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TOP SQUEEZE OR TOP FILL: IMPROVED SECONDARY CEMENTING FOR GEOTHERMAL WELLS

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ABSTRACT

Complete cementing of casing strings is critical in geothermal wells to protect the casing and provide mechanical integrity to the well bore. Surface indicators allow drilling personnel to select the best method for remedial cementing. The ‘top fill’ method is selected when cement is observed at the surface during the primary cement job, but the cement subsequently falls down the annulus. The ‘top squeeze’ method is selected when there are no cement returns to surface during the course of the primary cement job. For each case, specific procedures must be followed to successfully complete a remedial cement job. These procedures should be planned in advance. In addition, these procedures are not dependent on the primary cementing technique. Either ‘top squeeze’ and/or ‘top fill’ may be used for any casing string that is run with a previously cemented casing string in place that has an annular preventer installed.

INTRODUCTION

Complete cementing of casing strings is a critical component of geothermal well completions. With any cement job, incomplete cementing may result, requiring remedial cementing. When incomplete cementing is observed by the lack of cement at surface, due either to partial cementing of the annulus or fallback from surface, a remedial cementing method must be used. There are specific indicators of downhole conditions that allow drilling personnel to select the appropriate remedial cementing technique. The drilling team should prepare contingency plans for each of these methods prior to beginning cementing operations. A lack of pre-defined procedures can create delays in drilling, unproductive wait times, and expensive remedial work. Due to ever-increasing geothermal drilling costs and the resulting scrutiny by major lenders of these projects, proven techniques and procedures are essential to a successful drilling program.

When there are no cement returns to surface, cement must be forced into loss zones by pumping down the annulus. This is commonly termed a ‘top squeeze’ or ‘flush and fill’ job. Squeeze cementing is widely used in oil, gas and geothermal wells. When there are good cement returns to surface initially, but the cement recedes back down the annulus before setting, it is necessary only to fill the void left in the annulus. The technique to fill this annular void is termed a ‘top fill.’ It is important to recognize and select the appropriate procedure for each of these conditions. Both of these procedures replace the use of a tremie.

FULL RETRUNS TO SURFACE

If cementing results in full returns to surface and the setting cement does not fall back down the annulus, the primary cement job is successful. Operations can continue, drilling ahead as per the defined drilling program.

FALLBACK (TOP FILL)

When there are good returns to surface, but the cement subsequently recedes back down the casing-by-casing annulus, immediately or while waiting on cement, it is termed fallback (Figure 1).

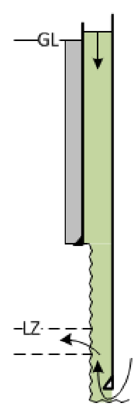

Figure 1: After good returns at surface (GL) cement falls away. Cement is circulated and encounters losses due to loss zone (LZ).

When this occurs, a specific remedial procedure, termed a ‘top fill’, should be applied. After fallback, the space in the annulus, initially filled by cement, will be air-filled. To prevent the introduction of contaminants into this void, immediately close the annular preventer and allow the cement to set (Figure 2).

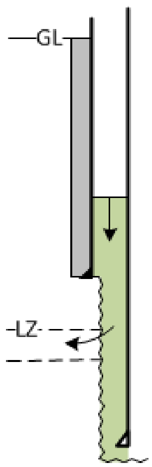

Figure 2: Initial cement is set. Keep all contaminants, such as water and drilling fluid, out of the annular space. Close the annular preventer.

The top fill technique is only effective when no contaminants are introduced into the annulus subsequent to primary cementing. A strict ban on the use of water hoses on the rig floor, in the substructure, or in the cellar should be enforced while waiting on cement. The cellar should be pumped out if the fluid level is above the side outlet valves. After ensuring all is clear, open both side outlet valves. The appropriate cement slurry is mixed and pumped though the lines before connecting to the side valve. This ensures that the lines are flushed clean and only good cement is pumped into the annular space. After the cement is pumped and all lines are full of good cement, it is connected to one of the side valves. Subsequently, water-free cement is pumped into one side of the annulus while the other side remains open. As the cement is pumped, any air in the annular space is displaced and evacuated through the open side outlet valve (Figure 3). An excess volume of cement must be pumped to ensure that the annulus is filled with good cement and that any condensation or ‘thin’ cement has been removed. Subsequently, pumping continues until there are only good cement returns flowing through the open side outlet valve (Figures 3 and 4). If good cement returns reach and stay at surface, as determined by stopping and starting to see if returns are immediate, the cement line is broken off and the job is complete.

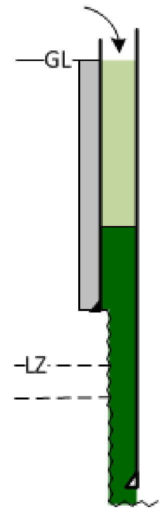

Figure 3: Pump top fill cement through one valve while other valve is open. Air in annular space is displaced and the annulus is filled with good cement.

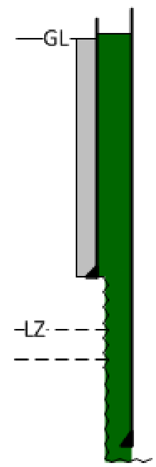

Figure 4: Entire annular space is now filled with good cement, free of contaminants, and job is successfully completed.

NO CEMENT RETURNS TO SURFACE (TOP SQUEEZE)

Partial or total loss of circulation may occur during cementing. This is caused by existing lost circulation zones, induced losses due to the excessive hydrostatic head of the cement column exceeding the formation pressure, or the presence of washouts (hole enlargement) that require more cement than initially calculated. If good cement does not return to surface during the course of the primary cement job, a ‘top squeeze’ remedial cementing method may be applied. The top squeeze method described herein is similar to the liner top squeeze that has been used for decades in geothermal drilling. The top of the cement column in the annulus may be above or below the shoe of the previous casing string (Figure 5).

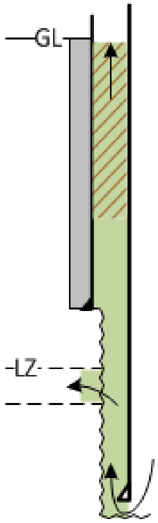

Figure 5: Cement returns never reach surface.

In any case, it is imperative to immediately flush the casing-by-casing annulus with at least one annular volume of water to force any cement above the casing shoe out of the annular space and into the formation (Figure 6).

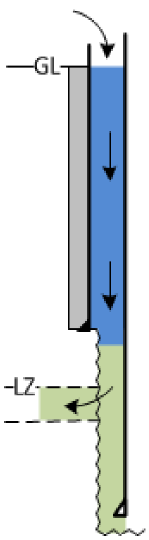

Figure 6: Immediately close annular preventer and flush casing annulus with at least one annular volume of water.

To properly flush the initial cement, the annular preventer must be closed immediately and the rig pumps or cement truck lined up to flush the annulus. Flushing must be done before the cement takes an initial set in the casing-by-casing annulus. Rapid setting is a special concern in geothermal areas where relatively high temperatures are encountered. Failure to flush before the cement takes an initial set will result in losing the ability to pump through the annulus, eliminating the possibility of a top squeeze and severely hindering a successful well completion.

After flushing, the fluid or cement top has been forced to where the lowest fracture gradient exists. Experience shows that this is usually found immediately below the shoe of the casing or at the loss zone. However, it is very possible that the fluid and cement from the initial cement job were forced into a newly created fracture, independent of previously identified loss zones. Regardless of the location of the cement top, the casing-by-casing annulus is now flushed, and is open to the formation.

After waiting on cement, it is time to start a top squeeze. Squeezing is the application of differential pressure to force cement into the formation. A minimum of at least one casing-by-casing annular volume of cement is pumped to fill the annulus, and pumping continues until a squeeze is achieved or cement is depleted (Figure 7).

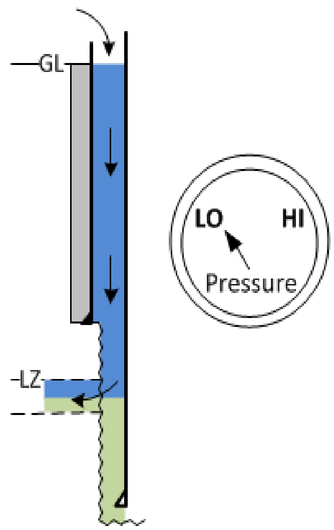

Figure 7: With closed annular preventer, pump water until casing annulus is free of cement.

To evaluate the need for further squeezing, pumping is halted after at least one casing-by-casing annular volume, and the pressure is allowed to stabilize. If pressure does remain stable, the top squeeze is done, and cement is allowed to set. If pressure does not remain stable, then pumping resumes, filling the loss zone with cement. Stopping numerous times to allow the cement to gel is known as a 'stutter squeeze.' In a stutter squeeze, the squeeze process is repeated until the pump-off pressure remains stable after squeezing (Figure 8).

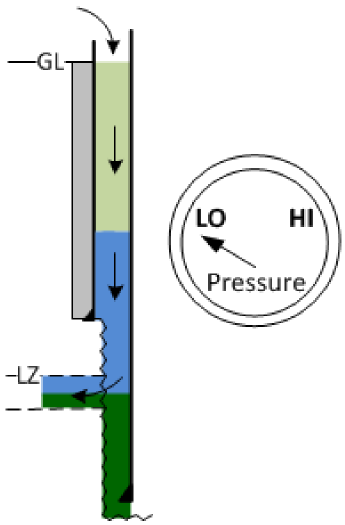

Figure 8: After casing annulus is clear of cement, begin pumping squeeze cement into the annular space.

As pumping continues, pressure is monitored while allowing the cement to gel; if pressure drops, the process is repeated. After the squeeze process is completed the cement line is removed from the side outlet valve and the valve is closed (Figure 9).

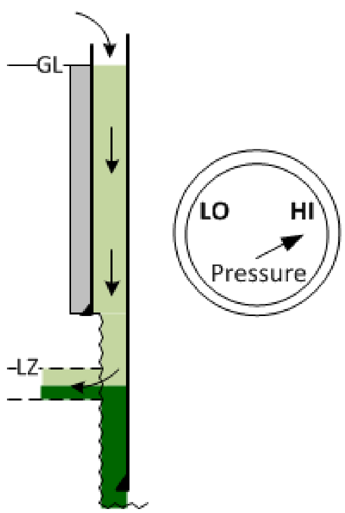

Figure 9: Pressure is stable after pumps have been turned off and cement allowed to gel. If pressure is stable, job is complete.

If fallback occurs, or if there is no fill-up after pumping cement, a top-fill is performed as previously described (Figure 10).

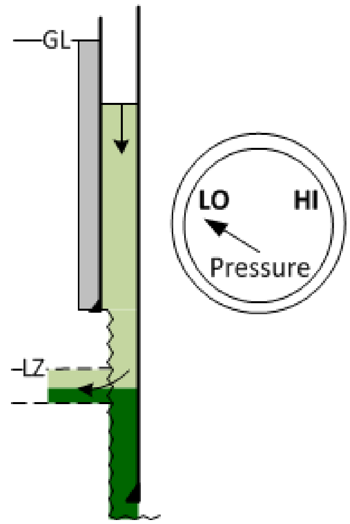

Figure 10: If fallback occurs after top squeeze, a top fill is performed.

A top-fill is appropriate because there is only air and cement in the casing-by-casing annulus. Once again, it is important to keep contaminants out of the annulus until job completion. Air in the annular space is then displaced by pumping, after which, the annulus is filled with good cement (Figure 11).

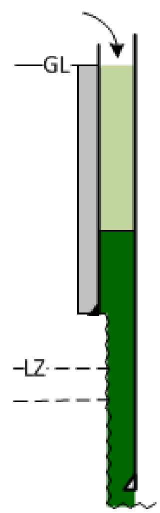

Figure 11: Pump top fill cement through one valve, while other valve is open. Air in annular space is displaced, and the annulus is filled with good cement.

After the entire annular space is filled with good cement, free of any contaminants, it is allowed to set and the job is successfully completed (Figure 12).

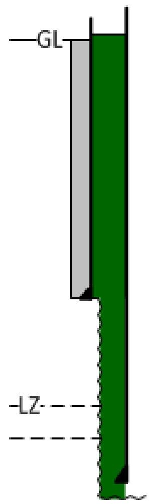

Figure 12: Entire annular space is now filled with good cement, free of contaminants, and job is successfully completed.

CONCLUSION

Cementing of casing is one of the most important operations performed in constructing a geothermal well. Unlike many oil and gas wells, geothermal wells are completed with fully cemented annuli. The two techniques discussed are suitable for performing ‘top jobs’, regardless of the primary cementing method.

Returns during a cement job serve as a visual indicator of downhole conditions. Depending on downhole conditions, there may be full, partial, or no returns at the conclusion of the primary cement job. When there are good cement returns to surface, but the cement subsequently falls down the annulus, secondary cementing is best performed using the top-fill method. When cement returns to surface are not observed, the top squeeze method should be considered. Cement bond logs have been run on several geothermal wells where a top squeeze has been performed. In all instances, good cementing results were indicated. The authors of this paper have used this method with unqualified success in over a dozen wells.

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