Challenges of Cementing Olkaria Geothermal Field

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Keywords
Thickening time, ECD (equivalent circulating density), Bearden Consistency, BHCT (bottom hole circulating temperature), WOC (wait on cement), lead cement, tail cement, scavange

ABSTRACT

Olkaria Geothermal field poses major challenges in cementing of well casings due to the fact that the area is highly permeable, the down hole temperature and pressure is very high and the cement sheath between the annular and casing is prone to carbonation which leads to strength retrogression. This paper documents the analysis of cement consumption per region in the entire Olkaria field to emphasis on the problem of permeable formations and various measures taken to improve on cement slurry design and cementing practices to handle this problem. A case study of cementing a high pressure well, #OW-724V is presented. Current cement design to handle high temperature and high pressure systems is also presented. Attempts to fight these challenges have been met with varying levels of success so suggested improvements to the current cement design and practices is also presented.

1.0 Introduction

Geothermal reservoirs in Olkaria geothermal field occur in regions of high temperature gradients and fractured, highly permeable formations. The energy is manifested on the earth’s surface in the form of fumaroles, hot springs and hot and altered grounds. To extract this energy, wells are drilled to tap steam and water at high temperatures (250-350°C) and pressures (600-1200 PSI) at depths of 1-3 km. For electricity generation, the steam is piped to a turbine, which rotates a generator to produce electrical energy.

2.0 Cementing Practice in Olkaria Geothermal Field

2.1 Objectives of Cementing

Cementing is the process of mixing and pumping cement slurry down to fill the annular space behind the pipe. When setting, the cement will establish a bond between the pipe and the formation. In general cementing is done:

i. To prevent the movement (migration) of fluids from one formation to another or from the formations to surface through the annulus,

ii. To hold the casing string in the well,
iii. To protect the casing from corrosive fluids in the formations and buckling,
iv. To support the well-bore walls (in conjunction with the casing) to prevent collapse of formations,
v. To prevent blowouts by forming a seal in the annulus,
vi. To protect the casing from shock loads when drilling deeper.

2.2 Typical Design of Wells in Olkaria

In Olkaria, wells are usually drilled to depths of between 3000m to 3500m depending on reservoir locations at different fields. The surface hole is drilled to a depth of around 60m where the 20 inch casing is set. Similarly, the intermediate hole is drilled to around 300m where the 13-3/8 inch casing is set and finally the production hole is drilled to a depth of between 750m-1200m where the 9-5/8 inch casing is set. This typical design is shown in figure 2 below.

2.3 Cement Lab Testing

Prior to actual bulk blending of cement with additives, lab testing is performed to determine the actual slurry design for the job. These tests include:

1. Thickening time:
   This is the amount of time for a cement slurry to become “too thick to pump.” Thickening time is measured in an HPHT (High Pressure High Temperature) consistometer at BHCT (Bottom Hole Circulating Temperature) and BHP (Bottom Hole Pressure). A slurry is considered “too thick to pump” when it reaches a cement consistency of 70 Bc (Bearden Units). This is performed at the maximum anticipated BHCT.

2. Density:
   Density of cement slurry is determined using the mud balance.

3. Compressive strength test:
   Compressive strength tests is conducted as per API RP 10B procedures. This is done by measuring the compressive strength reading after physically crushing a cement cube.

4. Fluid Loss:
   Fluid loss test is conducted by heating the slurry in a cell to achieve the BHCT then, 1000 psi pressure applied from the top, and fluid loss that passes through the 325 mesh screen is measured for 30 minutes.

5. Free water:
   This is the amount of clear fluid that separates from a cement slurry in a static condition. A basic free water test is performed by conditioning the cement slurry for 20 mins at BHCT and then pouring the slurry into a 250 ml graduated cylinder at room temperature and observing it after 2 hours.

2.4 Cement Placement

The cement placement method used in Olkaria is the conventional method and the operation is illustrated in Figure 3 (Nelson, 1990):

a) The casing string with all the required cementing accessories such as the float collar, guide/float shoe, centralizers etc. is run in the hole until the shoe is just a few metres off the bottom of the hole.
b) Cementing head, is then connected to the top of the casing string. It is essential that the cement plug is correctly placed in the cementing head.

c) The casing is then circulated clean before the cement operation begins.

d) It is followed by a water spacer, then cement slurry. When the required volume of cement slurry has been pumped, the top plug is released. This is followed by displacement water which is pumped until the top plug reaches the float collar.

e) After this the cementing head is shut and WOC time given for the cement to reach at least 500psi.

3.0 Cementing Challenges Experienced in Olkaria

To successfully tap the geothermal resource, conditions of high pressure and high permeability has to be met. However, these desired conditions lead to several major challenges when cementing a geothermal well. These include:

1. Loss circulation due to highly permeable formations leading to many backfill cementing jobs.
2. High reservoir temperatures have a direct effect on the hydration of the cement leading to shortened thickening time of cement.
3. High bottom hole pressures making it hard to cement.

3.1 Permeable Formation Influence on Cementing

The current Olkaria Geothermal drilling plan focuses on four major regions:

a) Olkaria domes
b) Olkaria North East
c) Olkaria East
d) Olkaria South East

Figure 4 below is an analysis of the cement consumption in the four Olkaria regions to emphasis on the problem of permeable formations on cementing.

From the graph we see that the Olkaria North East region is the highest consumer of cement per well with an average consumption of 253 tons per well, followed by Olkaria East with an average of 242 tons per well, then Olkaria South East with an average of 149 tons per well and finally Olkaria Domes with an average of 147 tons per well.

In cementing of these wells, a number of measures were taken during the drilling and cement design stage in the attempt to reduce cement losses. While drilling, a lost-circulation material (LCM) is used in the drilling fluid so as to attempt to plug these loss zones. In addition, during the cement design stage, an attempt was made to lower the equivalent circulating density of the cement slurry by using a low-density cement design through the addition of extender agents i.e. bentonite.
3.2 High Temperature Influence on Cementing

Temperature has a direct effect on the hydration of Portland cement and will shorten its thickening time. Maximum measured temperature at Olkaria field has been about 320°C with bottom hole circulation temperatures of about 150°C. In an attempt to lower this bottom hole static temperatures (BHST), cold water spacers is circulated ahead of cement. In addition, retarders and fluid-loss additives are used to extend the thickening time and prevent premature hydration of cement slurries. Graph 2 below is a representation of a typical design of slurry for 9-5/8” casing with retarders and fluid-loss additive added so as achieve a thickening time of about four hours.

![Graph 2](image.png)

Figure 5. Time to achieve 100 BC (Bearden Consistency) for a typical 9-5/8” casing slurry design.

3.3 High Pressure Influence on Cementing

This is illustrated in the case study below:

**Case Study: Cementing Well #OW-724V**

<table>
<thead>
<tr>
<th>Table 1. Well #OW-724V Profile.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface casing</td>
</tr>
<tr>
<td>Intermediate casing</td>
</tr>
<tr>
<td>Production casing</td>
</tr>
<tr>
<td>Openhole</td>
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<tr>
<td>Job cement volumes</td>
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<tr>
<td>Job excess</td>
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</tbody>
</table>

During the primary cementing for the 13 3/8” intermediate casings and the 9 5/8” production casings, standard lead and tail designs was used. This comprised of Mica flakes which is a lost circulation material (LCM), bentonite used as an extender to lower the equivalent circulating density (ECD), retarder, fluid-loss agent and dispersant. For the 20” surface casing, no cement additive was required since it was set at a shallow depth of 60m.

The casing cement jobs were performed using the conventional method of cementing. After casing was on bottom, water was circulated to lower the bottom circulating temperature and also to condition the well bore to ensure proper bonding of cement with the formation. Once the job has begun, a volume of 4000 litres freshwater spacer, was pumped to provide additional cooling. This fresh water was followed by 4000 liters of scavenge of about 10 ppg, lead of about 14.3 ppg and a tail of 14.4 ppg both totaling to 15,858 liters.

The main challenge of cementing this well, especially for the 9 5/8” casings was the very high pressures that were encountered. To handle this challenge, after pumping the primary job, the BOP was closed and WOC for 4 hours instead of the normal 8 hours to perform the backfill operation so as to create a high hydrostatic pressure of the cement column.
to balance the formation pressures. In addition to this, a high density cement of about 14.7 ppg was pumped. A total of six backfill cementing operations were performed and the method proved to be successful.

**Conclusion**

The cementing of wells in Olkaria Geothermal field has been largely successful with the biggest challenge being the presence of highly permeable and fractured formation. This causes a lot of time to be spent on cementing of wells in the drilling process leading to high costs of drilling. Suggested future improvements to further handle this challenge include:

- Use of high strength microspheres in the design of the cement slurry. This creates a lightweight cement and at the same time maintains a relatively good compressive strength.
- Use of foamed cement. When properly executed, the process creates stable lightweight slurry, with low permeability and relatively high compressive strength compared to conventional cements.
- Cementing using the inner string cementing method.

**References**

5. KenGen website, [www.kengen.co.ke](http://www.kengen.co.ke)