LONG RUN POLYMERIZATION EXPERIMENTS AT THE KAWERAU GEOTHERMAL LIMITED POWER PLANT

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ABSTRACT

Silica scaling is a key consideration in the operation of geothermal power plants. The silica saturation index (SSI) through different stages of process is an important factor in the overall design and operation of a plant, especially in the design of separation pressures and the disposal scheme of separated brine from the plant. Processes such as pH modification are applied to balance energy extraction from the fluid whilst preventing silica scaling in the plant and reinjection fluids.

Silica polymerization testing on a plant is normally the final proof that the process adequately prevents detrimental silica scaling from occurring.

There is a large amount of literature available that compares silica polymerization characteristics under varying temperature or pH settings, however there is a noticeable lack of polymerization curves available under conditions close to the pH, temperature and SSI conditions that Mercury's geothermal plants operate. This paper describes a set of long run polymerization experiments conducted at the Kawerau Geothermal Limited (KGL) power plant located on the Kawerau geothermal field. Results are compared against existing silica polymerization knowledge in the industry.

1 INTRODUCTION

Silica scaling can occur via two mechanisms within the plant. The first is by precipitation of single silicic acid molecules, to create a monomeric silica scale. This will generally be seen as a thin glassy to white layer distributed across a surface. The second mechanism is via silica polymerization where silica colloids form in the solution and then are transported and attached to a surface. This is the cause of mass scaling within a plant and is seen as a bulky white amorphous scale (Brown K. , Thermodynamics and kinetics of silica scaling, 2011). This paper focuses on silica polymerization leading to colloid formation and the time required for this occur under Mercury's plant conditions. Monomeric silica scaling is touched on in this paper, but overall it is difficult to measure whether monomeric silica scaling is occurring in a plant and similarly the method used for this testing is unable to assess if monomeric scaling is occurring. Generally monomeric silica scaling is only discovered during plant inspections.

1.1 General Process Description of the Kawerau Geothermal Limited (KGL) plant

The KGL plant utilizes two stages of flash/separation in order to drive a direct use steam turbine.

The first High Pressure (HP) stage of flash is at 12.0 bar(g) and 190°C producing ~550t/h of HP steam. The HP brine flow after this separation stage ranges between 1800-2200t/h and has an SSI of 0.9-1.0. This HP brine is dosed with sulfuric acid via a single injection point to bring the pH of the fluid down to pH 4.6 to inhibit silica polymerization prior to flowing to the Low Pressure (LP) separators. For this paper, pH refers to a pH measurement taken at 25 degrees Celsius. The LP stage operates at 1.5 bar (g) and 125°C and produces about 250 t/h of LP steam. The resultant LP brine flows at 1700 t/h with a $pH_{25^\circ C}$ of 4.6 and an SSI of 1.9-2.0 Overall the silica level in the brine sits between 880 – 920mg/L based on the previous 6 months of brine sampling results. This LP brine is then pumped to 16 bar (g) and piped across the field for reinjection to the reservoir. The Kawerau field re-injects ~75% of the all the fluid it produces back into the reservoir. A diagram of this process is shown in Figure 1.

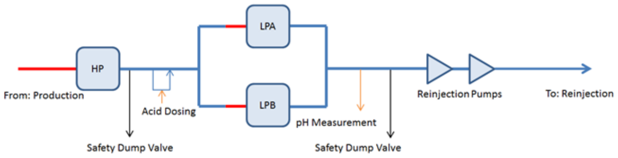

Figure 1: Basic process diagram for Kawerau Geothermal Limited (KGL) power plant

Because of the high volume of reinjection, it is important to ensure that silica polymerization does not occur prior to the fluid reaching the reservoir to prevent decline in capacity of the injection well or scaling of the reinjection pipework.

Figure 2 below shows how the SSI changes throughout the process due to steam flashing which results in increased concentration of silica and lower brine temperature.

1.2 Scaling Conditions at Kawerau Geothermal Limited Plant

The key factors which govern the time before silica polymerization is initiated in a geothermal plant are:

- Silica Saturation Index (SSI)
- Fluid pH
- Other ions present

1.2.1 Silica Saturation Index

Silica scaling only occurs at an SSI greater than 1 and becomes problematic at values above 1.2 (Brown K. , 2011). SSI is the ratio of silica concentration in the solution to the equilibrium solubility of amorphous silica. Equilibrium solubility is a function of temperature and pH.

The amount of silica present in geothermal brine is governed by water rock interactions with quartz in the reservoir. The SSI is altered throughout the plant by the different stages of steam separation changing the temperature and silica concentration. This is shown in Figure 2 below.

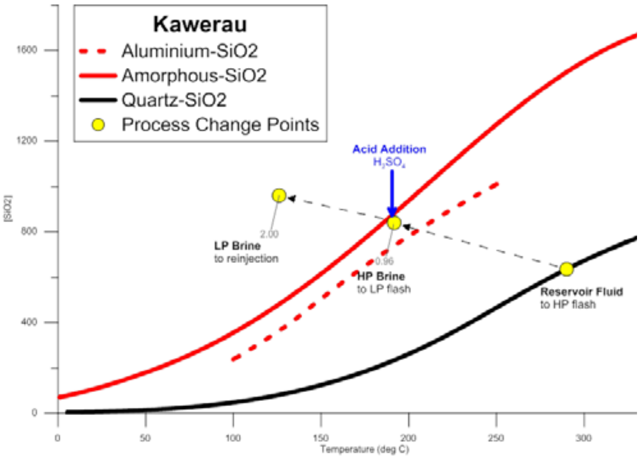

Figure 2: Kawerau process change shown on a silica concentration vs. temperature plot with various solubility trends. SSI values are provided relative to pure amorphous silica solubility Quartz solubility is shown as a continuous black line Aluminum-rich amorphous silica solubility is shown for 100˚C-250˚C

1.2.2 Fluid pH

Due to the high SSI in the LP brine/reinjection fluid which causes a strong driving force for silica polymerization, the pH of the brine is reduced to $pH_{25^\circ C}$ 4.6 from $pH_{25^\circ C}$ ~7-8 to inhibit the kinetics of silica polymerization prior to this oversaturation condition occurring in the HP brine line (Brown & Rock, 2010)

pH reduction of a fluid supersaturated in silica inhibits the kinetics of silica polymerization by reducing the concentration of OH^- ions present to mediate the condensation reaction between two silicic acid monomers (Brown K. , 2011).

1.2.3 Other ions present.

Presence of other ions with a strong positive charge and high charge density promote silica polymerization by 'bridging' and counteracting the repulsion forces between negatively charged colloids. Other positively charged ions in the brine act in a similar way making coagulation ionic strength dependent. (Brown K. , Thermodynamics and kinetics of silica scaling, 2011). The relative SSI required for precipitation/polymerization in the presence of these ions is lower than in a fluid with comparatively few positively charged ions.

Due to the considerable number of variables that can affect the silica polymerization rate, to get a truly representative test it is necessary to test geothermal fluid in the plant under the specific conditions for that plant. This is the basis for the long run polymerization tests conducted at KGL described in this paper.

2 EXPERIMENTAL METHOD

Testing for this paper was conducted on the LP Brine stream of the KGL plant. Tests were initially conducted at standard operational conditions however later tests included variation of pH.

The basis for this method is measuring molybdate reactive silica levels at various time intervals until a significant drop occurs to indicate polymerization has occurred. Further information on measuring molybdate reactive silica is given in Section 2.3.

2.1 Polymerization Vessel

The key piece of equipment for this testing was a polymerization vessel. This piece of equipment is essentially a hold up vessel, fitted inside a larger pressure vessel that allows a flow of brine around the outside of the smaller vessel to maintain temperature.

The vessel is rated to 33 bar (g) and 240°C and is constructed with 316 stainless steel. The volume of the internal chamber is 1.81L including the volume of the two tubes that project towards the top of the vessel.

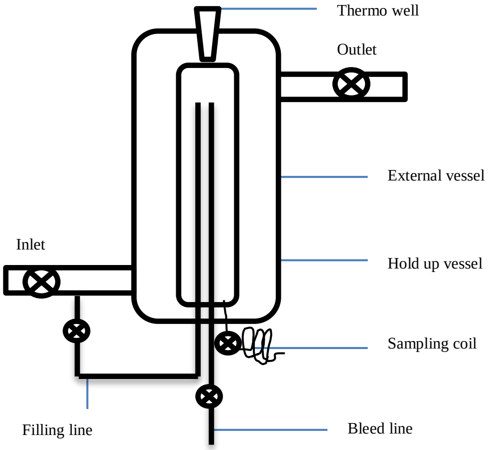

Figure 3: Polymerization Vessel Simplified Configuration

There are three tappings into the internal hold up vessel. Two of these tappings project toward the top of the vessel. These two tappings are for filling the vessel and for bleeding off air from the top of the vessel. The third tapping is directly off the bottom of the vessel and is used for sampling fluid during the testing.

The internal vessel can be removed and opened via a cap in the top to allow it to be cleaned if there is concern that scaling within the vessel has occurred.

During testing, hot brine is flowed constantly through the outer vessel to maintain the temperature of the internal fluid. A temperature probe inside a thermo-well is used to measure and monitor temperature throughout the test, with temperatures recorded each time that a sample is taken.

The test procedure requires the vessel to be heated up prior to filling. This generally takes ~1 hour to get a stable temperature measurement. Prior to filling the internal vessel for the test, it is flushed once with the brine being tested. This involves filling the internal vessel once, and then draining it. The aim of this step is to remove any residual fluids and remove oxygen and other atmospheric gases out of the internal vessel as this would not be present in the process condition.

To commence the test, the vessel is filled and a T=0 sample is taken. When sampling from the vessel there is an aim to minimize the amount of sample taken to minimize the amount of flashing inside the hold-up vessel. Generally 5mL of sample is sufficient for the required analysis method. However more brine is used per sample to flush the sampling coil to ensure fresh, hot sample is taken.

Samples are collected into a small container (2-4mL) with a drop of concentrated HCl in order to temporarily halt further polymerization until the sample can be diluted to below saturation. Dilution is required immediately after taking the sample despite the acid addition to bring the SSI below 1. This is to ensure that the molybdate reactive silica concentration stays steady throughout the analysis method.

2.2 Sampling Frequency

Sampling frequency from the vessel had to be balanced between gaining sufficient data to capture decline of molybdate reactive silica and ensuring there was sufficient sample to run the test to completion without causing excessive flashing of the fluid in the vessel. Generally a residual volume of 50-60% in the test vessel is desirable to prevent against excessive flashing. This is confirmed by draining the remaining volume out into measuring cylinder at the end of a test.

In the first set of tests samples were taken at <1 hour intervals. However the first test showed that a much longer run time than initially anticipated was required if observation of the majority of a polymerization curve was desired.

Sample frequency was altered to 3 samples per day with 2-3 hours between each sample to accommodate the longer test runs.

2.3 Analysis

Prior to analysis samples required degassing of residual H_2S to prevent it interfering with the analysis method. Residual H2S in the sample caused reduction of the molybdate to the blue colour measured in this method, causing excessively high readings Removal of H2S from the sample was achieved by bubbling air through the sample after it was diluted.

A silico-molybdate method was used for analysis of the brine samples. For this experiment Hach Method 8185 was followed (Hach Company, 2014). This method uses molybdate to form a yellow silico-molybdate complex with silica under acidic conditions via addition of both a “silica reagent” and “acid reagent” powder pillow. After a 10 minute reaction time a citric acid powder pillow is added to remove phosophate interference and a further 2 minute reaction time allowed. After this 2 minute reaction time absorbance at 452nm is measured by a spectrophotometer. This method was chosen due to its simplicity of execution and low cost requirements for instrumentation to perform it.

The molybdate reacts with monomeric silica and low molecular weight silica particles such as dimers and trim~~m~~ers. Thus it is necessary to refer to the silica level measured by this method as “molybdate reactive silica” versus simply “monomeric silica”.

The range of detection for this method is 0 to 100mg/L; therefore dilution was required not only to prevent further polymerization from occurring in the sample, but also to bring the brine into the measurable range for this method.

3 RESULTS

Four tests were run on the KGL LP Brine Line.

Tests 1 and 2 were run at the station’s current operating pH_{25} = 4.6. Test 3 was run at pH= 5.0. Test 4 was run at pH_{25} = 3.8.

3.1 Test 1 - Brine pH=4.6

For Test 1 the run time was 6 hours. This was based on a general understanding from experiments in the past that a standard test ran for 3 hours and was aimed at providing a reference point for further tests (Figure 4).

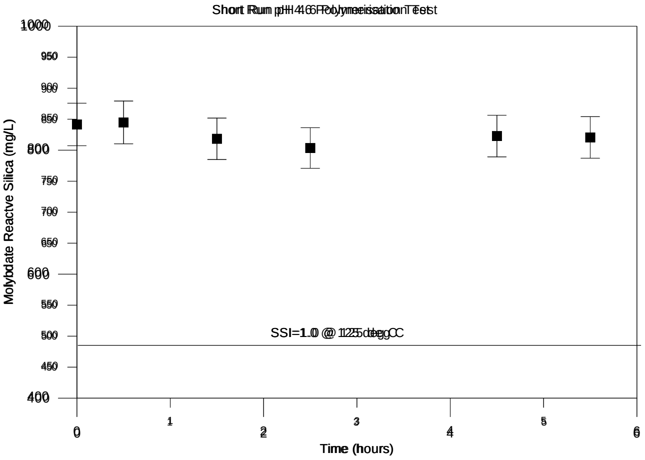

Figure 4: Test 1 Silica Polymerization results pH = 4.6 Short Run Test. Error bars shown indicate +/- 4.08%.

3.2 Test 2 - Brine pH=4.6

Test 2 was stopped at T=192 hours. This test was finished when the monomeric silica reading stabilized at an SSI of ~1.2 (Figure 5). This indicated that significant polymerization had occurred and observation of any further polymerization would have likely taken an extended period of time. There is a gap of 71.25 hours in the data which represents the time between Friday afternoon and Monday morning measurements. The monomeric silica concentrations then appeared to stabilize at an SSI of 1.2.

Overall the result showed a long and slow polymerization process for the majority of the test. However a period of comparatively more rapid drop in monomeric silica in the first hour of the test was observed with the measurement dropping from 897mg/L to 849mg/L. Whilst this drop has been observed, there are no indications of scaling in the plant as evidenced by inspections of injection pipework during outages over several years.

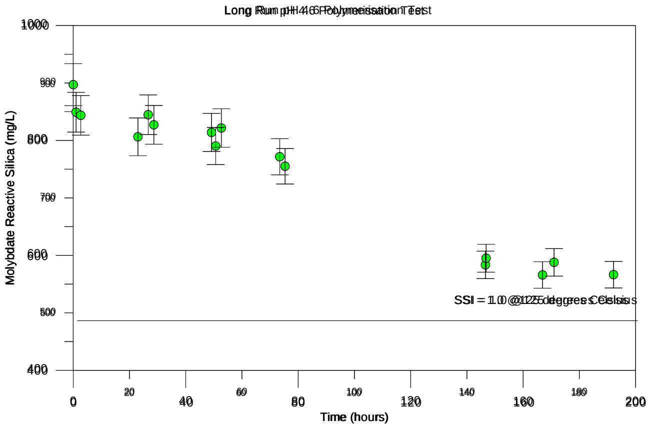

Figure 5: Test 2 Silica Polymerization results pH= 4.6 Long Run Test. Error bars shown indicate +/- 4.08%.

3.3 Test 3 - Brine pH=5.0

A single test was run at a pH of 5.0 (Figure 6); this was done by raising the plant's pH control set point to reduce the rate at which acid was injected into the HP Brine. The set point was raised gradually until the LP Brine pH measurement was reading steadily at 5.0 (using the plants permanently installed pH monitoring equipment.) (Addison, Stabler, & Gresham, 2013). Approximately 30 minutes after a stable pH of 5.0 had been reached, the polymerization test vessel was filled and the pH confirmed at 4.9 by a manual pH probe measurement of the fluid in the vessel.

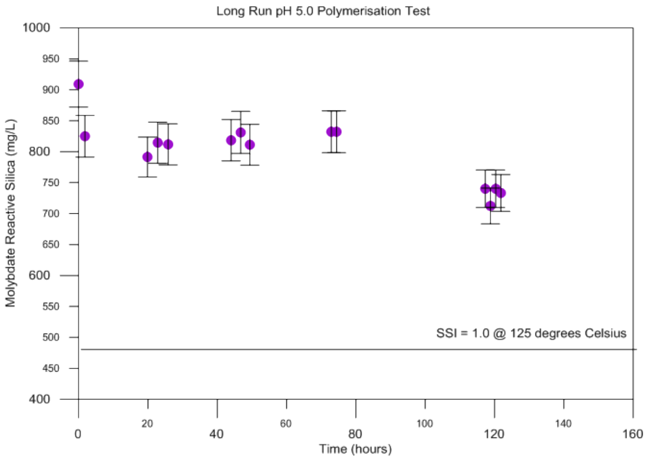

Figure 6: Test 3 Silica Polymerization results pH=5.0 Long Run Test. Error bars shown indicated +/- 4.08%.

The pH_{25} 5.0 test results indicated that again a slow and gradual polymerization process is active at KGL at $pH_{25}=5.0$ with a drop in molybdate reactive silica concentration from 909 mg/L to 771 mg/L over a 121 hour period.

There again appears to be a short rapid drop in the monomeric silica concentration within the first two hours of the test with the reading dropping from 909 to 825 mg/L.

3.4 Test 3 - Brine $pH_{25}=3.8$

A pH 3.8 test was run and indicated that there was still reductions in the polymerization rate to be obtained when hold up times of T=70hrs were reached. The test was begun on a Friday afternoon after the conclusion of the pH 5.0 test, hence only a single point is taken initially with the next data taken at T=69 hours (Figure 7).

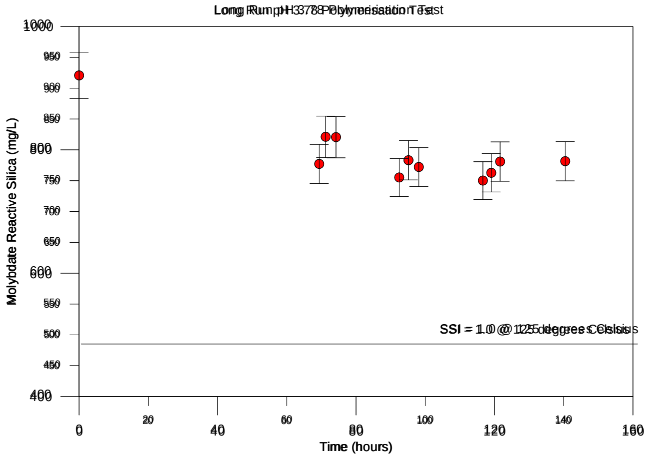

Figure 7: Test 4 Silica Polymerization results pH=3.78 Long Run Test. Error bars shown indicate +/- 4.08%.

3.5 Combined results

All three long run tests had a starting molybdate reactive silica concentration within +/- 23 mg/L of each other as can be seen by the three start measurements being grouped closely on the graph (Figure 8). This is within the error of analysis so it is reasonable to say that each test had a comparatively similar start point to the others and therefore direct comparison of the results is appropriate.

The combined graph of all three long run tests shows that the pH 3.8 test does show a slower decline in molybdate reactive silica than the pH 4.6 test, yet at T=70 hours there is no significant difference between the two molybdate reactive silica concentrations at that time.

Comparison of the pH 5.0 test and pH 3.8 test at T=120 hours shows only a small difference between the set of results, within the experimental error of the testing.

Both the pH 4.6 and pH 5.0 test show an initial period of comparatively rapid decline in their molybdate reactive silica concentration during the first 1-2 hours followed by a long slow period of decline. Unfortunately a sample was not taken for the pH 3.8 test to see if it too showed this rapid initial drop at 1 -2 hours.

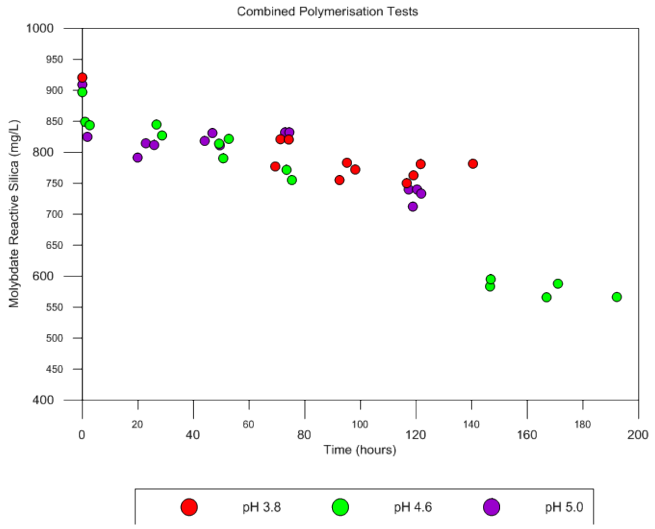

Figure 8: Combined Long Run Polymerization Results

4 DISCUSSION

4.1 Quantitative vs. qualitative nature of the data

When interpreting the results from this testing it was important to remember that the tests were conducted on an operational pipeline where various parameters could be controlled whilst some others could not.

For example, the operational temperature and pressure of the pipeline being tested remains relatively steady over the majority of the tests. However the fluid needs of the plant could vary between tests as steam field activities require variation in well utilization to maintain production of the plant.

During this set of testing the wells being utilized for the KGL plant was relatively steady however there were slight differences in the percentage contribution of fluid per well at the start time of each test. The level of impact that this has on results is unknown and adds an extra layer of error to the testing as particular wells may have slightly higher brine silica concentrations or have a tendency to produce more particulates through the plant.

Because this error cannot be directly quantified without large amounts of repetitive testing with wells being operated in varying configurations it has not been included in the error calculation for the test method.

There is a similar issue in quantifying the error from sampling the polymerization vessel. Therefore in calculating an error for this testing only the error in dilution and analysis of the samples is considered.

Error in the method is stated at 4% by Hach Pacific, the supplier of the reagents, and spectrophotometer that was used in the testing. This combined with the error from dilution method set an error of 4.08%. There is a systematic error present from the addition of one drop of acid to each sample to prevent further polymerization; however given that it is the trend in data vs. the absolute value that provides the most information in this testing this is not accounted for. Therefore the error bars in Figures 2-5 are set at 4.08%.

It is clear from this testing that the level of error present means it is best utilized for qualitative testing, though this still provides valuable data for plant operations. Further reductions in error would be needed to provide quantitative results. The qualitative data from tests similar to these can provide indication of whether a plants pH dosing is adequate or if it needs to be reconsidered. It also means that if someone wanted to use data from this operationally based test for modeling polymerization curves that it would be best for several tests to be carried out on a variety of well conditions, flows and pH set points to create a ‘fuzzy’ curve from a larger data set.

4.2 Comparison of results to previously established relationships in literature

Previous polymerization tests conducted on other plants were run for a time of 3-6 hours. The reasoning being that time for brine to reach reinjection wells from the power plant typically range from 30 to 90 minutes. However this does not aid understanding of polymerization behaviour past this time which could impact understanding of the process occurring in the reservoir.

4.2.1 Brown and Rock 2010

Brown and Rock (2010) completed a full set of trials at the Kawerau field using a large scale test rig prior to development of the KGL plant. Their polymerization test at pH 5.0 was run for 120 minutes with a start silica concentration of ~980mg/L and showed essentially no polymerization for the first 40-60 minutes, and then a rapid drop after this period of time down to ~780mg/L molybdate reactive silica at T=120 minutes (Figures 7 and 8).

When comparing this result to the pH 5.0 test in this paper, the results of the Brown and Rock 2010 paper could correspond with what is referred to in this paper as the ‘rapid initial drop’ in molybdate reactive silica content seen in the first 1-2 hours. In the pH 5.0 test results of this paper, the T=0 reading was 909mg/l, with the next reading taken at 110 minutes or 1.8 hour being 825mg/L (Figure 9).

It is important to note that these tests were conducted more than 6 years apart, and the Kawerau field has seen significantly more development, and resultant changes in field chemistry since the original Brown and Rock test with confirmed injection returns and significant sulfate increases in injectate fluids with time. The Brown and Rock test used only the PK6 well, whereas the most recent testing represents a combined production fluid of several wells. When the results of the two tests are compared on the same graph, it can be seen that they are in reasonable agreement with each other despite the disparity in starting silica concentration. The T=110 minutes result of 825mg/L of this test, coincides with a time of ~T=115 minutes for the Brown and Rock (2010) test.

In the Brown and Rock trial, they indicate difficulty in controlling pH at 5.0 in their test and attribute a slight pH increase over time believed to be responsible for causing the rapid drop seen after T=40-60 minutes. However in the trial conducted for this paper, a very stable pH control system is in use at the KGL plant the tests were run off the pH modified brine. The magnitude of drop after the T=40-60 minutes is greater in the Brown/Rock trial given their higher start concentration, however the fact that a drop is seen in approximately the same time period for the most recent test indicates that the difficulty in controlling pH for the Brown et al test was likely not the sole reason for the polymerization seen after T=40-60 minutes.

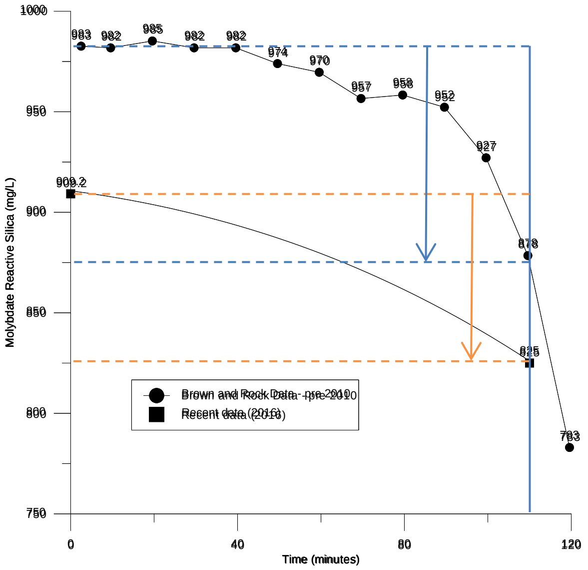

Figure 9: Brown and Rock 2010 original short run polymerization curve. Magnitude of drop in Molybdate Reactive concentration is relatively similar given the differences between tests.

4.2.2 Gunnarsson and Anorsson 2005

There is a large amount of literature that discusses silica polymerization from experiments performed under laboratory conditions.

The most recent lab testing performed under similar conditions to that of the KGL brine was by Gunnarsson and Arnorsson (2005) who conducted a series of laboratory experiments observing molybdate active silica under pH's of 2.3, 4.5, 6.0 and 8.25 at a temperature of 80°C, initial silica concentration of 890mg/L and ionic strength of 0.124M.

The pH 4.5 test in the Gunnarsson and Arnorsson paper is most applicable for comparison to the pH 4.6 results from Kawerau. The initial silica concentration of this test is 890mg/L whilst the Kawerau initial silica result was 897 ± 37 mg/L. The ionic strength of the Kawerau brine was ~0.04M based on conductivity measurements.

Gunnarsson and Arnorsson's paper showed an approximate induction time of just under 10.5 hours (Gunnarsson & Arnorsson, 2005). In comparison, the Kawerau test shows little change in molybdate reactive silica concentration before 72 hours. This difference can be accounted for by both initial oversaturation values and difference in ionic strength between the two brines. The initial SSI for the KGL brine experiment was 1.86 at a temperature of 125°C. The initial SSI for the Icelandic experiments was 3.16 due to its lower initial temperature of 80°C. Higher SSI and higher ionic strength are known to accelerate silica polymerization so it would be expected that the Gunnarsson and Arnorsson's study would show a more rapid polymerization time. The two results are within the same order of magnitude and thus in reasonable agreement with each other given their relative differences (Figure 10).

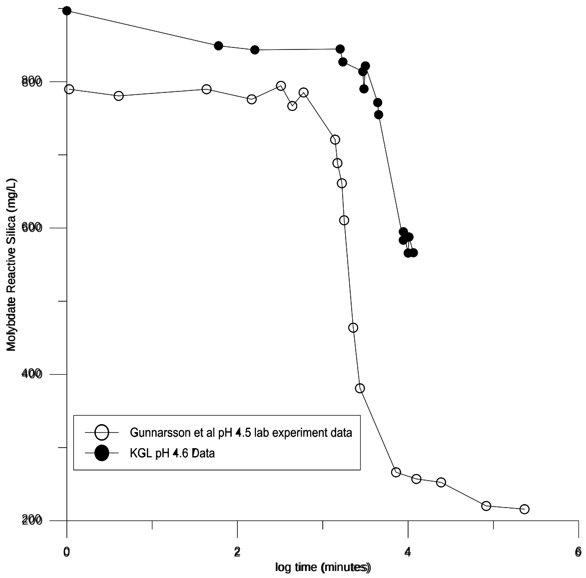

Figure 10: Comparison of KGL recent pH 4.6 test to Gunnarsson et al experimental results

It is important to note that all the ionic strength in Gunnarsson and Arnorsson's study was from NaCl whereas the mixture of ions in the Kawerau brine was much more complex and included Fe and Al ions at concentrations of 0.05-0.1mg/L and 1.8mg/L respectively. This could explain why the KGL polymerization test shows an initial short rapid period of polymerization whilst the Gunnarsson and Arnorsson's experiment does not.

4.3 Possible explanations for rapid initial drop versus long slow phase of polymerization

Of concern is that the short run polymerization test did not show the initial rapid period at any time in its 6 hour run time. The starting silica concentration for that test was lower compared to the long run tests, with a starting concentration of 841mg/L which is near to the values that the 'slow' polymerization trend begins from the long run tests. It is possible that this rapid period was somehow missed in the test perhaps by error in the initial sampling or that there is another reason for the drop off associated with the testing process rather than the plant process.

Initial concerns were that perhaps the vessel was not heated up enough before beginning the test, however referring back to temperature data showed little variation in the temperature at the start of the tests versus the rest of the test period.

If this period was associated with silica scaling, then it should have been seen within the plant piping. However there are no signs of silica scaling within the reinjection pipework.

In the discussion above, when comparing these results to the Gunnarsson and Arnorsson experiment it is noted that their results do not show the rapid initial phase of polymerization, but the idea that Al^{3+} and Fe^{3+} presence in the natural geothermal brine vs. the NaCl brine that they used in their experiment is one possible explanation for this..

To investigate this further a quick calculation was done to estimate how much aluminosilicate scale could form from the 2.6mg/L Al concentration measured in the KGL geothermal brine.

Aluminosilicate scale in geothermal has a non-stoichiometric formula of $Al_2O_3.(10\text{-}20)SiO_2$ (Amjad, 2010). With a brine aluminum concentration of 2.6mg/L and assuming a maximum SiO_2 contribution of 20 molecules per 1 molecule Al the maximum possible amount of silica that could be drawn into aluminosilicate scale would be 116mg/L. If a minimum SiO_2 contribution of 10 molecules per one molecule of Al the minimum amount of silica that could be drawn into an aluminosilicate scale is 58mg/L.

These values are within the correct order of magnitude to the amount of silica seen during the initial rapid decline period of the long run silica polymerization tests. Therefore it is hypothesized that the initial rapid decline period seen in the long run polymerization tests relates to aluminosilicate polymerization or scaling versus pure amorphous silica polymerization. This would also help to explain why this period is short lived as the Al and/or other highly charged ions are consumed in the polymerization process. It also indicates that acidity had some impact on the aluminosilicate polymerization based on differences between the pH 4.6 and 5.0 test.

However, if the initial drop is due to aluminosilicates, the particles formed would have to be non-scaling, in order to match the observation of a lack of scaling within the plant pipework.

4.4 Relevance to plant operation

The key summary of results from this testing is that the long run polymerization tests show an initial short rapid period of decline in molybdate active silica concentration before a long slow period of polymerization begins in the KGL brine.

An important interpretation to make of these results is how significant or important is the initial rapid period of decline to the plant operation and injection wells.

The long run pH 4.6 polymerization test showed a decline from 897mg/L to 849mg/L by T= 1 hour. This is equivalent to 5.3% of the total silica content polymerizing. This has been the pH set point for the KGL plant for a number of years.

For the pH 5.0 long run test there as a decline from 909 to 825 mg/L prior to T= 2 hours before reaching the slow phase. Equivalent to a 9.2% of the total silica content polymerizing.

It is unclear whether further pH depression could prevent this apparent initial rapid decline period if it is real. The pH 3.8 test conducted did not have a T=1 or 2 hours sample taken, however out at T= 70 hours, its silica concentration was 777mg/L after starting at 920mg/L. The 777mg/L value at T= 70 hours is very close to the results of the pH 4.6 and pH 5.0 test at T=70 hours, indicating that a similar magnitude of drop in silica concentration had occurred for the 3.8 test.

Overall assessment of the apparent initial rapid decline period between the pH 4.6 and pH 5.0 test indicate that there are advantages to operating at a pH of 4.6 compared to pH 5.0 simply by the reduction in the magnitude of the ‘initial rapid’ period of scaling that occurs in the first 1-2 hours of hold up time if the observation of the ‘initial rapid decline’ is real.

The long run polymerization tests showed that out beyond the T=2 hour time frame, there is very little advantage when looking specifically at silica polymerization to be gained in operating at a pH 4.6 or pH 3.8 compared to pH 5.0 as there is little difference in the molybdate reactive silica values between the different pH tests up to T=70 hours.

5 CONCLUSION

Overall there were some unexpected results from this set of polymerization testing at the KGL station. The long slow polymerization that predominates the process took considerably longer than that seen in similar literature examples of testing. The apparent rapid decline period observed could relate to aluminosilicate formation, however further testing is required to confirm if this is the case, or if there is a variable in the test method causing this.

6 ACKNOWLEDGEMENTS

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