Case study: Silica Inhibitor Trial in Central America Plant

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ABSTRACT

This paper provides a description of a field trial performed in a geothermal plant in Central America affected by severe silica scaling.

Silica is one of the most common and serious scale that geothermal operators have to face, and it typically deposits in the colder sections of the plant. Among all the different ways currently available for preventing silica deposition, the use of chemical inhibitors is considered one of the most promising and cost-effective approach.

The presence of highly charged cations such as Al^{3+} and Fe^{3+} in the geothermal brine increase the severity of conditions as those cations boost silica polymerization and precipitation also affecting the efficacy of scale inhibitors and dispersants. For this reason, it is crucial to select and correctly apply the best product able to provide good protection even under harsh conditions.

The trial started with two runs, as base lines, without the application of the scale inhibitor followed by a run where the scale inhibitor had been applied. All the trial runs had a duration of 30 days each and the plant operating condition were kept constant for the entire trial period. After each run, the system was cleaned up and scale coupons, placed in different area of the system, were extracted and analysed by measuring the scale weight and thickness together with a visual inspection of the pipelines.

The performance comparison showed very good results obtained during the run with the scale inhibitor which registered a reduction of scaling by 70 to 80%. Also, the visual inspections showed much cleaner pipelines conditions after the run with the product.

This work confirms how the use of a proper scale inhibitor, even at low dosage, could mitigate the negative effects of silica deposition, increasing the efficiency of the plant and the power recovery and eliminating the need of costly shutdowns for mechanical cleaning.

1. INTRODUCTION

Silica precipitation is quite common in geothermal applications. Deposits can restrict flow, reducing heat transfer efficiency and power generation and increasing operational cost. It is caused by silica co-polymerization and/or co-precipitation with other mineral or divalent and trivalent cations present in the brine. A simplified scheme showing the polymerization process is shown in Figure 1:

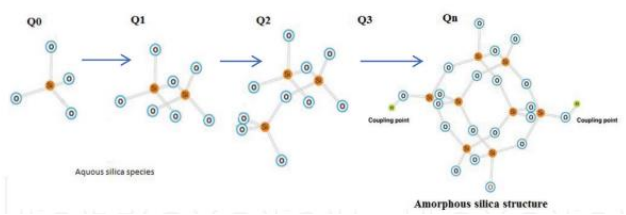

Figure 1: Dissolved silica species polymerization path into amorphous silica structure.

This process is typically affected by several thermodynamic and kinetic factors. The most important thermodynamic factors are pH and temperature (Figure 2), while the kinetics of the process are mainly influenced by:

- Degree of supersaturation
- pH
- Temperature
- Flow rates
- Aeration
- Other ions in solution

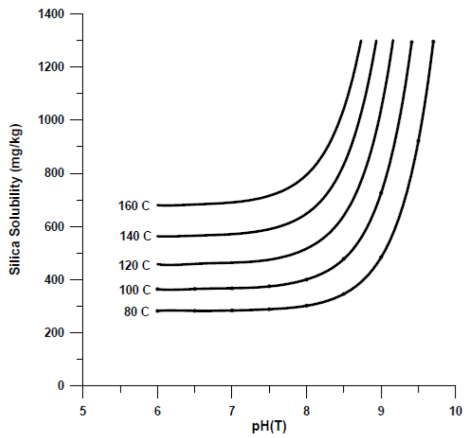

Figure 2: Silica solubility vs pH and temperature.

The complexity of silica chemistry and the number of factors that could play a role in the field affecting deposition make silica a very challenging scale to be mitigated. Over the last decades, several approaches have been investigated:

- Removing silica by precipitation
- Mechanical cleaning
- Avoiding supersaturation conditions
- Acidification of the brine
- Stabilization/dispersion of colloidal particles

The first two methodologies in the above list are typically quite expensive and reduce the amount of power / heat that can be extracted while the use of acid could lead to corrosion issues. For these reasons, chemical inhibitors or dispersants have been introduced becoming one of the most used and cost-effective technologies for controlling silica deposition in geothermal wells, as confirmed by the trial described in this paper.

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The plant where the trial was performed has a capacity of 55MW. The biphasic fluid has a maximum temperature of 240°C while after the separator it decreases to about 150-160°C. The steam formed is used to generate electricity while the liquid is directly sent to reinjection wells. The plant is experiencing silica issues, especially on the eastern side of the field where the amount of scale on metal coupons is in the range of 8-17g/y. In this area of the field, the brine has a higher silica content, leading to more severe issues. The scale is observed in the pipeline between the well heads and the separator, in the separator and in the pipeline between separator and reinjection wells. For this reason, the operator was looking for a proper scale inhibitor to mitigate the deposition of this scale and avoid, or at least delay, expensive mechanical cleaning.

Typical silica levels are in the range 60-300ppm as Si, calcium levels are 120-150ppm as Ca while pH is typically in the range 6.0-6-8. These data have been used to run scaling software simulations and outcomes are summarized in Table 1.

Table 1. Software scaling simulations for different wells and conditions

Well	T(°C)	P (bar)	SI[1]	Silica Deposit (ppm)	SR[2]
A	188	13	<0	/	<1
	153		0.01	20	1.02
B	183	12	<0	/	<1
	153		0.07	114	1.17
C	201	15.5	<0	/	<1
	153		0.07	100	1.17
D	153	13	0.04	63	1.10

Simulations indicates that amorphous silica precipitation starts to be thermodynamically favoured when temperature decreases to 150-160°C. Typical deposition rate is in the range of 20-115ppm depending on which well is considered. No metal silicates or other scales are predicted to have an SI above zero under these conditions.

These indications have been confirmed by scale samples analysis performed at an external lab. Results show that samples are mainly composed by amorphous silica with the presence of other elements such as aluminium, iron, calcium and sulphur. Presence of aluminium and iron is very important as these highly charged cations could catalyze silica polymerization and precipitation, leading to more severe conditions compared to what predicted by the software. Furthermore, it is well known that some scale inhibitors are affected by the presence of iron, decreasing performance in the field. The technology selected and proposed for this challenging case is Geogard®SX, an effective and thermally stable inhibitor already tested and globally used in geothermal plants to treat amorphous silica.

2. FIELD TRIAL

The trial with Geogard®SX was performed during 31 consecutive days, dosing 12.5ppm of the scale inhibitor in the reinjection line having the higher scaling tendency. The Key Performance Indicator (KPI) was the amount of scale formed on different metal coupons located in three different areas of the pipeline and the target is to reduce the amount of scale by 60-80%.

To properly evaluate the scaling reduction and assess performance of the inhibitor, two different one month long base lines without the addition of the inhibitor were made. Scaling build up on metal coupons after these test is shown in Table 2.

Table 2. Scaling deposition observed after one-month long baselines

Point	Baseline 1	Baseline 2
1	2.8g/y	3.9g/y
2	14.9g/y	6.0g/y
3	8.9g/y	12.5g/y

The lower value obtained in point 1 compared to point 2 and 3 could be explained considering that, based on operating conditions, this point is located slightly before most of the silica starts to polymerize and precipitate. The difference in scaling deposition among the points can be also seen in Figure 3.

Difference observed in Table 2 for different coupons and baselines can be explained considering the effect of solids dragged by the fluid. In order to consider the worst-case scenario, for each point it was considered the highest deposition rate obtained from the two baselines.

[1] Saturation Index
[2] Saturation Ratio

Figure 3: Baseline n°2, point 1, 2 and 3 respectively.

Figure 4: Point 2 coupons after the trial with Geogard®SX.

2.1 Results

Scaling deposition and product efficiency are summarized in Table 3.

Table 3. Scaling deposition and product's efficiency

Point	Scaling deposition	Geogard®SX efficiency
1	1.7g/y	57.7%
2	2.7g/y	81.9%
3	3.3g/y	73.2%

For all the points a significant lower deposition rate has been observed, meaning that Geogard®SX is mitigating in an effective way silica deposition. Concerning the efficiency, good results has been achieved, with a reduction of about 70-80% in the most critical part of pipeline (point 2 and 3).
Overall, Geogard®SX at 12.5ppm as product provided an inhibition efficiency in line or above the target value set up by the operator. This also means that a further dosage optimization could be possible.
Good results achieved have been confirmed by the visual inspections of different pipelines sections (Figure 5).

Figure 5: Pipeline inspection after the trial with Geogard®SX.

3. CONCLUSION

Trials represent the best way to prove the efficacy of a technology, especially when silica is the main scale to be mitigated. In this work, Geogard®SX has been tested to prevent precipitation and deposition in a geothermal plant in Central America. Despite the very critical conditions due to the presence of highly charged cations in the brine and challenging target (reduction of scaling on metal coupons

>60% after one month), this scale inhibitor provided good results, with an inhibition ranging from 60% to 80%, depending on which part of the pipeline is considered. These results confirm that chemical treatment is one of the most cost-effective way available to geothermal operators to mitigate scaling issues. Furthermore, a future dosage optimization might be performed in order to decrease the cost of the treatment and increase benefit for the plant.

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