Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Online Geothermal Well Stimulation and Silica Based Deposit Removal

Muller, Logan[1]; Wilson, Daniel[2];

[1] Solenis New Zealand, New Zealand

[2] Contact Energy Limited, Taupo, New Zealand

LMuller@Solenis.com

Keywords: Online Chemical Cleaning. Silica Scaling, Geothermal Well Stimulation,

ABSTRACT

Loss of production and efficiency by reduced reinjection capacity is a common issue for many geothermal power companies with silica being the most common culprit. Permeability can be significantly impaired and there are many cases where wells are abandoned as a result. This issue not only can limit the production of the geothermal power plant and be a major cost to the plant owners to remedy but in cases in NZ and Mexico has led to permanently running production assets below design capacity.

Conventional well stimulation techniques usually all require the well to be taken out of service and have other disadvantages including significant health & safety risks, high cost of implementation, corrosion and well stressing. This paper describes the results of an alternative approach where the well is kept in full use during the chemical stimulation process: Online cleaning. This process combines chemicals and application techniques. The process is not a silver bullet chemical rather a process derived from understanding how the specific scaling deposits form, discerning the deposition pathways specific to the well, brine chemistry, temperatures, and kinetics. This synthesis facilitates the formulation of tailored treatment chemicals that react with the geothermal silica scale at temperature and are a series of steps tailored to the specific case. This paper reports the significant and sustained restoration of well permeability observed in a number of applications using this new technique and documents the results that offers the industry an alternative solution that has substantial benefits over traditional approaches.

1. INTRODUCTION

Geothermal plants around the world are challenged by the loss of reinjection capacity due to silica and silica -based deposits. This paper discusses a new technique for cleaning and rejuvenating reinjection systems using an online method that does not require the well to be taken out of service.

This paper also compares the performance and cost of using off-line techniques such as hydrofluoric acid and mechanical drilling. It concludes that for removing silica based deposits in the formation, this online method is considerably safer and more cost-effective than those results obtained simply by dosing with hydrofluoric acid (HF) or mud acid (an HCl HF blend). It discusses the benefits of not having to take a well out of service and the associated benefits of preventing casing cooling during the cleaning process.

2. BACKGROUND

In early 2018 the research and development team of Solenis meet with personnel at Contact Energy Ltd. (CEL) to understand the major issues and costs impacting efficient power production. One high priority was to improve the capacity of the existing reinjection system. Another imperative was to avoid taking a well out of service during any cleaning operation. Up until 2015, operators considered hydrofluoric acid (although known to dissolve silica) to be too dangerous and costly to implement as a potential solution. However, by early 2018 the cost benefit and risk profile allowed CEL and other operators in New Zealand to reconsider the use of HF. Such was the impact of silica on the ability to maintain electrical production of these companies.

In addition it had been observed that in most cases mechanically cleaning deposits in the casing had a varying effect on the amount of brine the wells could receive. In some cases the predominant restriction was in the well casing, in others it was permeability reduction. However in either case mechanical cleaning does not stimulate or remove deposits from the formation.

3. RESEARCH AND DEVELOPMENT TEAM FINDINGS

A part of the process to develop a cost-effective online cleaning regime, Solenis initiated a fuller analysis of the root of the problem. In recent years the chemical industry trialled products used in other sectors (e.g. cooling and boiler water treatment) to try and reduce silica polymerisation in geothermal systems. However, no 100% effective inhibitor was found. This left the industry with the need to continually drill new reinjection wells and or revert to HF cleaning. Operators recognised that if SiO_2 deposition was occurring within the formation, that well work overs using mechanical techniques within the wellbore did not improve permeability. Some companies use acid to modify the pH of the reinjection brine to delay Silica precipitation. However, over time, companies observed that the costly and difficult to manage pH dosing systems failed to curtail the loss of injection capacity despite the theoretical predictions by pH precipitation models. Even with pH modification companies were still faced with the need to recover reinjection capacity.

It was apparent that the industry needed a cost effective and safe method of maintaining or recovering reinjection capacity that did not negatively affect power production or potentially compromise the physical integrity of the well by successive cooling and taking out of service.

Solenis's study and modelling shows that silica polymerisation was not the entire issue. An Example is the presence and role of cations that precipitate silicates. These silicates then act to catalyse polymerisation and precipitation, forming deposits that are not soluble by hydrofluoric acid (Weres et al., 1981; Amjad and Zuhl, 2010; Ngothai et al., 2012) Sample analysis of well deposits showed a magnitude of 40,000 times the presence of Aluminium in scale samples that was present in the brine from which the deposit was formed. Similar observations were made with other cations when present in the range of brines studied. Thus, any dosing solution needs to dissolve both silicate and polymerised silica as well as prevent scale re-deposition triggered by the re dissolution of the cations into the silica laden bring. Previous studies had shown the ability of an alkaline step to remove amorphous silica (Muller, Rodman 2014) but this did not allow for the removal of silicates, now determined as a key factor in the deposition mechanism.

Solution

After hundreds of Lab simulations of different brine chemistries and deposit samples, Solenis formulated a system to first identify the exact composition of intra-formation scale deposits and secondly assess the effectiveness of different treatments to remove scale these and keep cations soluble.

Furthermore, field experiences showed that off-line cleaning fluids did not penetrate into the formation, resulting in poor results. In some cases, due to the well not being at full pressure, cross flows of water in the formation would carry the off-line chemicals away with no impact or cleaning happening at all.

Solenis also investigated a range of acid alkaline polymers and organic constituents to inject into the brine above the well head, or into the reinjection pipework at full capacity flow to dissolve the deposits that were blocking the formation.

RESULTS

The following graphs depict the results of a series of cleans that have been performed at CEL over the last year. What is immediately apparent is the quick and effective recovery of reinjection capacity using this online method. Figure 1 shows the results from a well that had declined to zero and had not been used for several years. The graph is a screen shot of the flow recovery from zero to it once full flow.

Figure 2 shows the load charts for three further well BR 40 BR41 BR55. BR41 was the first well treated with the cleaning method. This involved a single tanker load of treatment fluid. BR41 and BR55 are on the same reinjection line at Ohaaki, both these wells had suffered from a significant decline in injectivity. BR41 was flowing about 60t/h at max 6.7 bar WHP. BR55 could only achieve 15-20 t/h at max 7.4 bar WHP. Initial results on BR41 were encouraging but we were limited by our Flowmeter at 220t/h. Figure 1 shows the injection flowrate into the treated wells. As can be seen at BR41, the decline dropped to 100t/h in 35 days before being shut in for a plant outage. BR55 initial treatment followed shortly after BR41 and showed similar performance from the BR41 first treatment and maxed out the flow meter at 220t/h at less than max WHP. Decline was similar and dropped to 30 t/h after 80 days although during this period the well was shut for 25 days due to plant conditions. Eventually the well flow fell back to pre-treatment flow at 15-20 t/h

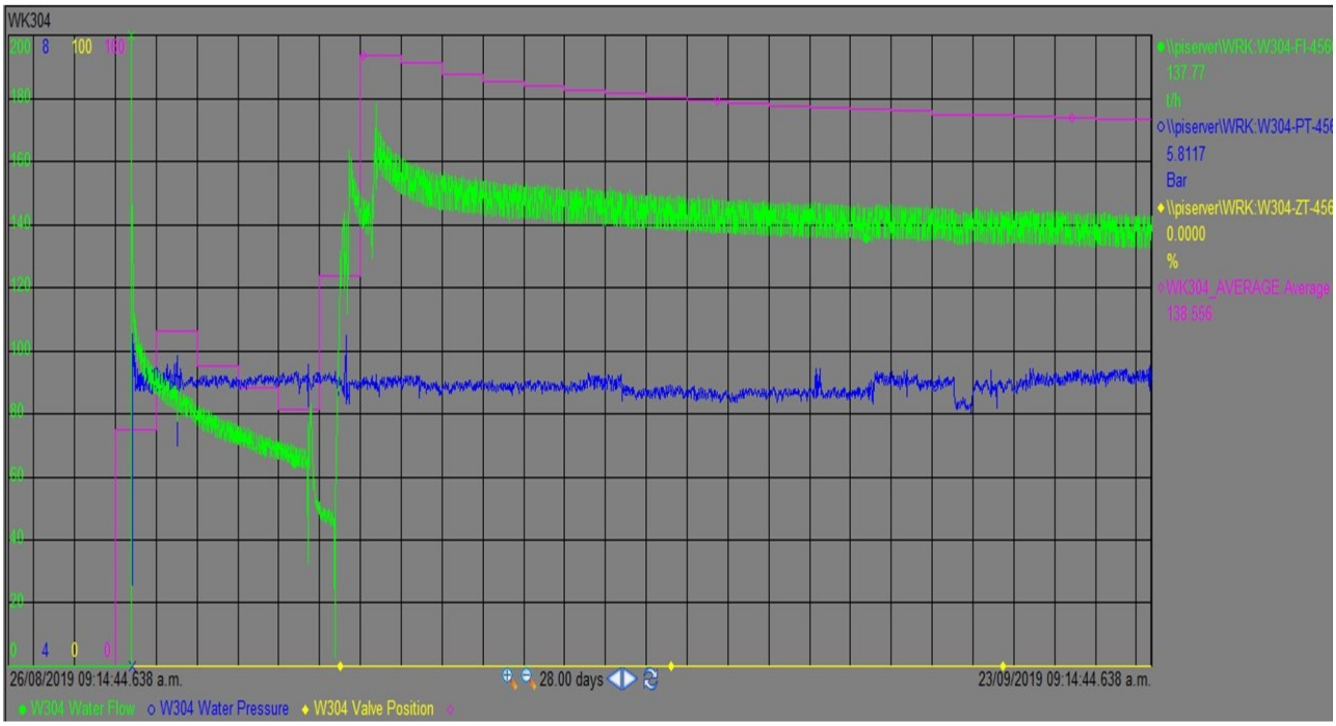


Figure 1: WK309 Screenshot showing flow increase from zero t/hr preclean to 140t/hr post clean The duration is 20 days.

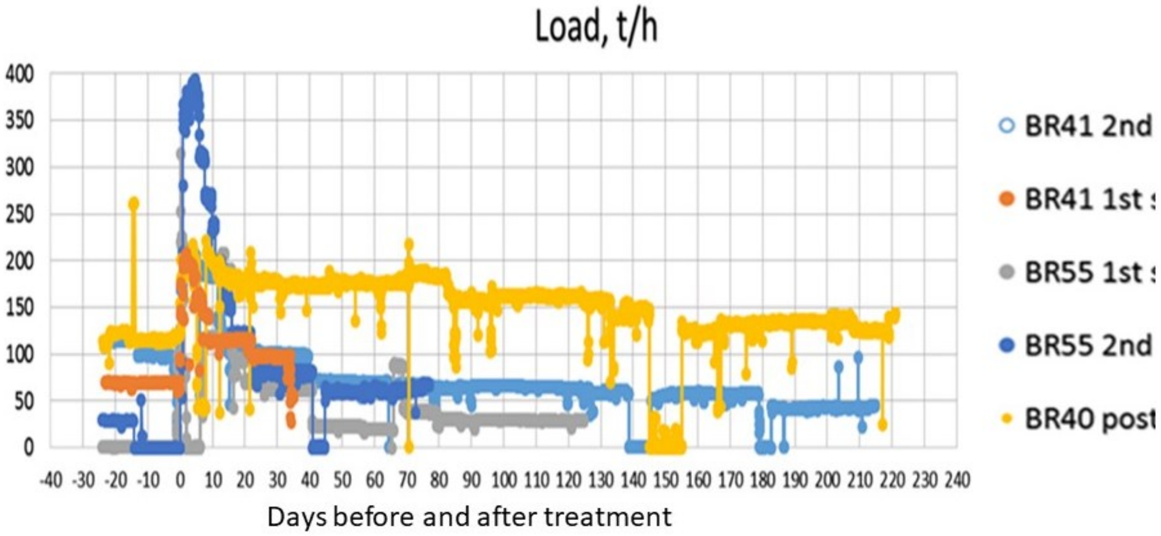


Figure 2: Treated wells load chart.

BR40 is a deeper well in the south west of the Ohaaki field and had a much better response. Initially this well was producing 110t/h at 15.8 bar. Solenis conducted a clean-out job over three days with two tanker loads of treatment chemicals. The first tanker load was pumped away at starting concentrations and didn't have a marked affect, as shown in figure two. This well previously had a live mechanical cleanout to remove wellbore scale from the perforated liner but the production casing still had significant wellbore scale. The post-facto analysis suggests the treatment removed wellbore scale from the casing but exhausted its dissolution capacity. On the second day, we upped our treatment concentration rate and had a better response. However, this well had a much higher well head pressure limitation and we found ourselves constrained by available pump head and we couldn't match the treatment concentration with increased well flow rate. The performance increase in BR40 however was sustained for a lot longer than BR55 and BR41. It did suffer decline but injectivity on BR40 has had the most stable response and even now 8 months after treatment is still accepting 150t/h at 15. 4 bar WHP. Figure three shows the injectivity measure on the treated wells.

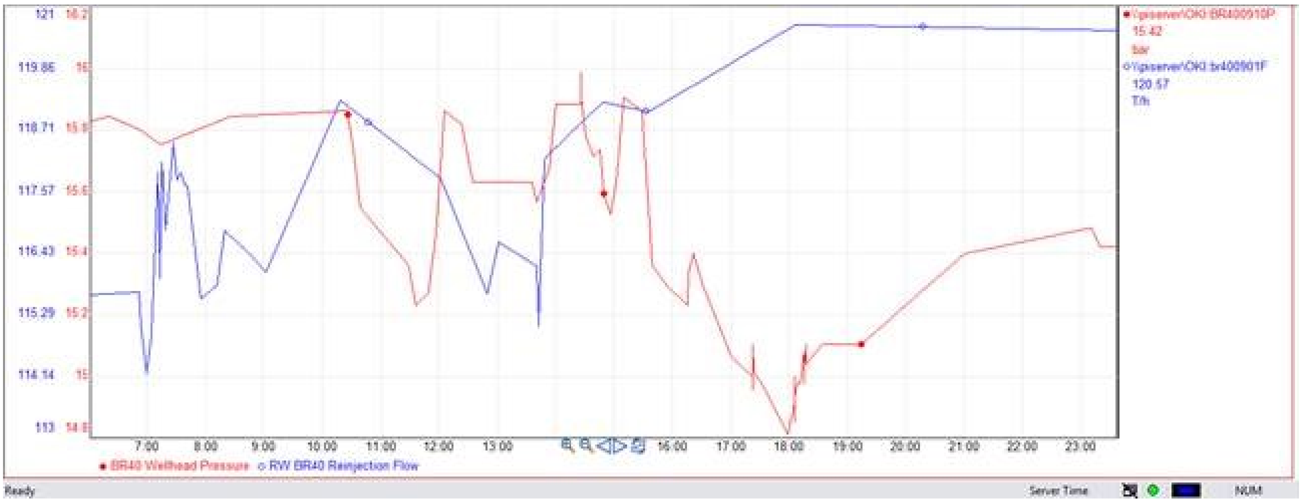
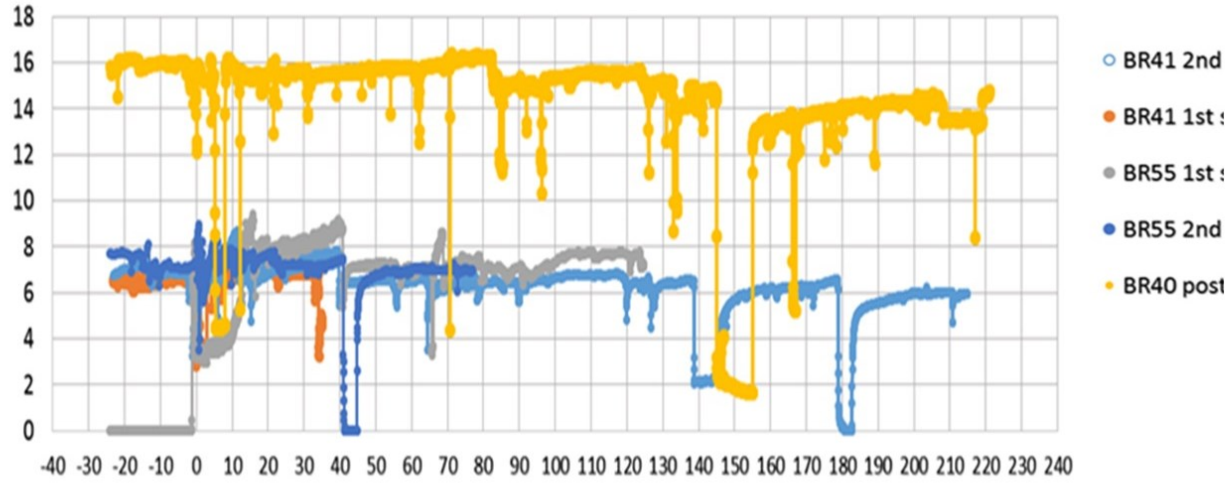


Figure 1: Injectivity for the treated wells.

Solenis attempted a second clean-out of BR41. The treatment has marked results and increased flow up to 230t/h. However, this improvement was short lived and the subsequent decline was similar to the first attempt; within 20 days BR41 was back to 100t/h and eventually settled in at 50t/h although at 5.4 bar WHP.

For the second attempt at BR55, a different approach was taken to pump a far greater volume of treatment chemical down hole and also increase the pump capacity to achieve higher discharge pressures and flowrate to match potential injection pressures and flow. At BR55 we also needed to change the dP orifice plate to be able to measure greater flow. Initial success with the second treatment was almost instantaneous; within 1 minute of the treated fluid hitting the target feedzone we had a measureable WHP drop and increase in reinjection flow. Most of the gains achieved in this well were from the first day increasing the flow from 20t/h to 350t/h at 6 bar so 1.4 bar below max. This was a great response but it was desired to treat deeper into the reservoir and at the highest flow possible. The following day saw BR55 with a 2 bar increase in WHP but flow was the same. Treatment involved pumping away a second full truck load and resulted in an increase from 350 to 380t/h at 5.9 bar; thus proving the high flow treatment was pushing deeper into the formation. Mass flow decline this time round was reasonably similar although the well maintained higher flow and injectivity. BR55 is currently still doing 60t/h at max WHP 3 months after treatment. This is a 3 fold increase in injection capacity

Figure 4 shows the WHP curves for treated wells. BR40 has had the most promising result and this is likely due to it being in a deeper section of the reservoir and has had less decline than the rest of the wells.



Hours from time of clean.

Figure 2: WHP over time for the treated wells

OBSERVATIONS

In Coutts Richardson et al paper (2018) they documented a bounce back phenomenon in performance from the HF acid off-line method. It seemed that the loss of capacity after a clean-out using HF could be broken into three periods: the first being a rapid decline due to the thermal expansion of the rock formation that restricted permeability (due to the offline clean method using HF at lower temperatures than the reinjection brine). During the second period, mass flow decline continued but at a slightly slower rate; this possibly reflects accelerating deposition on the newly cleaned mineral surfaces in the formation. During the third period, the flow decline slowed further; this may be due to the steady-state natural re-deposition of polymerising silica.

In the online clean results there are two distinct post clean observations. In the case of BR 40, there is no post clean rapid loss of permeability and the rate of loss of capacity is equal to historic disposition rates. The second observation is that Wells BR55 and 40 experienced a massive improvement in permeability; in one case flow increased from 20 tons per hour to over 380 tons per hour and the subsequent decline extended over six weeks before reaching a plateau reinjection rate at between 60 and 80 tons per hour. There are two theories for this phenomenon. The first being that the rapid increase of flow into the reservoir increases the reservoir pressure and therefore the flow decreases due to the increased back pressure. It's worthy of noting however that if this was the only cause that the permanent permeability would regain as the flow slowly decreased. The other is that both of these Wells BR55 and 45 are considerably throttled to reduce the feed pressure to the well from over 25 bar to 8 bar and that this process causes fine precipitate of amorphous silica and potentially silicate. This has two potential impacts on the well performance, the first being the fine precipitant can block near bore fissures and secondly that the fines act as a catalyst for lowering the activation energy of the polymerisation process causing more rapid near bore deposition.

However when the steady-state is reached, we suspect due to the deep penetration of this cleaning method, the steady-state maintains for a long period of time. This can be observed in the data above.

VARIANCE AND FURTHER WORK

In BR55 a second approach was taken. In the first clean-out, the chemical treatment took six hours; it was clear that a rapid improvement was observed. In order to test if the flow decline rate could be reduced, a second clean-out was completed over a period of three days with a total pumping time of the cleaning solutions of 14 hours. The intention was to try and clean deeper into the formation in the second attempt to see if the rate of the initial loss of permeability could be decreased. As can be seen by the results that the well has settled at over three times its pre- clean capacity but the early decrease in permeability was about the same. This tends to suggest that the permeability in this well is impacted by nearby deposition possibly due to the throttling or other dynamics.

The graphs also show that a rapid increase in permeability can be achieved after only one hour of chemical dosing. It is therefore planned to do much shorter but more frequent online cleans to maintain the capacity at around 200 tons per hour; this being a tenfold increase in its uncleaned state.

COST EFFECTIVENESS

CEL now has the ability to increase the reinjection capability of its reinjection wells without impacting plant production or triggering safety issues associated with the use of hydrofluoric acid. It is also apparent that a significant rise in permeability can be achieved in the very short time frame using this method.

Solenis's solution and development show that even using the deep penetration method (the most costly of the clean-out methods) the solution is over 13 times more cost-effective and much safer than the old off-line method using hydrofluoric acid. This factor of 13 is without taking into account any generation lost during the well outages during offline cleans.

CONCLUSION

At the time of writing, more clean-outs are planned in other fields and a program to maintain reinjection capacity using this method has been built into CEL's maintenance program due to its cost effectiveness and results.

The conclusion is that this online system helps deeper penetration into the formation and has longer lasting impacts over HF and HF-HCl offline cleans. The well life expectancy is not compromised by the heating and cooling and reheating of well bore casing. Solenis is adamant that there is not a silver bullet chemical solution but a thorough investigation identifying the impacts of interfering cations, developing and understanding of the precipitation and polymerisation processes are key to the solution. Every plant is different, every brine is different, and hence the solution is the development of an analytical approach to each case. For CEL this has shown to be very beneficial.

REFERENCES

Catherine Coutts, Ian Richardson, Jaime Quinao, and Olivia Goh.: Acid Stimulation of Kawerau Injection Well Pk4a Using Hydrofluoric Acid, *Proceedings* NZGW 2018

Muller, L., and Rodman, D.: Online Calcite Removal, Silica Prevention and Removal, NACE Test and Calcium Acrylate Prevention: An Update on R&D Progress, *Proceedings*, 36th New Zealand Geothermal Workshop, Auckland, New Zealand (2014).

Weres, O.; Yee, A. and Tsao, L.: Kinetics of Silica Polymerization, *J Coll. Interfac. Sci.,* **84**, (1981), 379-402.