SILICA SCALE INHIBITION BY PHOSPHINO-CARBOXYLIC ACID COPOLYMER IN LOW-TEMPERATURE INJECTION OF GEOTHERMAL FLUID

Richard C. DE GUZMAN[1], Fidel S. SEE[1], Almario D. BALTAZAR JR.[1] and Noel D. SALONGA[1]
[1]Energy Development Corporation, Ortigas Center, Pasig City, Philippines
e-mail: deguzman.rc@energy.com.ph

ABSTRACT

Simultaneous discharge test (SDT) for wells TW1D and TW4D of the Bacon-Manito Geothermal Business Unit (BGBU) was conducted, following an atmospheric flashing of the fluid and low temperature brine injection scheme. The process supersaturates dissolved amorphous silica at the silencer weirbox (T~ 90°C) to 753 and 694 ppm with a silica saturation index (SSI) of 2.42 and 2.28 for TW1D and TW4D respectively. The condition has resulted to silica deposition and scaling in the pipeline prior to injection in the RI well.

A silica scale inhibitor, Geogard SX (GSX), was used to treat the brine at an initial dose of 2 ppm and was found with minimal inhibitory effect. The treatment concentration was increased to 8ppm and was found effective as the deposition rates decreased from 4.2mm/mo (2ppm GSX) to 1.2mm/mo (8ppm GSX). An inhibition efficiency of 71.4% was taken by comparing the scaling rates of the 8ppm from the 2ppm applications. The scale inhibitor prolonged the acceptance capacity of cold RI lines and wells.

Keywords: chemical inhibition, cold injection, phosphino-carboxylic acid copolymer, silica scaling

INTRODUCTION

The Tanawon (TW) sector is one of the three main expansion areas of the 130-MW Bacon-Manito Geothermal Business Unit (BGBU). It is located at the southern part of the field and currently has three production wells (TW1D, TW2D, and TW4D) and one reinjection well (TW1RD). While in the early development phase, the wells are discharged to the atmosphere thru silencers while the brine is disposed via a cold reinjection system consisting of a catchment and alvenius lines to TW1RD. Last July 2012, this set-up was also utilized in conjunction to the Tanawon Simultaneous Discharge Testing (SDT) to evaluate the long-term sustainability of the sector. In the SDT, wells TW1D, TW2D and TW4D were continuously discharged while TW3D served as the pressure monitoring well. In geothermal systems, heat extraction is maximized based on the fluid's silica scaling potential (Gunnarson & Arnorsson, 2003). Deposition is highly dependent on the silica concentration, pH levels, temperature, flow rates, aeration and ions in the solution (Brown, 2011). The primary measure of scaling tendencies is thru the silica saturation index (SSI) which is a ratio of the fluid's silica concentration and the equilibrium concentration (a function of temperature). The silica equilibrium concentrations at high temperatures and pressure are calculated (Fournier & Rowe, 1977). As the temperature drops, the solubility of silica in solution also decreases and effectively yields higher saturation indices. An SSI of greater than 1.0 means that thermodynamically, silica deposition is expected to occur along the system. The kinetics of this precipitation is a different aspect but is usually characterized by the fluid flow rates and induction period.

The Tanawon discharging wells have relatively high silica concentrations (Table 1) while the cold reinjection system (atmospheric flashing) gives much lower operating temperature. This combination of conditions and process promotes silica supersaturation, and scaling is expected to occur within the duration of SDT. During the short-term and medium-term discharge tests, silica deposition must be mitigated to ensure sustained acceptance of reinjection wells, and prevent or prolong costly work over/ acidizing jobs.

Table 1. Tanawon wells sample discharge flow rates and water chemistry (weirbox, as analyzed)

	TW1D	**TW4D**
Total mass flow (kg/s)	77	50
Ave. weir flow (kg/s)	49	20
Opening	Full bore	Throttled
Estimated Temperature (°C)	90	88
Silica (mg/kg)	753	694
Chloride (mg/kg)	8218	7700
pH	8.5	8
SSI	2.42	2.28

Tanawon Discharge Set-up and Early Scaling Mitigation

The simultaneous discharge of wells TW1D and TW4D commenced on July 24, 2012. Schematic diagram of the discharge set-up is shown in Figure 1. These two wells discharge to their individual silencers, but the brine from their weir boxes are mixed immediately at the Tanawon catchment. The mixed TW1D and TW4D brine goes through six alvenius pipe lines while TW2D has its own lines directly connected to the reinjection well. At the onset of the discharge, fresh water dilution was utilized as initial silica scaling mitigation measure. This aims to decrease the silica concentration by adding 20-30 kg/s of fresh water to the brine in the Tanawon catchment basin. However, it was a balancing act with temperature as the fresh water also reduces the operating temperature of the brine, and continuously reduces the injection capacity of TW1RD. Silica deposits were later found present near the wellhead of TW1RD. Silica deposits were later found present near the wellhead of TW1RD indicating the inefficiency of the process to control silica scaling (Alvarado & See, 2013).

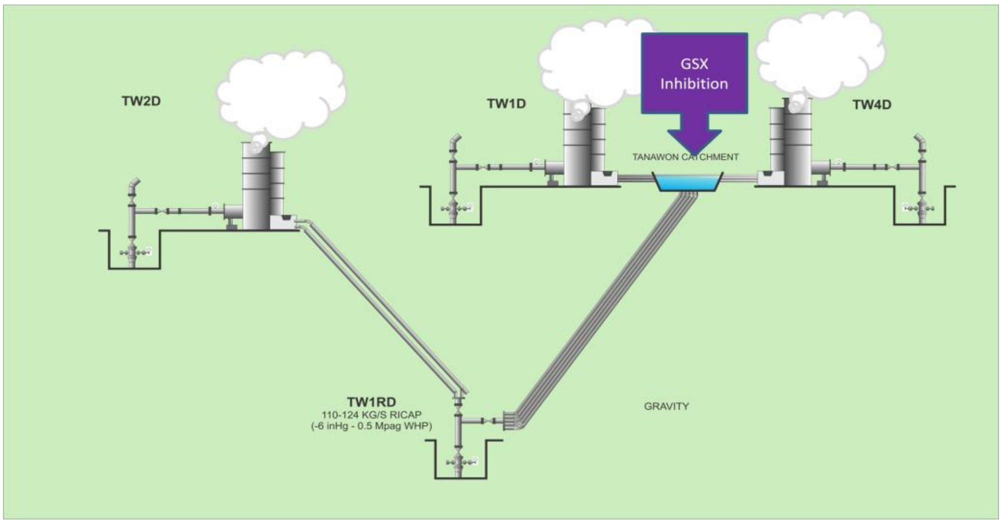

Figure 1. TW Simultaneous Discharge set-up (drawn not to scale)

The application of Geogard SX (GSX) was considered in the test to salvage TW1RD from any further decline in injection capacity. Geogard SX (GSX) is an anti-scalant inhibitor that has been experimented and commercialized before in the then Botong Fluid Collection and Disposal System (FCDS). Botong was one of the sectors in the BacMan field. The phospino-carboxylic acid copolymer GSX was then used to treat the Botong fluids with extremely high silica concentrations of 1000-1300ppm (Baltazar, et al., 1998). The inhibitor was injected at the separator vessel earlobe just after separation of steam and brine. The GSX was proven effective with inhibition efficiencies of 38.1%-95.7% (Baltazar, et al., 1998) and was also implemented in the Malitbog sector in 2003 (Alcober, Candelaria, Mejorada, & Cabel, 2005).

The Tanawon testing was completely different from that of the Botong sector, but the inhibitor's safety data sheet was reviewed and there was no thermal degradation concern with the inhibitor's low temperature injection. Thus, the GSX injection replaced the freshwater dilution in November 2012 with an original dose of 2 ppm. An opportunity to inspect and document the alvenius lines came about in February 2013 and at this time, scaling was visibly reduced but was still present. The GSX dose was recalculated and increased to 8 ppm starting February 2013 until the SDT's termination this June 2013. Chemistry of the fluids was also monitored as samples are taken at the weir box and at the two-phase lines using a Webre separator.

INSPECTION AND DOCUMENTATION

Two major inspections were conducted, one was in February 2013 in lieu of the replacement of the alvenius lines and the second was June 2013 upon the termination of the Tanawon Simultaneous Discharge.

February inspection

The first full inspection of the Tanawon reinjection lines since the beginning of the simultaneous testing was done in February. This period covers both the water dilution method and the initial 2ppm GSX dosing. The two methods are differentiated by the installation of a redundant line where fresh and dosed brine would have passed through.

Significant depositions were discovered at the original reinjection lines with thickness 25-40mm at the lines, as shown in Figure 2. The depositions were adherent and very hard scales, and had multi-layers of vitreous compact scales and powdery grain-like.

Figure 2. Depositions at the first TW line inspection (Feb 2013)

In addition, deposits were also found at joint connections (valves and elbows). These are points wherein shift in the flow velocity and direction occurred. One of the valves was actually completely blocked (Figure 3). Deposition characteristics were similar to those previously described.

Figure 3. Massive depositions at joints, elbows and valves

As mentioned, the initially dosed redundant brine was also inspected and shown in Figure 4. The scale patterns were uniform with thickness 2-15mm.

Figure 4. Redundant line used for dosed brine fluid

Petrological analyses confirm the scales collected from these lines are amorphous silica as summarized in Table 2 (Ramos, 2013).

Table 2. Petrologic analysis findings

Sample	Description
TW RI line	Amorphous silica (~100%)
TW RI line elbow	Amorphous silica (~99%) Impurities (silt-sized calcite, amorphous clays)
TW RI redundant line	Amorphous silica (~98%) Impurities (silt-sized calcite/feldspar crystals)

June Inspection

Re-inspection after almost four months with an increased GSX dosing did not fully eradicate the scaling in the alvenius lines. However, much improvement has been observed as the thickness of the scales in the lines was only 4-5mm. The scales were dark gray, uniform and still very adherent. Photo documentation is shown in Figure 5.

Figure 5. Inspected alvenius lines after increased GSX dosing to 8ppm

A fuller scale line inspection (catchment to TW1RD) was also conducted to find deposition profiles. This however was not conducted in the previous inspections. It was found out that right at the downstream pipe line of the catchment, the scales were found similar to Figure 5 with thickness of 3-5mm only, while right prior the injection to TW1RD, the scale was measured to be 6mm.

INHIBITION EFFICIENCY

There is indeed an apparent reduction in the scaling rates at the 8ppm injection strategy as adapted from the Botong FCDS set-up. Figure 6 shows a comparison of scales collected at the two GSX dosing concentration while Table 3 summarizes the three silica mitigation methods and their calculated deposition rates using average thickness measured.

Figure 6. Scale samples collected in June 2013 (leftmost) and February 2013 (middle)

Table 3. Comparative scaling properties

	Initial GSX dose 2ppm	**Modified GSX dose 8ppm**
	Nov 2012- Feb 2013	Feb 2013- June 2013
No, of days	95	116
Thickness, mm	13.0	5.0
Scaling rate mm/mo	**4.2**	**1.2**

These values validate the positive effects of the inhibitor GSX even in the low-temperature reinjection set-up. However, optimum inhibitor concentration and dosing rates must be identified to maximize the inhibition effects as is the case of the 2 ppm and the 8 ppm dosing. Taking the baseline as that of the 2ppm dosing, the deposition rates were reduced by as much as 71.4% at dosing rate of 8.0 ppm.

CONCLUSION AND RECOMMENDATION

Visual inspection and deposition rate calculations prove the favorable performance of Geogard SX (GSX) in silica inhibition at low-temperature injection scheme. This is consistent with the previous findings of the same set-up in Botong and Malitbog sectors. The 71.4% reduction in deposition rates translates to less probability of work over and acidizing in the reinjection wells, and continuous well discharge.

Optimization of inhibitor concentration and dosing rates was pronounced in the study conducted. The low dosage 2 ppm was able to reduce the deposition rate (provided that this was also in place of another method: freshwater dilution) while the optimum dose of 8 ppm was able to reduce the scaling much further. In addition, one of the issues encountered was the accumulation of scale in the weirbox and catchment basin which could be a result of absence of the inhibitor or not being fully mixed in the brine yet respectively. In the box-type geometry of the weirbox and the catch basin, the corners and surfaces of the fluid may not be reached by the mixing space of the inhibitor. This could be resolved by injecting the inhibitor further upstream (in the two-phase line) as is the case of the injection set-up of Botong FCDS.

Overall, the GSX inhibition technology is an effective mitigation measure in future wells for discharge tests (as in the case of the Rangas expansion area in BGBU) and could be revived in the operational FCRS set-up. Ample time must be allotted in the actual dosing optimization with respect to the fluid's chemistry. Regular and scheduled inspection and documentation is recommended to check and balance the performance of the inhibitor.

REFERENCES

Alcober, E. H., Candelaria, M. N., Mejorada, A. V., & Cabel, A. C. (2005). Mitigation of Silica Deposition in Wellbore Formation in Malitbog Sector, Tongonan Leyte, Philippines. *World Geothermal Congress.* Antalya, Turkey.

Alvarado, P. B., & See, F. S. (2013). BacMan meduim-term discharge (MTD) low temperature injection evaluation and GSX dosing set-up. *TSS Annual Technical Meeting.* EDC.

Baltazar, A. D., Garcia, S. E., Solis, R. P., Fragata, J. J., Lucero, E. R., Llenarizas, L. J., et al. (1998). Silica scale prevention technology using organiz additive, Geogard SX. *20th NZ Geothermal Workshop*, (pp. 325-329).

Brown, K. (2011). Thermodynamics and kinetics of silica scaling. *International Workshop on Mineral Scaling.* Manila.

Fournier, R. O., & Rowe, J. J. (1977). The solubility of amorphous silica in water at high temperatures and high pressures. *American Mineralogist, Volume 62* , 1052-1056.

Gunnarson, I., & Arnorsson, S. (2003). Silica scaling: The main obstacle in efficient use of high-temperature geothermal fluids. *International Geothermal Conference* , 30-36.

Iler, R. K. (1979). *The Chemistry of Silica Solubility, Polymerization, Colloid and Surface Properties, and Biochemistry.* United States of America: John Wiley and Sons, Inc.

Ramos, S. G. (2013). *Petrological Analysis of BGBU Demister 701 and BM-1 Scales Samples (February and March 2013).* Taguig City: EDC Petrology Laboratory.