Cementing Tool Supports Cement Plug in Large Diameter Geothermal Well Casing

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ABSTRACT

Cement plug setting is one of the most unpredictable and time consuming operations in the drilling process of a geothermal well, thus adding considerable cost and risk to drilling, completion, and workover operations. Setting of ten to twenty consecutive plugs for a single sidetracking job, each requiring up to 8 hours of wait time for the cement to cure, are not unheard of in the industry. Significant risk arises from the inability to support the cement slurry while it cures inside the wellbore.

Perigon’s cement support tool (CST™) was designed to increase the success rate of setting cement plugs by physically separating the plug from the drilling fluid while the slurry cures, just as if it was set at the bottom of a well or above a bridge plug. Another attractive feature of the CST™ tool is its drillability, and foldable aluminum and composite construction (Harestad, 2015), which enables it to be pumped through small diameter tubing and then enlarged in the wellbore. This paper summarizes a recent, first-ever and successful plug setting operation using coiled tubing in a large diameter geothermal well casing.

Introduction

Collapsed casing is common in geothermal wells. In many cases, if not all, plugging the wellbore below the collapse is the safest way to proceed when attempting a repair. In most cases, the collapse prevents the use of all but an inflatable plug below the collapse, and in some cases even an inflatable plug has a running outer diameter (OD) that is too large to pass the collapse in the casing. In years past, a wireline-set, fabric and metal, drillable plug, with a flow tube through it, was used with gravel and sand bailed onto it, to establish a plug between the productive interval and the plug setting point. Then, a cement plug was set above the sand. That technology, which consumed excessive rig time, is now considered obsolete. A well in the Salton Sea was recently diagnosed with a collapse down to less than 5” in 16” casing with 13-3/8” casing below. Plans were made to set a cement plug using a coiled tubing (CT) unit just above the 13-3/8” casing, which was well below the collapse, to plug the highly productive well. The 2-1/2” Perigon CST™ MK2 cement support tool (Figures 1 and 5) was deployed through a tube attached to the CT, and the cement plug was set right above the support tool (Figure 6). The plug did move down the hole (inside of premium thread casing), but resulted in a solid barrier with no cement stringers above or below it. This was a successful, trouble free operation, especially in that it was the first CST™ deployed on CT into large diameter geothermal well casing.

The previous (pre-2000) track record for setting cement plugs was around 50% (Heathman, 1994). Another article stated a success rate of only 25% in 2000 (Fosso et. al, 2000). This is consistent with the geothermal field experience where setting more than one cement plug is usually required for success.
Background and Product Tests

The CST™ tool was developed in 2001 and is patented in a majority of the countries with a drilling industry in place. The new version (CST™ MK2), which is discussed in this paper, was developed last year and is still patent pending (See Tables 2 and 3) (Harestad, 2015).

The first field job with the CST™ tool was performed in 2002 and, to date, more than 2,100 CST™ tools have been run all over the world. The CST™ has been used under various well conditions such as: horizontal, higher than 90 degree inclination, at 8,000 m (26,246′) depth, within oil and water based drilling fluids, and seawater-filled wells. Six consecutive CST™ deployments were successfully applied for setting six cement plugs in a single run with the drill pipe. There are no indications that the well conditions influenced the success rate.

During the initial product testing phase in 2002, the 2-1/2” CST™ tool was pumped through a flow loop combination of 3-1/2″ and 5″ drill pipe (DP) for more than 7,300 m (23,950′). Well conditions were simulated as the CST™ was pumped out into a 13-3/8″ casing joint filled with water. Eleven runs were made with the dart above the tool, and one run without the dart, in a 610 m (2001 mi) long line. The only erosion observed was at the tip of the release arm (Harestad, 2015).

The second test in 2008 was conducted with a 2-1/2’ long, 16.0 ppg cement plug inside an 8’ long and 10″ wide Plexiglas pipe above a 10.0 ppg weighting water based mud. The 2” Slimline CST™ was placed in middle of the pipe. The pipe was tilted to about 60 degrees from vertical before the cement was poured into the pipe. Figure 2 shows the result after the mud has been washed out below the cement (Harestad, 2015).

The last set of tests in 2014 were carried out to identify and verify the minimum internal diameter (ID) of the DP connection that the new design could be pumped through into a pipe full of fluid. Loop tests were done pumping the tool through a 5″ ID flow loop, with 2″ and a 2-1/2″ stinger at the ends, respectively, for the two sizes of CST™. A total of eight runs were made at a flow rate of 600 lpm (158.5 gpm). No issues were observed and the CST™ and the dart were successfully pumped through the 5″ pipe into the 9″ ID water filled artificial casing at the end, as depicted in a collage of photos in Figure 3 (Harestad, 2015).

According to Perigon company records, more than 2,000 CST™ tools have been run since its first test run in 2002 with a reported success rate of over 95%. The causes of failure are categorized in Table 1.

![Figure 1. Perigon CST™ cementing support tool in expanded position (Perigon, 2015).](image1)

![Figure 2. CST™ test photo, after the mud has been washed out below the cement, 2008 (Harestad, 2015).](image2)

<table>
<thead>
<tr>
<th>Reported Failure Reason</th>
<th>Ratio (%)</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>Losses deeper downhole</td>
<td>15</td>
<td>n/a</td>
</tr>
<tr>
<td>Hole enlargement</td>
<td>10</td>
<td>n/a</td>
</tr>
<tr>
<td>Operational problems</td>
<td>15</td>
<td>Cement mixing problem</td>
</tr>
<tr>
<td>Sub and crossover ID restriction</td>
<td>15</td>
<td>Pipe not drifted, narrow cross over ID, 90 degree shoulders</td>
</tr>
<tr>
<td>DP ID</td>
<td>15</td>
<td>CST and Dart comiled together (lead to the CST™ MK2 design)</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
<td>Tool stuck in DP with wireline (WDP)</td>
</tr>
<tr>
<td>Unknown</td>
<td>20</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Table 1. Failure reasons and rates of the original CST™ tool (Harestad, 2015).
Coiled Tubing Application

A well at the Hudson Ranch project in the Salton Sea geothermal field was completed at a total measured depth of 6,895’ in April, 2011 (Figure 4). The well was reported to have a collapse in the 16” tieback casing from 1,034’ to 1,040’ while still in operation as a producing well for the power plant. It was also reported that the maximum opening inside the 16” casing at the collapsed interval was less than 5”. After analyzing possible remedial options, it was proposed to repair the well by milling through the collapsed section of 16” casing and running a 13-3/8” scab liner to patch the collapsed section. Prior to rigging up the conventional drilling rig to perform the casing repair, a coiled tubing (CT) unit was used to set an initial suspension plug at 1,960’, 16’ above the 13-3/8” to 16” crossover joint, at 1,976’. Using a CT unit to set the suspension plug is significantly less expensive than using a conventional rig. The outline of the operation procedure is given below:
1. While mobilizing the rig, move in and rig up a 2-3/8” CT unit.
2. Kill and cool the well as needed.
3. Rig and run a temperature survey to the 16” x 13-3/8” XO depth.
4. Rig up 2-3/8” CT unit and strip in the hole with the CST™ to 1,950’ (±25’ above the 13-3/8” x 16” crossover depth).
5. With the well static, deploy the CST™.
6. Set 100’ suspension cement plug above the CST™, and then pull out of the hole to wait on cement.
7. Run back in the hole and determine the top of the cement.
8. Set additional plug(s) if the first plug is deemed inadequate to secure the well.
9. Fill the hole and pressure test to establish the integrity of casing and the plug.
10. Displace the casing volume from the top of the cement to surface with mud. Use the cementing unit to mix and pump the mud through the coiled tubing.
11. POH and rig down the coiled tubing unit.

Due to the large diameter of the casing, which typically decreases the chances of setting a successful plug, the operation planning crew decided to include an extra level of support by employing the CST™ tool. Other reasons for selecting this tool was its simplicity in design (less prone to mechanical troubles than an inflatable packer) and ability to be run through the wellbore restriction at the collapsed casing interval using coiled tubing just before pumping the cement slurry, without requiring extra trips.

Following the well kill operations, the 2-3/8” CT unit was rigged up while cooling the well by pumping fresh water at maximum pump rate down the well bore. The CT dimple connector was made up and successfully pull-tested to 30,000 lb. Subsequently, the CST™ running adapter sub was made up to the dimple connector and ran in the hole to 1,960’. The prejob safety meeting was conducted prior to the deployment phase and pumping procedures were thoroughly discussed. After the successful pressure testing of the cement lines, 40 bbl fresh water was pumped ahead, shearing and deploying the CST™ at 2,100 psi. The tapered plug in the bottom of the deployment tube is suspected to have caused the higher pressure to deploy the CST™ tool. Next, a 22 bbl, 15.8 ppg cement plug slurry was mixed and pumped at 3 bpm. The slurry was displaced with 34 bbl.

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Figure 4. Hudson Ranch Well 13-2 schematic before repair.

Figure 5. Transport box (rear) and conventional CST™ with dart (front) (Perigon, 2015).
fresh water, pumped first at 3 bpm and then at a reduced pump rate of 1.5 bpm (two stages of 12 bbl and 22 bbl, respectively). The theoretical fill of the cement plug was calculated to be 100’ (from 1,960’ to 1,860’) by the field crew. After the plug was set, 2-3/8” coil tubing was pulled out slowly from 1,960’ to 1,760’, and 10 bbl of fresh water was pumped to flush the tubing string clean. Following flushing of the coiled tubing, it was pulled out at 80 fpm into the lubricator assembly at the surface and the well was shut in. A maximum wellhead pressure of 20 psig was observed while waiting on the cement plug to cure.

After waiting on cement, 2-3/8” CT was run in the hole to 900’. At this depth, the hole was filled with the pump unit and the CT was run deeper in the hole. The top of the cement was tagged with the CT at 1,933’. The plug was successfully pressure tested to 500 psi. Water inside the well was replaced with drilling fluid and, finally, the CT unit was pulled out and rigged down. Once the drill rig was moved, the milling operation was completed, and the cement was tagged with 5” open-ended drill pipe at 2,023’. The plug was easily drilled out from 2,023’ to 2,202’ following a series of casing repair operations. The plug and CST™ had moved down the hole, but no cement was found below the CST™.

**Conclusion and Analysis**

The purpose of supporting the plugging operation with the CST™ was to reduce remedial costs and protect the productivity of the well. The operation was an overall success. No cement was encountered below the CST™. The CST™ plug will be used in the future, whenever needed, to set a cement plug if a restriction in a well bore arises. This will be done to ensure that the open hole productive zone below the shoe is protected. Additional work on various applications of the tool is planned. Use of pea gravel and sand above the CST™, to establish a bridge inside of the casing that is permeable to wellbore fluids, but not cement, is also planned. These additions are intended to
eliminate any tendency for the CST™ to move down the hole, due to density differences, when precise top and bottom depths of the plug are critical. The possibility of reversing the direction of the centralizing arms to minimize plug movement down hole will also be explored.

The CST™ is not a bridge plug; the differential pressure across the canvas is close to zero. The function of the CST™ is to keep the cement separated from the wellbore fluid and restrict flow of the cement slurry downward. As long as the cement slurry doesn't tend to flow toward the bottom, wellbore fluids cannot migrate upward. In this application, the CST™ was used to support the cement plug, replacing a bridge plug, and ensure that cement does not drift down into the productive interval where it could have significantly damaged permeability.

Some of the conditions that will lessen the chances of successfully deploying and unfolding and limitations to the use of CST™ are listed below:

- When losses are expected below the CST™ setting depth. Set the CST™ below the loss point to cure losses, if possible.
- Within uncertain hole sizes (if there are indications of washout larger than the max size of the CST™). Deploying two consecutive CST™s in one occasion when the hole size was thought to be larger than the maximum supported size of the CST™ has been accomplished.

- When sharp shoulders are expected within crossovers which could stop the CST™. If there is tapered pipe in the deployment string, make sure that the crossover sub does not have a sharp change of the internal diameter (ID) and also that the specific CST™ will fit all DP IDs that are being used.
- When wired drill pipe (WDP) is being used.

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### References


