The CaSil Technology at the He Ahi/Tauhara Geothermal Field: Silica Scale Elimination in the Presence of a Calcite Inhibitor

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ABSTRACT

Silica scaling is a major problem in the utilisation of geothermal resources worldwide. It blocks valves, heat exchangers, and reinjection wells, severely limiting the energy that can be extracted. Current mitigation efforts are not wholly successful in preventing scale from forming, so costly and time-consuming cleaning and maintenance efforts are still required.

CaSil Technologies Ltd has developed a novel and transformative technology that approaches the problem of silica scaling in a different way. Instead of sequestering or delaying the precipitation of silica, the CaSil technology chemically captures dissolved silica and transforms it into a new calcium silicate hydrate (CaSil) material. With rapid reaction kinetics, the Silica Saturation Index is lowered significantly below 1, effectively eliminating silica scaling. The CaSil material forms discrete and finely dispersed particles which can freely flow through heat exchangers and pipework, without sticking to metal surfaces.

The CaSil technology has been previously proven at automated pilot scale at three different New Zealand geothermal resources (Wairakei, Kawerau, Mokai). Contact Energy Ltd invited CaSil Technologies to demonstrate the technology at the He Ahi Eco-Business Park, located on the Tauhara geothermal resource near Taupo. The field is designed for the supply of direct-heat to industry and is serviced by a single well. To prevent calcite scaling in the production well, a calcite inhibitor is dosed downhole. This was the first time the CaSil technology was trialled in the presence of a calcite inhibitor, which may interfere with the calcium containing treatment agent dosed for the CaSil reaction.

This paper presents performance data of the pilot plant and complementary batch experiments performed on-site which demonstrate the robustness and effectiveness of the CaSil process. The Silica Saturation Index was reliably reduced << 1 across the trial period and a good compatibility between CaSil and the calcite inhibitor established.

1. INTRODUCTION

1.1 Silica Scaling

Geothermal power stations can be used to harness the vast thermal energy in earth's core for electricity generation. As fuel, hot water, steam, or a mixture of both is extracted from the ground in naturally occurring geothermal reservoirs. The extracted fluids typically contain dissolved minerals such as chloride salts, carbonates, metals, and silica, with varying compositions based on the local geology, pressure, and temperature of the reservoir.

In the steam production process, the hot fluid is depressurised, causing a part of the liquid to vaporise to drive a steam turbine, while lowering the liquids temperature due to the pressure-dependent boiling point. However, this process concentrates the dissolved chemical species in the brine and lowers the silica solubility due to the reduced brine temperature. As a result, silica typically becomes supersaturated after a flashing process and polymerisation begins. The kinetics of the polymerisation process are dependent on pH, salt content, and saturation level. The polymerised silica compounds lead to scale formation in equipment like piles, heat exchangers, and reinjection wells, progressively lowering plant efficiency and requiring costly maintenance and downtime (García et al. 2005; Iler 1979; Makrides et al. 1980).

Various mitigation methods, such as hot reinjection, acid dosing, and sequestration agents, are used worldwide but often suffer from drawbacks like limited resource utilisation, corrosion, or high operating costs. No current method fully prevents silica scaling, so regular cleaning and maintenance remain a necessity (Gunnarsson and Arnórsson 2005; Thorhallsson 2011; Richardson et al. 2014).

1.2 The CaSil Technology

The Calcium Silicate (CaSil) technology has been developed as a root-cause silica scale elimination technology to address the shortcomings of currently utilized mitigation efforts. Instead of delaying the onset of polymerisation, or keeping polymerised silica in suspension, it transforms dissolved silica into a novel calcium silicate hydrate material which does not stick to metal surfaces. This means, significantly lower brine temperatures are possible after the CaSil technology treatment without inducing any silica scaling, than with any other commercially available and economical technology.

In the CaSil process, a treatment agent is injected into the geothermal brine flow under controlled conditions. A rapid transformation of silica into CaSil effectively lowers the dissolved silica concentration significantly below a Silica Saturation Index of 1. The finely dispersed CaSil particles can easily flow through pipework and binary cycle heat exchangers and are finally separated prior to fluid reinjection. The CaSil material is a usable and sustainable material and can be used for environmentally beneficial applications.

The CaSil technology can be readily installed into existing geothermal power stations or greenfield projects to offer a comprehensive silica scaling prevention technology as well as enable the full utilisation of a geothermal resource.

1.3 He Ahi Eco-Business Park

The He Ahi Eco-Business Park is a direct-use heat park for climate related businesses and industry, located immediately north-east of Taupo, New Zealand. The land is owned by the Te Pae o Waimihia Trust, which facilitates the development of the park. The geothermal heat for direct-use is supplied by Contact Energy.

The field sits on the Tauhara geothermal resource and is supplied by a single well, TH6. The well can supply approximately 250 t/h of hot geothermal fluid at 210 °C. Currently, Contact Energy supplies low carbon heat to Tenon and Nature's Flame for timber and wood pellet drying, and Tnue for the manufacture of a controlled release nitrogen fertiliser.

Due to the dissolved bicarbonate concentration in the sourced brine, a Calcite Inhibition System (CIS) is used on site (Ferguson et al. 2024). This prevents excessive calcium carbonate scaling at the flash point in the well bore and significantly reduces required workovers.

2. CASIL TRIALS

2.1 Purpose and Setup

The CaSil development plant was mobilised to the TH6 well pad at He Ahi in 2024 for trials of the CaSil technology at this site (see Figure 1). The purpose was the demonstration of the effectiveness of the technology in lowering the Silica Saturation Index, further validate its applicability across a broad range of geothermal brine compositions, and investigate the effect of a CIS chemical on the CaSil process.

Figure 1: CaSil development plant deployed at the He Ahi Eco-Business Park.

To simplify the trial setup and lower Health and Safety requirements, flashed geothermal brine from a weir box was utilised. The fluid was sourced straight from the flash vessel outlet and pumped through the CaSil demonstration plant. Treated and clarified geothermal fluid was mixed back into the flashed brine stream downstream of the weir before the fluid was ponded and later pumped to reinjection.

2.2 Trial Results

2.2.1 Plant Availability

For the trial, the development plant operated a total of 126 hours over 16 days of operation. A very high plant availability of > 99 % was achieved with one plant trip due to an incorrect Variable Speed Drive setting for an electric motor, which was part of an upgrade package for a plant component during mobilisation.

The first 64 hours of operation were performed in August 2024. The second part of the trials were completed in February 2025.

2.2.2 Silica Saturation Index and Temperature

The Silica Saturation Index (SSI) describes the fraction of dissolved silica in solution to the solubility of silica at process conditions (pH, temperature). If the SSI is below 1, all silica remains in solution. For an SSI > 1, polymerisation will occur after an induction period and silica scale forms. This makes the SSI a useful tool to compare brines from different steps in a process at different conditions or different geothermal resources and offers a quick interpretation in regard to the silica scaling potential of a fluid.

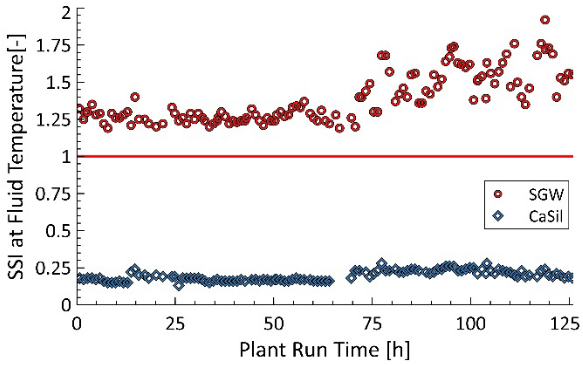

Figure 2: Silica Saturation Index at fluid temperature over total plant run time for sourced SGW and CaSil treated brine.

The SSI for the sourced separated geothermal water (SGW) as well as the CaSil treated brine over the trial period is shown in Figure 2. All SSI values are calculated for the respective fluid temperature and pH.

In the first trial period, the SSI of the sourced SGW was on average 1.26 with relatively little variation. Silica is supersaturated and will precipitate over time. However, the CaSil process reduced the SSI to an average of 0.17.

In the second half of the trial, the SSI of the SGW was significantly more varied due to the variation in silica concentration of the sourced fluid over time. An SSI of up to 1.9 was calculated. In contrast, the SSI after CaSil treatment remained stable. An SSI of 0.22 was achieved on average due to the slight variations in SGW fluid chemistry.

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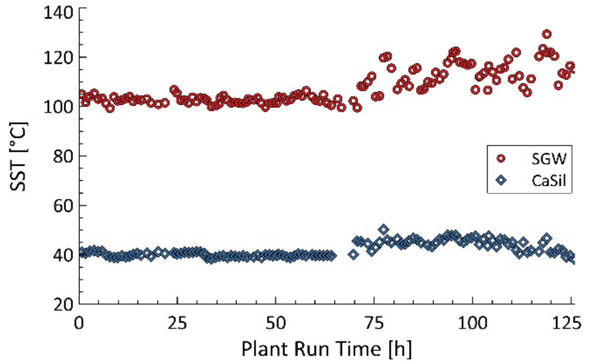

Figure 3: Silica Saturation Temperature over total plant run time for sourced SGW and CaSil treated brine.

The Silica Saturation Temperature (SST) is the fluid temperature at which the SSI equals 1 and silica scaling will commence at a fluid temperature below the SST. Figure 3 depicts the SST over the plant run time for the sourced SGW and CaSil treated brine.

The SST of the sourced fluid was significantly reduced from approximately 105 °C to an average of 42 °C. This significant reduction in the SSI and SST by the CaSil technology enables substantially more utilisation of geothermal fluids without silica scaling. This could be for the supply of geothermal heat (also see section 2.3) or additional electricity generation, depending on the geothermal resource and location.

Additionally, due to the dampening effect of the CaSil process on outlet SSI and SST in response to varying inlet parameters – such as short-term fluctuations or long-term changes in the geothermal resource – the technology can provide greater stability and assurance for downstream equipment operating near the SST. This means that even if inlet silica concentrations rise unexpectedly in the future, the outlet SSI remains controlled, allowing downstream components to continue operating safely within their design parameters without being subjected to silica scaling.

While this trial was completed with flashed fluid at the He Ahi resource, the principle remains the same for other geothermal fields or process conditions.

2.2.3 Effect of CIS chemical

The CaSil technology has been demonstrated in three other geothermal fields before (Schweig et al. 2024). However, none of these fields used a Calcite Inhibitor System. During the first phase of the trials, TH6 was dosed with 1 ppm of CIS chemical, whereas during the second part, a concentration of 0.5 ppm was dosed.

CIS chemicals are designed to prevent calcium ions to form calcite with the present dissolved bicarbonate. Therefore, the chemical could interfere with the CaSil treatment agent to form the calcium silicate material, which requires a form of calcium. Complementary batch experiments to the pilot plant operations were conducted to investigate the effect of the CIS chemical on the CaSil process efficiency.

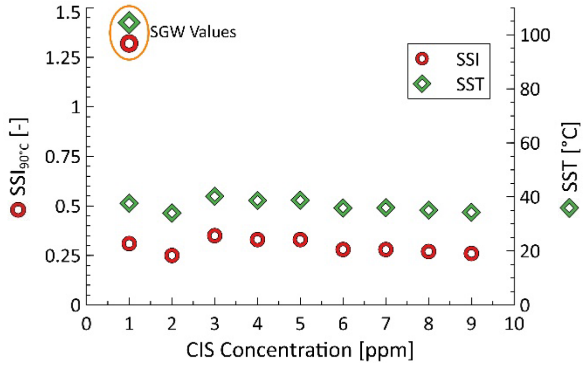

Figure 4: Silica Saturation Index for 90 °C and Silica Saturation Temperature for sourced SGW and CaSil treated brine over CIS concentration.

The SSI of the sourced brine for this experimental series was 1.32 (see Figure 4). After the CaSil treatment, the SSI was reduced to 0.31, which is slightly higher than the results achieved in the pilot plant (see Figure 2). This difference in treatment efficiency is due to experimental constraints in the batch approach which are not present in a continuous process.

Additional CIS chemical agent was added to the sourced brine before CaSil treatment. However, no significant difference in treatment efficiency can be seen, even at concentrations as high as 9 ppm of CIS treatment agent. Slight variations in the achieved results are visible but are due to naturally occurring errors for the repeatability of a batch process.

The result of this experimental series shows that the CaSil technology is compatible with CIS treated brines, even when heavily dosed. No penalty in treatment efficiency is imposed by increasing CIS concentrations.

2.3 Heat Extraction for Industrial Use

The significantly lower SSI after CaSil treatment means the fluid temperature can be lowered further without silica scaling. In the case of a direct-use heat park such as He Ahi, more businesses could be supplied with low carbon direct-heat from the same fluid flow. Currently, geothermal resource owners must carefully choose how many industrial users they can co-locate to their heat park and which applications they can support. While timber drying, pulp and paper, or dairy processing will require high grade heat (> 130 °C), these applications quickly saturate the available heat before silica scaling starts (Climo et al. 2022).

However, significant amounts of heat remain in the geothermal water below 130 °C which can be unlocked with the CaSil technology. This allows further co-location of medium grade heat users such as food and beverage processing or rendering of animal products (60-140 °C), as well as the inclusion of low-grade users such as aquaculture, meat processing, greenhouses, or bio-fermentation (< 80 °C).

A significantly higher load factor and resource utilisation can be achieved by including medium and low-grade heat users into the park. A visualisation of the usable heat can be seen in Figure 5 on the example of the He Ahi Eco-Business park.

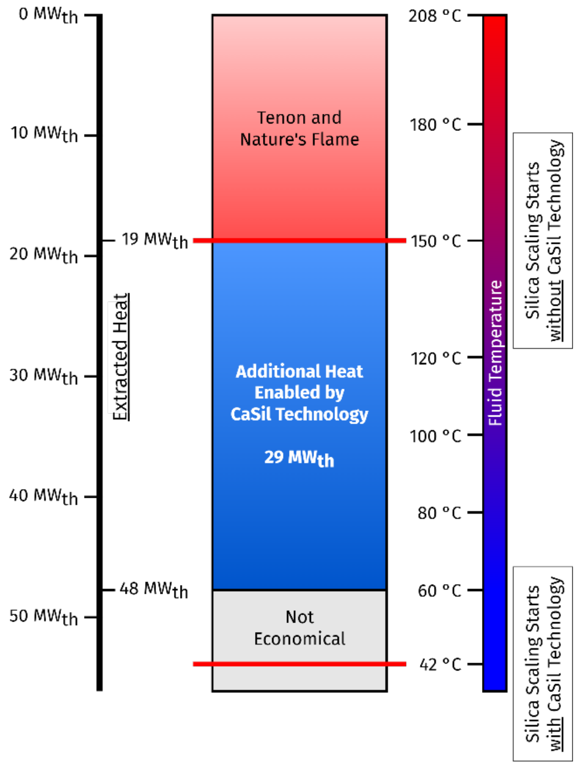

Figure 5: Visualisation of the extracted heat on the example of the He Ahi Eco-Business Park.

At He Ahi, the geothermal fluid enters the direct-use heat exchanger with 208 °C and is gradually cooled. On average 19 MW_{th} is supplied to Tenon and Nature's Flame for timber and wood pellet drying, which relates to a rejection temperature of 150 °C. However, at this temperature an SSI = 1 is reached and silica will start polymerising.

As depicted in Figure 2 and 3, the CaSil technology offers a significantly lower SSI and the geothermal brine could be cooled below 45 °C before an SSI = 1 was reached. Therefore, more heat can be extracted without scaling. Assuming a lower economical limit of 60 °C, an additional 29 MW_{th} in heat supply could be added to the field, which is unlocked by the CaSil technology. This equals an additional 152 % of saleable heat, significantly boosting the fields utilisation from the same water flow.

3. CONCLUSION

The CaSil technology was tested for 126 hours, over two trial periods during August 2024 and February 2025 at the He Ahi Eco-Business Park, located on the Tauhara geothermal resource. While the technology was demonstrated at three different resources before, it was never tested with the presence of a Calcite Inhibition System.

The field trials showed a significant reduction in the Silica Saturation Index, from approximately 1.26 to down to 0.17. An average silica saturation temperature of 42 °C was achieved after CaSil treatment. Batch experiments confirmed that the CIS chemical is not negatively interfering with the treatment efficiency of the CaSil technology, with CIS concentrations up to 9 ppm tested. This means, the CaSil technology is compatible with CIS treated brines without performance loss.

Due to the significant reduction in SSI, more heat energy could be extracted for energy generation or direct-heat utilisation such as in a heat park like the He Ahi Eco-Business Park. For the example of He Ahi, an additional 152 % of saleable heat could be unlocked by CaSil, without the fluid being supersaturated in silica.

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