conventional method down the drill pipe and displaced with water (Fig. 4). The unfoamed cap cement is used to prevent the nitrogen from breaking out.

2.1.2 Float Equipment and Surface Equipment Layout

The reverse circulation cement job requires some specialized float equipment for performing the cementing job successfully, including the stab in float collar and guide shoe. The stab-in float collar should have a flapper valve which allows the flow of fluids in either direction, the drill pipe stab-in stinger with a centralizer for the appropriate casing size and the drill pipe latch in plug. The reverse foam cementing equipment layout is shown below (Fig. 3) and the gauges are marked as follows: P1 – Wellhead Pressure, P2 – Backside Pressure, V1 – P.S. Discharge, V2- D.S. Discharge.

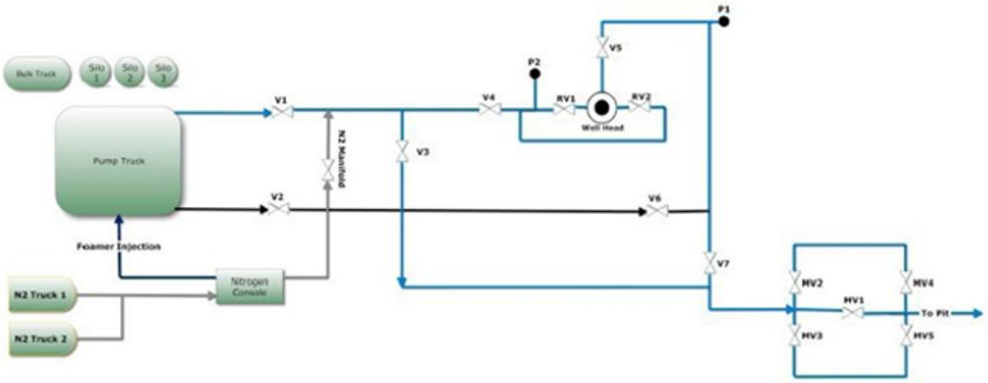


Figure 3: Reverse Foam Latex Cementing Equipment Layout, Peters et al. (2013).

2.2 Cementing Job Execution Process

The reverse circulation foam latex cementing schedule includes the following steps: 1) Making up and laying out the surface equipment 2) Pump the freshwater spacer down the annulus 3) Pump the scavenger spacer down the annulus 4) Pump the foamed lead cement down the annulus till the lead cement is observed at surface. 5) Switch to the drill pipe and pump unfoamed tail cement 6) Drop the dart and pump the displacement fluid 7) After the plug is latched, then close the drill pipe side 8) Switch to the annulus side, pump the unfoamed cap cement 9) Shut the well in and WOC.

3 REVERSE CIRCULATION FOAMED LATEX CEMENTING EXECUTION

The job design (cementing 11.75-inch casing in 14.75-inch open hole (4709 ft) and 16” casing (2292 ft) procedures were reviewed prior to the job with the cementing and drilling engineers. At the well site, a safety meeting was first conducted, all the iron and valves necessary to switch back and forth from a reverse to conventional type cement job equipment were spotted and rigged up. A detailed written procedure was distributed to personnel running the valves and all the valves were labeled in accordance with the design prior to the job. All the cement and nitrogen lines were tested to 2500 psi. The rig then stopped circulating.

The pre-flushes were pumped as follows:

50 barrels of unfoamed Mud Flush III
50 barrels of foamed Mud Flush III
5 barrels of foamed Fresh Water Spacer
7 barrels of foamed Neat Flochek
5 barrels of foamed Fresh Water Spacer

The cement was pumped as follows:

80 barrels of 10.0 ppg foamed Non-Latex Excess
136 barrels of 11.0 ppg foamed Non Latex
80 barrels of 12.0 ppg foamed Latex
148 barrels of 12.0 ppg foamed Non Latex
31 barrels of 15.0 ppg unfoamed Non Latex shoe cement

After pumping the lead cement, shut down and swapped the valves to pump the tail down the drill pipe
43 barrels of 15.0 ppg unfoamed Non Latex
Displaced drill pipe with water and landed the plug

Then annulus valve was opened to pump cap cement17 barrels of unfoamed Non Latex was pumped in the annulus (Fig. 5). Well shut in and waited on cement, cement was observed at surface, no need for top up job

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Note: As health, safety and environmental risks and concerns have been considered when foamed cement comes back to surface during the pumping stage, new equipment and processes have been put in place to avoid foamed cement coming to surface.

OptiCem Simulation Plots

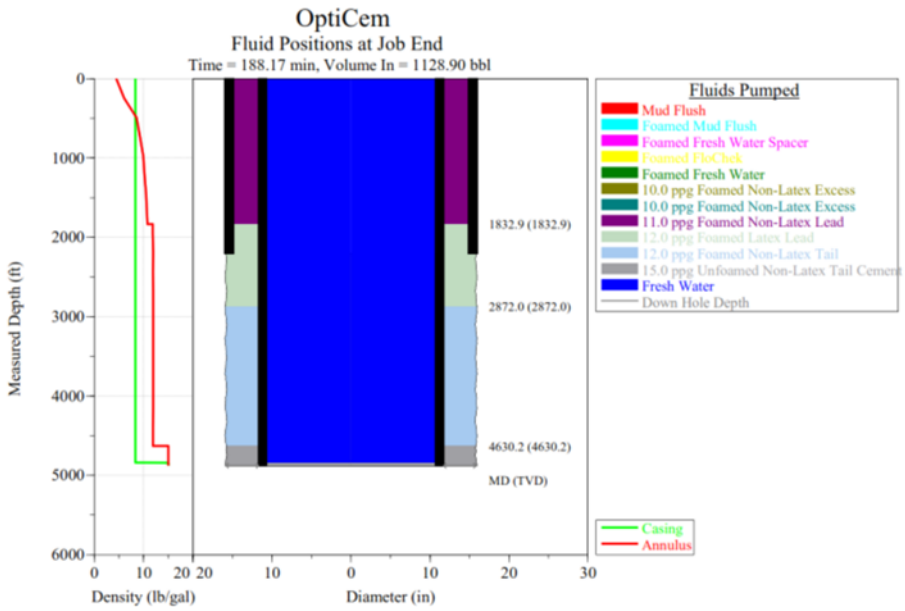


Figure 4: OptiCem- Fluid Position at End of Job, Peters et al. (2013).

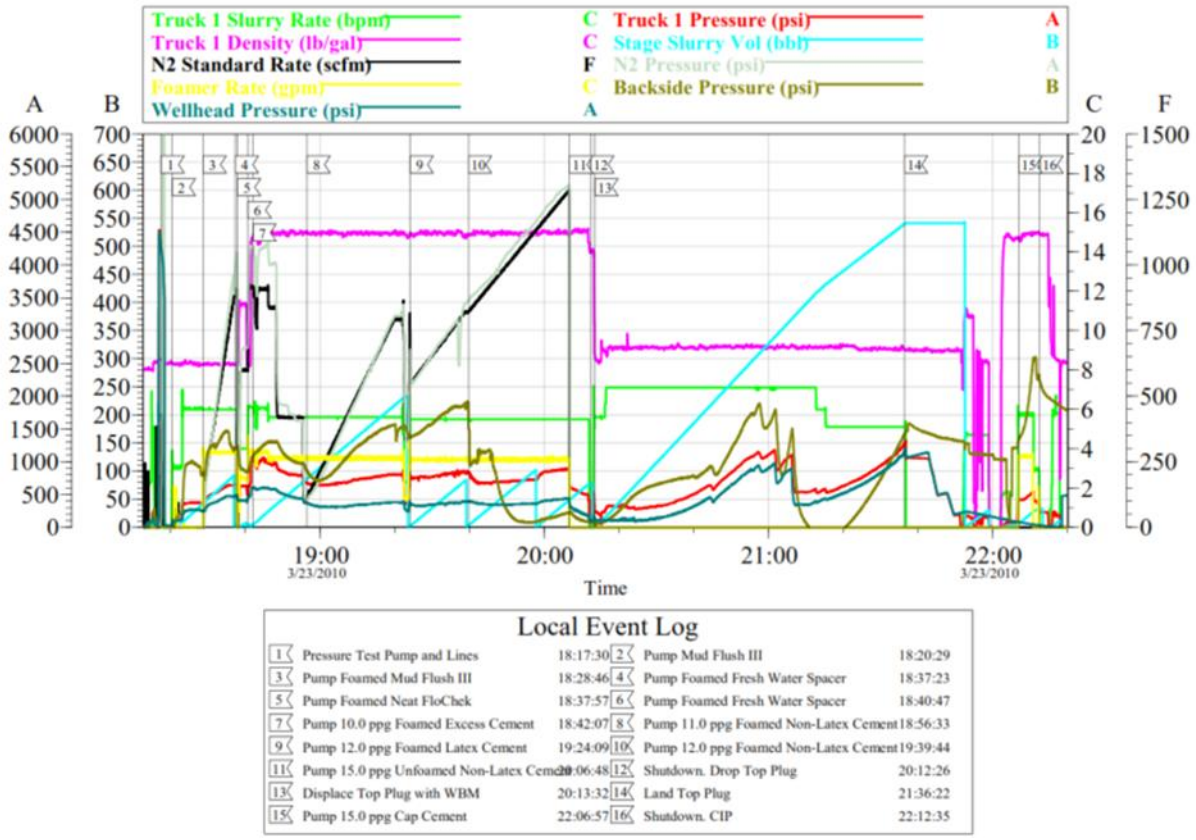


Figure 5: 11-3/4" Casing Reverse Cement Job Graph.

4 CONCLUSIONS

Proper design and preplanning of the reverse circulation foam cement job helps to avoid lost circulation during the job and eliminate the need for a top job and reduce the non-productive time. The pressure on the formation

during the reverse circulation cementing placement was significantly lower, and the excess cement needed to be pumped was minimized. The retarder was mixed at various stages which helped to reduce the WOC. Using drill pipe and a float collar with a flapper valve can eliminate the presence of cement inside the casing after the job, eliminate the need to hold pressure on the casing while the cement is cured, and provide a good indication of the position of the cement in the well, Spielman, et al (2006). Various cementing companies like Halliburton are working on a standard operating procedure for modeling and pumping the reverse circulation cement job, so that operators can choose the cementing techniques suitable for their projects.

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