Novel Method of Dissolution Scale in The Inaccessible Geothermal Wellbore

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ABSTRACT

SIL1-2, an old well drilled in 1997 located in Indonesia, initially produced up to 420 t/hr at 22 barg. By 2023, its production rate had declined to approximately 80-90 t/hr. A scaling simulation indicated that calcite deposits likely formed near the wellbore. Limited by wellbore accessibility, the only feasible stimulation method was Solenis patented well recovery and stimulation novel method. Since the wellbore was inaccessible, the acid stimulation was initiated under less-than-ideal conditions, with no scale deposit removal or pressure-temperature logging performed beforehand. The goal was to dissolve scale buildup within the wellbore and nearby formation, sweep the solution into the formation, and prevent calcium ions from redepositing, thereby expecting permeability enhancement. Laboratory tests on core samples, the only physical reference, involved exposing them to acid and alkali chemicals. After several days of preparation, SIL1-2 was brought back online, and production recovered to about 290–300 t/hr, nearly its original capacity, as confirmed by the production separator. The well recovery and stimulation successfully increased production while also minimizing equipment requirements and reducing loss generation compared to other stimulation methods previously attempted.

1. INTRODUCTION

The Silangkitang (SIL) geothermal field in North Sumatera, part of the Sibualbuali Working Area, powers a 110 MWe plant using four production and seven injection wells. UNOCAL's exploration in the late 1990s resulted in five wells, two of which are now used for production and reinjection. The field's geothermal system is fault-related, near the Great Sumatera Fault (GSF). SIL1-2, a production well targeting the GSF, initially yielded 420 t/hr (23% steam, 1360 J/g), independently supplying ~18 MWe from 2017 to 2019. A subsequent 45-50% annual decline was observed, addressed with large flow control valve (FCV) settings.

The presence of an obstruction was identified in well SIL1-2 via static Pressure-Temperature (PT) logging in early 2020, with a reduced effective depth of 1943 ft.MD compared to the original 7644 ft.MD. To address this, a mechanical cleanout with Coil Tubing (CT) was attempted in August 2020, targeting scale near the top of the 7-inch perforated liner at 3710 ft.MD. This effort was hampered by the loss of approximately 3750 ft of 1 ¾-inch CT within the wellbore, precluding successful scale removal and potentially causing further restriction. A subsequent fishing operation in March 2021 recovered only 1674 ft of the lost CT, although this might have loosened some scale. Temporarily, the mass rate rebounded to ~200 t/hr before resuming its decline at 50%/year (Figure 1).

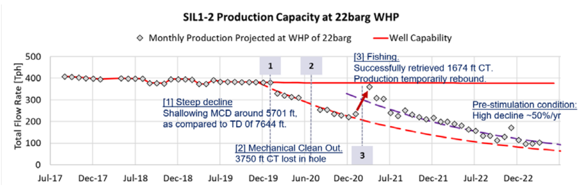

Figure 1. Sequential observation of SIL1-2 well.

2. PRE-STIMULATION ASSESSMENT

2.1 Geochemistry Assessment

Geochemical data were routinely gathered as part of SIL1-2's well surveillance program. To assess scaling risks and understand wellbore/production dynamics, these data were modeled using the WATCH aqueous speciation software (Arnorsson, et al., 1982) to determine the types of scale that might form. Initial flowing chemistry from December 2017 was used as the baseline to represent equilibrium conditions. Simulation results, focusing on retrograde solubility minerals like calcite and anhydrite, showed an initial calcite saturation index (SI) of 0.21, slightly above equilibrium (SI=0), suggesting a calcite scaling tendency. Over time, the calcite SI increased, indicating a higher probability of calcite deposition in the reservoir or near the wellbore (Figure 2). Anhydrite, however, remained undersaturated. This scaling may be driven by low operating pressures causing deeper flashing, which disturbs fluid equilibrium and leads to calcite precipitation due to CO2 degassing (Kaya et al., 2010; Satman et al., 1999).

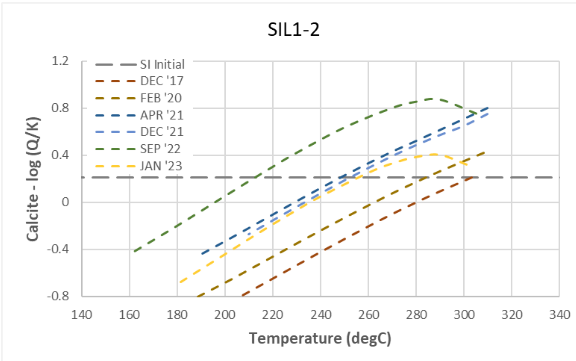

Figure 2. Calcite oversaturation in the SIL1-2 wellbore, as determined from monitoring data, is presented alongside simulated oversaturation resulting from mixing reservoir fluid and injectate. Both simulations were performed using an adiabatic cooling model.

2.2 Dissolution Test

The two cutting samples were obtained from SIL1N-4 or an adjacent well and treated with oscillation of basic and acidic solutions at 80 °C for 2 hours for each step in the laboratory. Each treatment is followed by a rinse step using tap water. For blank tests, samples are treated with the same procedure but with only the rinse solution. With the given chemical program and test method, the weight loss of the 6750-6800 m and 4400-4500 m samples during the dissolution test was 9.0% and 12.3%, respectively. And for blank tests, no weight loss for 6750-6800 m scale and just 1.1% weight loss for 4400-4500 m scale when just treated with mimic water.

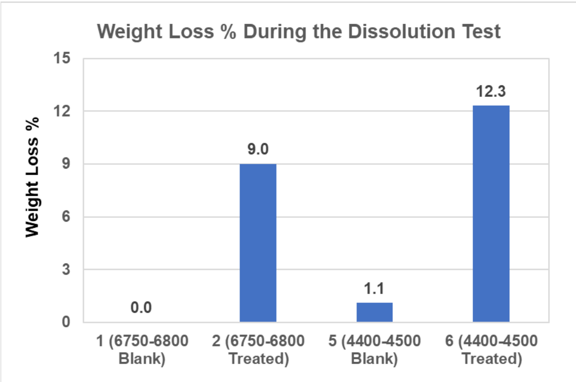

Figure 3. Dissolution test result above 10% considered a good result because during the execution, temperature, pressure, and velocity will enhance the scale dissolution and stimulation of the formation.

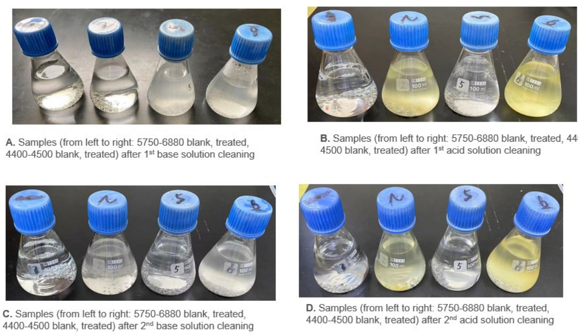

Figure 4. All samples were treated with oscillation steps between acid and alkaline

3. WELL RECOVERY AND STIMULATION PROGRAM

Due to the SIL1-2 wellbore's inaccessibility, no scale samples could be directly obtained. Instead, the scale type was inferred from chemical simulations and by referencing a nearby well exhibiting similar characteristics, namely calcite oversaturation, pressure and mass flow decline, and potential injection breakthrough. In that analogous well, acetic acid effectively removed calcite scaling. Hydrochloric acid (HCl) is also a recognized and frequently employed solution for dissolving calcite deposits in geothermal production wells (McLean et al., 2021; Kaya et al., 2010).

This novel method has proven successful in other fields for addressing both calcite and silica scaling. For instance, in Domo San Pedro, the chemical cleaning effectively treated calcite and silica scaling in both the wellbore and formation, resulting in a substantial 351% improvement in well performance (Rodriguez, et al., 2021). The chemical solutions used in that case included HCl and formic acid for calcite removal, and alkaline solutions for silica dissolution. Similarly, a combination of acid and base solutions was used in the Wairakei geothermal field to remove both calcite and silica scaling, restoring 100% of the production well's capacity (McLean et al., 2021).

Drawing upon these precedents, a strategy to enhance in-situ permeability was developed, involving solubility tests on core samples representing SIL1-2 feedzone depths as previously mentioned. These cutting samples, primarily composed of silica (quartz) with minor calcite in fractures, underwent dissolution testing using alternating alkaline and acid solution. The weight loss, representing the solubility of the rock samples, was measured at 9% and 12.3%, respectively. While the acid was the primary dissolving agent, these results indicated that increasing the dissolution rate could improve permeability. This informed the selection of chemicals for the cleanout program, which included a combination of acid, alkali, and a surfactant. The acid solution, developed by Solenis, incorporated a food-grade corrosion inhibitor effective up to 200°C and designed to be environmentally safer.

The chemical stimulation program was carried out in three steps over two days, with each step successfully completed (Figure 5). The first step involved establishing a vacuum in the well by quenching it with fresh water, in preparation for the acid treatment. Next, an acid solution (GS1127) was injected to dissolve scale in the wellbore, followed by condensate displacement and an overnight soak. An alkaline treatment was then performed, using GS1014 and GS1824, to improve the formation's permeability and prevent calcium redeposition. The final step consisted of injecting GS1127 to target any remaining calcite within the reservoir rock.

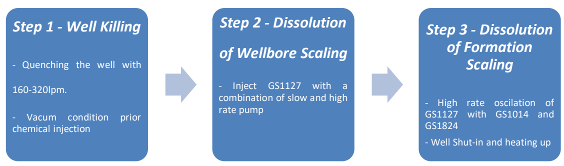

Figure 5. Summary of the executed chemical injection

4. RESULT AND DISCUSSION

Following a four-day shut-in period, the SIL1-2 well was brought back online. Due to concerns about the accuracy of orifice metering in a two-phase flow line, well performance was assessed using production separator measurements. At a wellhead pressure of 27-28 barg, the total mass rate increased by 292 t/hr (Figure 6). A simulated deliverability curve (Figure 7) indicated that, at a normalized wellhead pressure of 22 barg, SIL1-2 could potentially achieve a mass rate capacity of 420 t/hr, restoring it to its original potential. The Silangkitang power plant returned to its full electrical output of 116 MW. Given the reduced generation losses from shorter cleaning downtime and lower risks, this novel patented method emerges as a preferred method compared to previous chemical stimulation efforts in SIL, such as those using coil tubing or rigs.

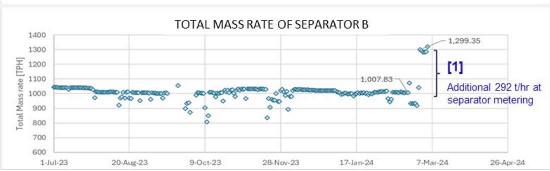

Figure 6. The observed mass rate increment at production separator after the stimulation completed.

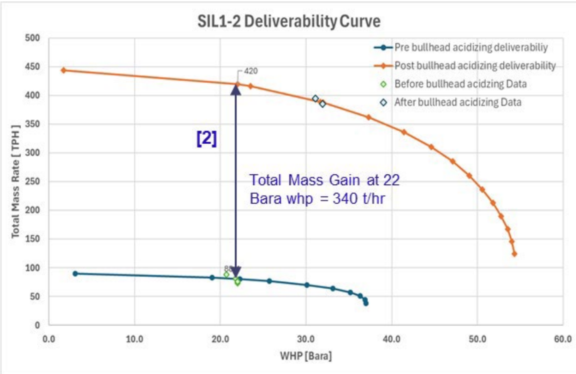

Figure 7. Post-well recovery updated deliverability curve of SIL1-2 which shows a 340 t/hr improvement (normalized to 22 barg).

5. CONCLUSION

The new method successfully brought the SIL1-2 well back to its initial mass rate capacity. While the extent of permeability improvement could not be directly quantified, the acid-alkali combination is thought to have effectively dissolved calcite deposits within the wellbore and near-wellbore region.

Compared to Coil Tubing methods, the Solenis approach offers several advantages:

- It simplifies the operational sequence, eliminating the need for high-pressure pumping units and lifting equipment.
- Increasing the pumping rate offers several potential benefits:
  - It prevents wellbore heating, minimizing the risk of corrosion inhibitor failure due to exceeding its temperature rating.
  - It can improve formation coverage, promoting more extensive chemical reactions with the scale.
  - When using a chelating agent, a higher rate may improve the dissolution rate, as Rose et al. (2010) found that higher injection rates can enhance dissolution by 4.5% and extend radial penetration.
  - It eliminates the risks associated with downhole equipment and potential loss of equipment in the hole.

Recurring scaling is expected due to the well's operating conditions and fluid composition. Therefore, SIL1-2 will continue to be closely monitored and fine-tuned for optimal performance. This successful application of well cleaning and stimulation validates its potential in the SIL field, and it will be strongly considered for future stimulation initiatives.

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