Enhancing the Viability of Calcite Inhibition Systems via Targeted Dose Rate Reduction

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ABSTRACT

Calcite scaling of Te Ahi Tamou **(**geothermal) production wells is an issue that requires ongoing attention and maintenance to maintain generation. Chemical cleaning is an important maintenance activity where the well is flashing in the formation, while broaching and live well cleanouts using air hammer are mechanical means to recover production when the scaling occurs within the wellbore. These methods have the limitation of accepting loss of production as the well scales up between interventions (Moya *et al*, 2005). Calcite inhibition systems (CIS) are a viable alternative that, when functioning correctly, remove the need for mechanical workovers and can maintain production without the need to accept productivity losses.

The installation of CIS on 13 of our production wells has been successful in allowing us to maintain a clear wellbore in wells that would typically have scaled up rapidly. As part of an ongoing optimisation of our systems, we have undertaken a targeted programme of work to optimise our chemical dose rates to reduce our operational costs and enhance the viability of installing CIS in further wells. This paper details the steps taken to reduce our chemical usage, while still maintaining clear wells. Dose rates have been tuned through assessment of chemical trends, comparison of calcite saturation of similar wells, analysis of operational data and through the use of an XY caliper tool to assess the effectiveness of reduced dosing rates. Analysis of this data has given us confidence that our targeted dose rate reductions have been successful and has allowed us to realise valuable operational savings that increases the appetite for future installations to maintain production for our wharehiko (geothermal power stations).

1. INTRODUCTION

1.1 Use of CIS in Geothermal

The use of CIS to protect Te Ahi Tamou **(**geothermal) production wells from calcite scaling is well documented, with many successful installations detailed around the world (Vetter *et al*, 1979; Moya *et al*, 2010; Mejorada *et al*, 2011). This protection system is required due to the propensity for calcite to become supersaturated under boiling conditions, causing scale to deposit according to equation 1 (Brown, 2013). With many products available, the selection of an inhibitor chemical can be challenging, although with careful lab and field screening a suitable solution should be available in most cases (Siega *et al*, 2021).

Equation 1:

$$Ca^{2+} + \ 2HCO_3^- \rightleftharpoons CaCO_3 + H_2O + CO_2\uparrow$$

1.2 Assessment of Downhole Conditions

Prior to installing CIS, the downhole conditions in the well need to be assessed to ensure the system is correctly installed and there are no downhole issues that could affect the downhole assembly. A flowing pressure, temperature spinner (PTS) survey allows assessment of the flash point, ensuring the dispersion head is installed deep enough in the well. The casing integrity and maximum clear depth are also assessed to highlight any areas that could give rise to wear points on the tubing or cause the assembly to be stuck in the well. This pre-install check can also include a mechanical cleanout of previously formed scale to ensure the wellbore is clear from obstructions.

1.3 Standard CIS Setup

The standard CIS setup involves running capillary tubing into the well, usually at least a couple of hundred meters below the flash point to allow sufficient mixing of the chemical prior to reaching the zone where calcite scale typically forms (Figure 1). Weight bars are attached to the dispersion head to stop the buoyant forces of the production fluid lifting the tubing out of position. Tubing is secured to the riser to ensure minimal vibrations on the tubing.

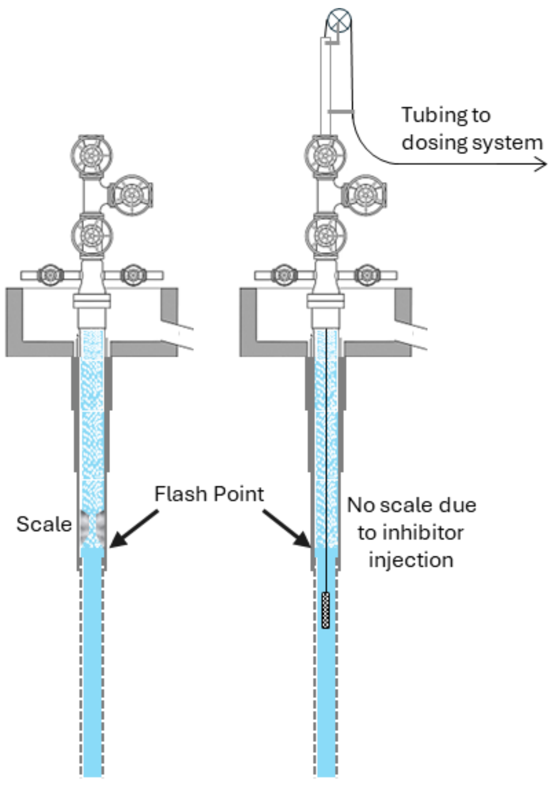

Figure 1: Typical CIS setup detailing chemical injection below flash point. Adapted from Watson, 2013.

1.4 System Maintenance

One major risk of a CIS setup is the risk of tubing failure. While tubing failures have been an issue in the past, improvements in material selection, tubing maintenance activities and stabilisation of the setup have improved reliability, making CIS an attractive option for inhibiting calcite scale. Our CIS tubing is periodically inspected to look for any wear points of issues with the integrity of the tubing. This allows us to identify issues early, before they lead to a catastrophic failure of the system. The dosing system is also checked on a regular basis to ensure the correct dose rate is being delivered to the well and the system is operating as designed.

2. DOSING STRATEGY AND HOW TO ASSESS EFFECTIVENESS

2.1 Dosing Strategy

Given the importance of the wells that have CIS installations, we have traditionally taken a precautionary approach when selecting an appropriate dose rate for our inhibition chemicals. Selecting a conservative dose rate provides a buffer if there are any issues with the system causing a deviation from the planned dose rate and gives confidence that the system can handle any changes in waiwhatu (geothermal fluid) chemistry that may alter the required dose rate. Prior to this optimisation work, most wells had continued to be dosed at or close to their initial dose rate as the systems were protecting the wells sufficiently. The selection of an initial dose rate and the assessment of the effectiveness of the dosing was carried out in multiple ways, depending on the conditions of each well.

2.2 Comparison of Calcite Saturation Indices

A key method to assess the initial dose rate is to compare the calcite saturation indices (CSI) of the wells. We calculate CSI using a combination of WATCH (Arnorsson *et al*, 1982) and Geochemist's Workbench (GWB, v15). WATCH is used to recalculate the māpuna (reservoir) composition of the waiwhatu (geothermal fluid) and to calculate the composition of the fluid upon boiling, while GWB is used to calculate the CSI at each boiling step. A combination of techniques is used as we found using WATCH alone overestimated the CSI of many wells when compared to field data and observations.

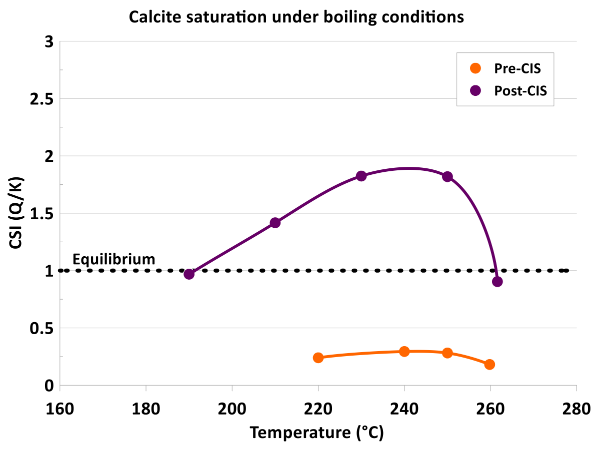

Figure 2: Comparison of CSI boiling curves pre- and post-CIS installation. The uncorrected pre-CIS curve is artificially undersaturated due to loss of calcite in the wellbore.

Once the CSI boiling curve has been generated, comparisons can be made with other wells already being dosed to help determine the initial chemical concentration to be used. For wells that are not already dosed and thought to be depositing calcite upon boiling, a correction is made to add back the lost calcite. This provides a more accurate picture of the true CSI curve. To do this an assumption is made that the waiwhatu (geothermal fluid) is in equilibrium with calcite before any boiling occurs. This has been tested for wells before and after installation of CIS and has been proven to be a reasonable assumption in most cases (Figure 2).

2.3 Calcium Trends

The simplest way to monitor the effectiveness of inhibitor dosing is to regularly monitor the calcium concentration of the waiwhatu (geothermal fluid). Many wells show a step change in calcium levels when the inhibitor dosing is switched on or turned off. This allows a baseline calcium concentration to be set, with the effectiveness of the chemical measured by observation of a calcium level above baseline (Figure 3). Baseline levels should be checked periodically to ensure the mātai matū **(**chemistry) of the well has not changed and the increased calcium concentration is still due to the addition of a chemical inhibitor.

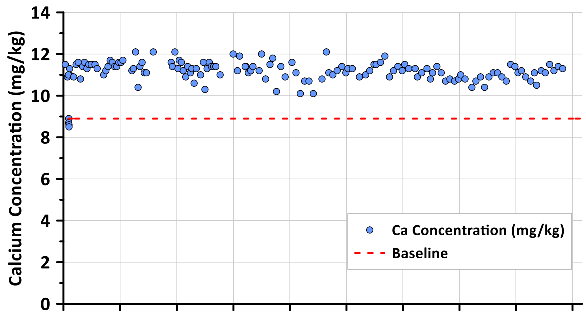

Figure 3: Regular monitoring of a CIS well where the calcium concentration remains above baseline levels.

While many wells display this step change in calcium concentration, there are others where the calcium levels are too variable to pick up the change or where the change is so small that is difficult to accurately assess. For situations like this we need other methods to determine the effectiveness of the dosing system.

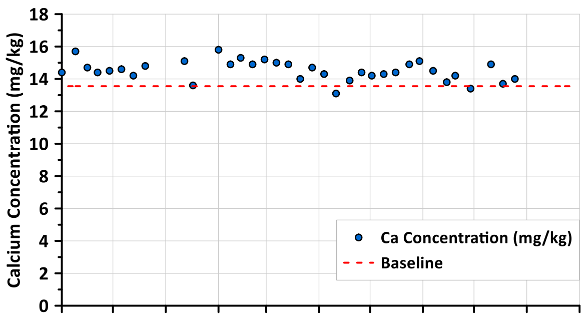

Figure 4: Example of a well where the calcium concentration is too variable to reliably assess effectiveness of CIS dosing.

2.3 Production Data Assessment

Monitoring of production data is another viable method to assess the effectiveness of CIS dosing. While it does not provide an instant confirmation of a successful installation, continuous monitoring can give confidence that the chemical is operating as required and can also act as an early warning system for any issues that cause the setup to stop functioning

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as intended. For many wells, simple monitoring of the well flow versus wellhead pressure can be enough to assess the performance of the well. There are occasions where this metering is not accurate or reliable, which requires some additional parameters to be monitored to ensure the well performance is being appropriately checked. Regular tracer flow testing (TFT) gives an early warning of any decline in performance, while well output testing provides a further check on the health of the well. In addition, several station parameters can be monitored including steam flow, total mass flow and generation output. Monitoring of these key station performance indicators in combination with direct assessment of the available production data should ensure that the effectiveness of the chemical dosing is reliably monitored, allowing any necessary changes to be made to the dosing before any issues such as wellbore restriction due to scaling becomes a major problem.

2.4 XY Caliper Assessment

Another useful tool in the assessment of CIS installation is the use of the XY caliper (XYC) tool. This tool allows accurate fingerprinting of any scale deposition currently in the wellbore or confirms the casing is clear of scale and provides a definitive assessment of whether the dosing is working as intended. The tool captures two continuous independent perpendicular measurements of the internal diameter of the casing and a fast-response temperature profile can be acquired in real-time or memory mode. The internal diameter measurement ranges from 3 " to 14 ", with ±0.25 " accuracy and data recorded at a rate of 20 samples per second. The tool has a maximum operating temperature of 325 °C. The fullbore profile acquired by the XYC allows for zone targeting and BHA selection to aid intervention planning for scale removal. The use of the XYC tool has been invaluable in our optimisation efforts, giving us confidence that our dose rate reductions have not caused a negative impact in the wellbore.

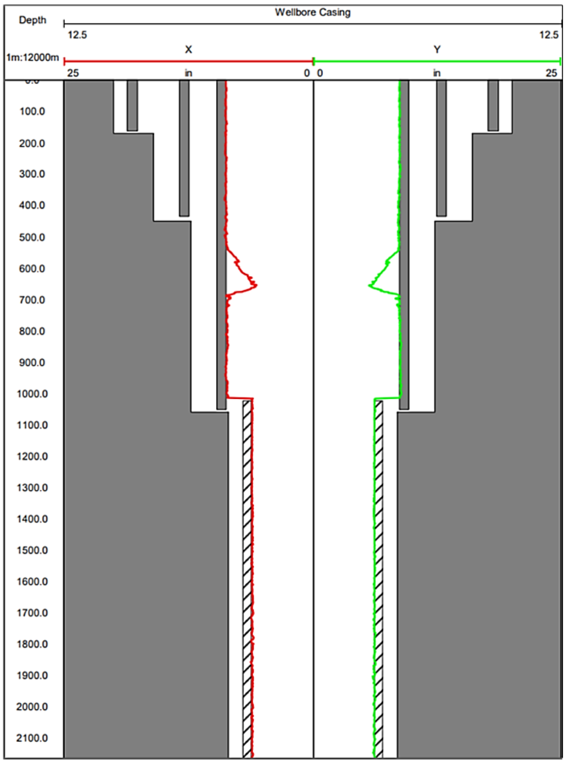

Figure 5: Representative XYC report, accurately detailing the scale profile within the wellbore.

3. STRATEGIC DOSE RATE REDUCTION

As many of our wells with CIS installations are critical to our generation portfolio, we started by assessing each well and its suitability for testing at a lower dose rate. Decisions were made considering the importance of the well, any known well issues and the ease with which we could monitor the impacts of reducing our chemical usage. With a suite of monitoring options and tools to assess any consequences of reducing the dose rate, we began by selecting wells for initial trials.

3.1 Easy Targets

The simplest wells to optimise were those that showed a step change in calcium concentration when the dosing system was on or off. Several tests were undertaken to establish the current baseline calcium concentration for each of these wells before the dose rate was gradually reduced over a period of a few months. Wells were prioritised based on the criteria detailed above before being sequentially optimised. During the optimisation programme calcium levels were measured weekly, or in some cases more frequently, to ensure rapid feedback on any dose rate reductions that were undertaken. After each change in dose rate there was a hold period to allow stabilisation of the well at the new dose rate and to check there were no unexpected deviations in the calcium concentration (Figure 6). Eight of our thirteen CIS wells were able to be optimised in this way, enabling us to make rapid reductions in dose rate over a relatively short period of time. Some of the wells that were part of this initial optimisation had varying amounts of preexisting scale within the wellbore. These wells were further monitored through XYC runs that were periodically undertaken during the optimisation programme to ensure no further scale growth.

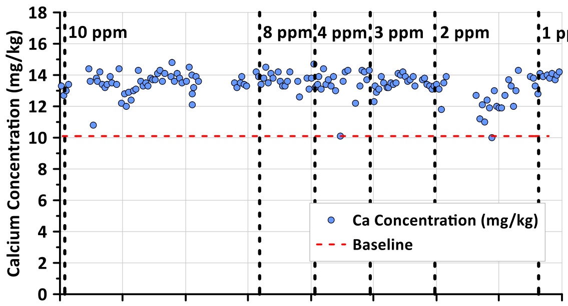

Figure 6: Gradual reduction of chemical dose rate. Periodic baseline checks were conducted throughout the optimisation process.

3.2 Challenging Reductions

Of the remaining five CIS wells, three have not yet been optimised for various reasons. The dosing in one of the wells provides an additional benefit at the Wairakei binary plant (Richardson *et al*, 2022) and so the dosing has been maintained to avoid reducing the downstream benefits. Another well has several downhole issues and was particularly troublesome to gain success with CIS dosing and as such has been maintained at the current successful dosing level. A third well has not yet been optimised due to its importance in our generation profile and because it will not be a straightforward optimisation. This left us with two wells to optimise, both of which could not be monitored using the simple method of tracking the calcium trend as used for the other optimised wells. Both wells were in a similar part of the māpuna (reservoir), with comparable waiwhatu (geothermal fluid) chemistry, so it was anticipated that once one well had been optimised the other well could have its dosing lowered to a similar level.

For the first well a combination of TFT, wellhead pressure and mass flow data was monitored to ensure the dose rate reduction was not impacting the performance of the well. In addition, the optimisation was aligned to start three months before a planned well outage, providing the perfect opportunity to run the XYC tool and check that the well was still being fully protected from calcite scaling. As we could not get direct feedback from the well in the form of the calcium trend, we made the decision to move the dose rate in one large step, rather than the small sequential steps used for the earlier wells to speed up the optimisation process. This was justified by comparing the CSI boiling curves of other optimised wells. While the māpuna (reservoir) well temperatures are quite different, the level of oversaturation reached upon boiling is similar, so it was inferred that a similar dose rate could be applied (Figure 7). This allowed us to take the chemical dosing from 6 ppm to 0.5 ppm in one step. Monitoring of the production data and the subsequent XYC run confirmed that the lower dose rate was indeed effectively suppressing calcite scaling in the wellbore. Further monitoring was conducted in the following months to ensure that the well remained protected by the reduced chemical dosing.

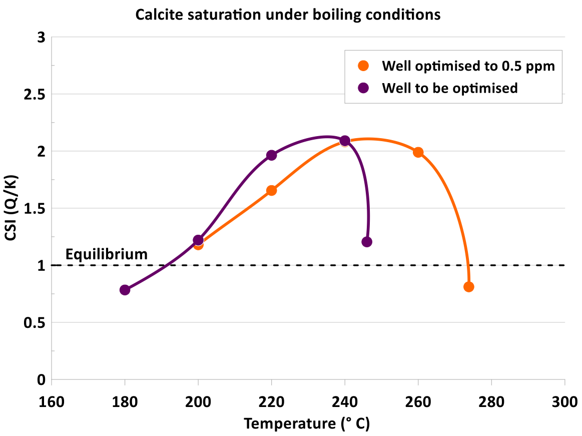

Figure 7: Comparison of the CSI boiling curves of an optimised well with that of the well to be optimised.

The final well target for optimisation was left until last as it already had preexisting scale within the wellbore, so the risk of building on this scale and restricting the wellbore was increased on this well. With similar waiwhatu (geothermal fluid) chemistry to the other optimised well, a one-step large reduction in dose rate from 6 ppm to 0.5 ppm was employed. Once again, the reduction in dose rate was aligned three months before a pre-planned outage to minimise generation loss and limit any potential negative impact from reducing the chemical dosing. The production data was monitored during the initial three months to check for any decline in output before the XYC could be run. The accuracy of the XYC tool allowed comparison with previous runs and clearly showed that the scale profile in the wellbore was unchanged following the dose rate reduction (Figure 8). Continual monitoring of production data confirmed this lowering of the chemical dosing was again successful.

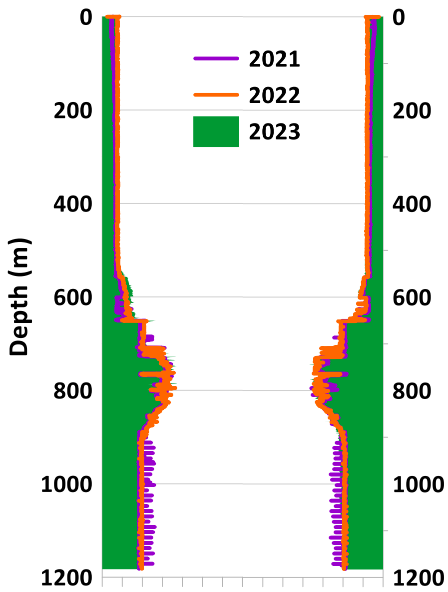

Figure 8: Comparison of XYC runs pre- (2021 and 2022) and post-optimisation (2023), showing no meaningful changes in the scale profile.

3.3 Summary of Optimisation

Ten of our thirteen CIS wells have been optimised, with significant reductions in chemical usage (Figure 9). Some of the wells listed may have some more room for optimisation, while one of the wells not yet optimised will be targeted in the coming months.

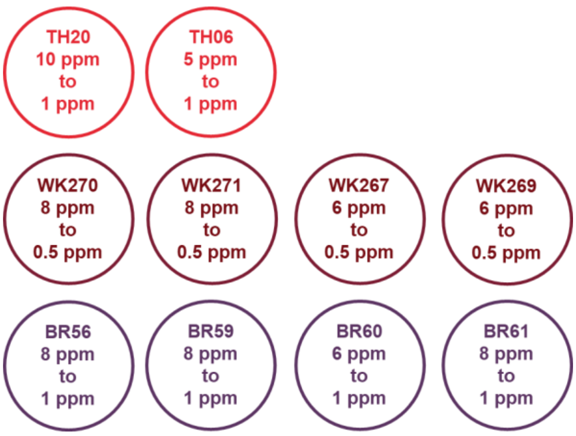

Figure 9: Summary of dose rate reductions at ten of our CIS wells.

4. COMPARISON WITH THEORETICAL DOSE RATES

In addition to providing support during the optimisation programme, Nalco also provides access to the recently updated Geomizer 3.0 software, which can predict the optimal dose rate required for the inhibition chemical. Geomizer 3.0 is a powerful modelling tool that was developed specifically for geothermal systems. Using the speciation engine of Watch 2.4 and Geochemist's Workbench, this tool allows easier parameter input for typical elements found in a geothermal system like production wells, separators, binary plant units and reinjection wells. It provides simulation visualisation using process flow input of the user; thus, offering better understanding of the system compared to line-by-line input typical to speciation engines. The software can model the process flow of the plant, mix fluids, predict saturation indices and suggest the optimal chemical and dosage to address scaling problems.

The software first calculates the calcite saturation under boiling conditions. An example of the output is shown in Figure 10. As expected, most wells became oversaturated with respect to calcite upon boiling, however, a couple of the wells currently dosed with inhibitor chemical did not show oversaturated. The software also predicted the potential for other scales to form such as metal silicates, smectites and clays.

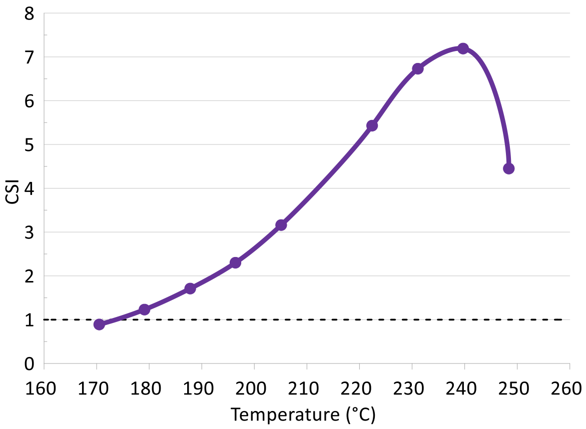

Figure 10: Example of the output from Geomizer 3.0 simulating calcite saturation under boiling conditions.

Once the calcite saturation of each well had been assessed, the available chemicals and their corresponding dosage were modelled using the software. From this analysis the current chemical used for all wells, GEO907, appears to be the best solution as it requires the lowest dosage to protect against calcite scaling in the simulations. Table 1 shows the results of this assessment. There is good agreement between the current dosage and the theoretical dosage, with the results for some wells suggesting that further minor adjustments could be made to reduce chemical usage even further. This excellent correlation suggests that Geomizer 3.0 can produce reliable predictions for optimal chemical dosage rates and could be used to speed up the optimisation process.

Table 1: Actual and theoretical chemical dose rates for the wells optimised in this study. N/A represents wells that appeared undersaturated in the Geomizer 3.0 simulation.

Well	Theoretical dosage (ppm)	Current dosage (ppm)
WK267	0.5	0.5
WK269	0.5	0.5
WK270	0.5	0.5
WK271	0.4	0.5
TH06	0.3	0.5
TH20	0.4	0.5
BR56	0.3	1.0
BR59	0.3	1.0
BR60	0.3	1.0
BR61	0.3	1.0

5. BENEFITS

The benefits of optimising the chemical dosage are financial and operational. The massive reduction in chemical usage has allowed us to realise annual operational savings of over $500K and many of our wells now have annual chemical usage costs of less than $10K. These efficiencies have been achieved while still protecting our production wells against calcite scaling and the associated generation losses. This, combined with the improved reliability of the systems, significantly enhances the viability of deploying CIS in other wells and we are currently assessing our fleet for further opportunities to install CIS. An additional benefit of reducing our dosing has been to make tubing removal safer. Previously, we observed formation of a thin blue or white scale on our tubing above the flash point, which could lead to complications when retrieving the tubing from the well for inspections or downhole surveys (Figure 11). XRF analysis of the scale suggests it is a mixture of silica, calcium and other metal ions along with organic material, most likely the inhibitor. Since optimising our dosing, the presence of this scale has significantly reduced or in most cases is not observed anymore, indicating that it was a consequence of overdosing the chemical inhibitor.

Figure 11: Example of the blue/white scale that previously formed on our downhole capillary tubing when overdosing the calcite inhibition chemical.

6. CONCLUSION

A targeted dose rate reduction programme has been successful in significantly lowering the chemical usage and costs required to protect our production wells against calcite scaling in the wellbore. The use of calcite saturation indices, calcium trends, production and operational data, and the XYC tool have allowed us to optimise the chemical dosing at ten of our CIS wells, opening up the opportunity to deploy these systems in more wells in the future given the economic viability of these setups has been significantly improved. The Geomizer 3.0 tool has been shown to have good correlation between theoretical and actual chemical dosing rates and suggests that further minor adjustments could be made to lower dose rates even more. The benefits of this programme of work are not only financial, with the operability of the setup improved through the reduction or removal of scaling on the tubing, apparently due to overdosing. This works highlights how valuable the use of calcite inhibition systems is in geothermal power generation and with the reduced operational costs, is likely to become an even more widely used solution to calcite scaling and the associated generation losses.

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REFERENCES

Arnorsson, S. and Sigurdsson, S. (1982). The Chemistry of Geothermal Waters in Iceland. I. Calculation of aqueous speciation from 0° to 370°C. *Geochimica et Cosmochimica Acta*, Vol.46, pp. 1513-1532.

Brown, K.: Mineral Scaling in Geothermal Power Production. *United Nations University, Geothermal Training Programme. Reykjavik, Iceland, No. 39*. (2013).

Mejorada, A., Daimol, A., Hermoso, D., Hollams, R., McCormick, J. Calcite Inhibition System: Lihir Experience. *Proceedings International Workshop on Mineral Scaling, Manilla, Philippines*. pp. 93 – 96. (2011).

Moya, P., Nietzen, F., Yock, A. Benefits from the Utilization of a Calcium Carbonate Inhibition System for Production Wells at the Miravalles Geothermal Field. *Proceedings World Geothermal Congress, Antalya, Turkey*. (2005).

Moya, P., Nietzen, F. Performance of Calcium Carbonate Inhibition and Neutralisation Systems for Production Wells at the Miravalles Geothermal Field. *Proceedings World Geothermal Congress, Bali, Indonesia*. (2010).

Richardson, S., Ferguson, A., Barrie, K. Scaling Rate Reduction at Wairakei Binary Through Application of Scale Inhibitor. *Proceedings 44th New Zealand Geothermal Workshop, Auckland.* (2022).

Siega, F., Ferguson, A., Richardson, I., Allan, G. Field Application of Calcite Antiscalant in New Zealand: Screening Process, Performance Evaluation and Management of Operational Issues. *Proceedings World Geothermal Congress 2020+1, Reykjavik, Iceland*. (2021).

Vetter, O.J., Campbell, D.A. Carbonate Scale Inhibition in Republic's East Mesa Geothermal Operations. *Geothermal Resources Council, Transactions*., 3, pp. 757-760. (1979).

Watson, A. Geothermal Engineering - Geothermal Drilling and Well Design. Ch. 5. pp 77-97. (2013).