Reinjection Lesson From Sibayak Geothermal Field, North Sumatera-Indonesia*

*A Paper For The NEDO International Geothermal Symposium
11 - 13 March 1997, Sendai International Center, Sendai, Japan

Sjafei Sulaiman** and Kris Pudyastuti***
) Planning Manager *) PERTAMINA-Geothermal Division

ABSTRACT

The strict environmental standards for disposal of waste geothermal brine to surface waters has constrained the testing of production wells at Sibayak geothermal field. The alternative action is to reinject waste brine into the ground but it is constrained by the high potential of silica deposition in the injection well. It is shown on the operations of reinjecting waste brine at low (ambient) temperature which has not successfully undertaken at Sibayak. The lesson from these operations, PERTAMINA will implement an action plan at Sibayak by considering an experiment result at Mac-Ban geothermal field.

INTRODUCTION

The Sibayak geothermal field is about 70 km SW of Medan in North Sumatra. A first stage geothermal development of 2 MW has been commissioned in 1994. An additional 20 MW plant is currently being developed in this field and expected to be in commercial operation by early 1998.

Several wells at Sibayak have been discharged and tested to characterise mass flow, enthalpy and fluid chemistry in order to confirm resource characteristic and optimum power plant size. Conventionally, testing of exploration and production wells is achieved by flowing the wells to atmospheric silencer with separated steam and brine discharged to atmosphere. Because of strict environmental standards that exist in Indonesia, it was recognized that all of the waste brine could not be discharged directly to surface water ways. Two alternatives for disposal of brine from well testing were then considered-hot or cold piped reinjection.

Hot injection was not preferred at Sibayak because of the unfeasible economic point of view. Thus, our interest in disposing of brine is to initially cooled by flash at atmospheric pressure and then flowed in open canal to injection well. The most significant constraint on injecting geothermal effluent at relatively low temperature is the occuring of silica deposition which are readily exist in canals and reinjection wellbore.

INJECTION OPERATION

The SBY-3, SBY-4 and SBY-5 wells have been planned to be the production wells for both the first 2 MW power plant and the additional 20 MW. The wells have totally produced brine water of 365 ton per hour. The brine with temperature of about 98 $^{\circ}$ C was injected to SBY-2 well. The SBY-2 well is a dry hole with measured depth of 2302 meters. The well permeability is 6.2 darcy meter and the well injectivity index is 2.9 kg per ksc.sec. Injection operation was started at 21 March 1994 when the SBY-3 well was in production for 2 MW power plant. A part of the brine water from SBY-4 and SBY-5 wells began injected into SBY-2 well at 24 May 1996.

At present the SBY-2 well depth was shallower to 647 meters than the original depth and the injection capacity of the SBY-2 well has decreased to 90 ton per hour.

At present the SBY-2 well depth was shallower to 647 meters than the original depth and the injection capacity of the SBY-2 well has decreased to 90 ton per hour.

FLUID CHEMISTRY OF PRODUCTION WELLS

Water samples were collected at separator location during production test of the SBY-3 and the SBY-4 wells. The production test of the SBY-5 well has not yet been conducted when water samples were collected. Analysis of the brine water indicated that its silicic acid concentration is about 500 ppm. Table-1 shows the recent data of fluid chemistry of the SBY-3 and the SBY-4 wells.

Table-1. Chemical Anaysis of Separator Water Samples (in ppm). Source: BATAN Preparatory Reports For Internal Documentation, 1997

Wells	Na	K	Mg	Ca	Li	HCO 3	SO4	Cl	pH	SiO2
SBY-3	539.8	116.7	0.57	41.5	1.7	0	12.5	1083	5.1	543.6
SBY-4	554	214.3	2.71	66.7	1.82	40.3	40.3	1344	5.5	517.3

EFFLUENT RE-INJECTION SCHEME

The simple design of the effluent disposal system (EDS) at Sibayak is shown in Fig.1. Two phase fluid from the wells is flashed to an atmospheric silencer with the separated brine draining to the pond located on the same well pad (Cluster A). The effluent was then piped into an open canal and directly injected to SBY-2 well (Cluster B) at approximately 1.5 km distance from the Cluster A. The elevation of the Cluster A is 1486 masl while the Cluster B is 1384 masl.

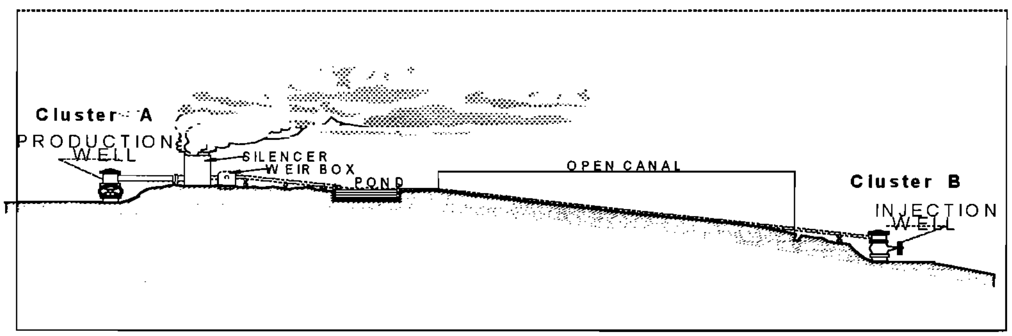
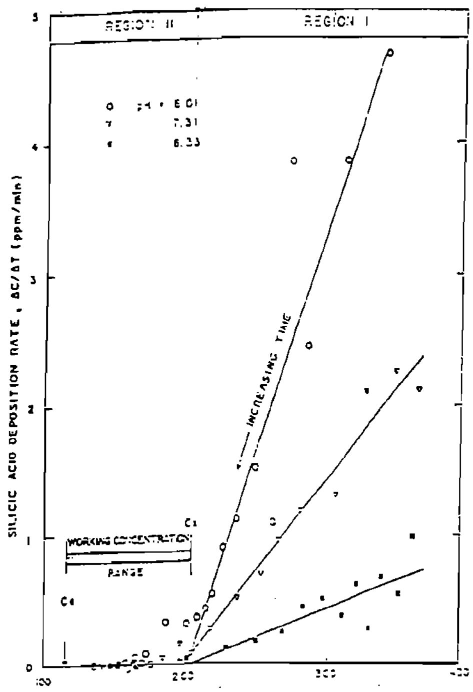


Figure-1. Discharge System For Cluster-A At Sibayak Geothermal Field

DISCUSSION

Current understanding on silica reaction kinetics as it was stated by Ramonito P. Solis et.all , that overall deposition occurs in three distinct stages: homogeneous nucleation of amorphous silica particles via silicic acid; continued growth of these particles via silicic acid polymerization at their surfaces; and a surface rearrangement process whereby chemisorbed silicic acid molecules condense fully into solid silica. At low initial silica supersaturation, So, the onset of polymerisation shows an induction period. This become progressively shorter with increasing supersaturation.



The fluid chemistry of production well data in Sibayak field say that So is very high (500 ppm in brine flashed to atmosphere).

If we apply the So on the Fleming model (1986), the kinetic regime will be in Region I. It mean the reaction are relatively fast and involve a condensation polymerisation reaction between a hydroxyl group on the amorphous silica surface and a dissolved silicic acid molecule. This polymerisation continues and approaches a pseudo equilibrium solubility value which is higher than the true thermodynamic solubility. In Region II there is a slower surface rearrangement, that proceed from the pseudo equilibrium point, Cx to the equilibrium .

Ramonito P. Solis et. all have taken advantage of these different regimes in the design of the cold reinjection scheme at the Bac-Man field. In the design of the effluent re-injection at Sibayak field, we have not taken the advantage. By having the bulk of the supersaturated portion of silica in the cooled brine polymerize and settle in surface ponds prior to injection, with hold up time of brine in the ponds minimized on the basis of pseudo equilibrium. Figure-2 shows the graph of the silicic acid deposition rate (ppm/min) . vs. silicic acid concentration, C (ppm) at Pseudo-equilibrium Point (Cx) of Fleming, 1986

ACTION PLAN

The experiments result at the Bac-Man Geothermal field which have conclude that the success of low temperature injection is dependent on: the initial concentration of silica in flashed brine; the magnitude and rate of temperature drop in the aging/cooling brine; the retention time of brine in cooling ponds and dilution of aged brine with fresh water prior to injection. Considering these results PERTAMINA has decided to make an action plan of re-design the EDS and monitoring program.

Re-Design The EDS

The basic considerations that will be taken into acount in the re-design of our EDS are: to maximise the amorphous silica supersaturation of the separated water; to cool the fluid as rapidly as possible; and to maximise the fluid residence time in ponds prior to reinjection. Therefore, a pond-2 will be constructed at Cluster B. Then baffles will be installed in pond-2 to increase residence time. A flow of fresh water will be tapped locally and piped to mix and dilute the brine flow to the SBY-2 injection well. Optionaly, an oil trap will be installed to filter out any solids and other driling waste that may be discharged.

Monitoring in the EDS and Chemical sampling

Taking a run time of the new design of EDS, then a monitoring and chemical sampling at various points in EDS should be conducted. The important chemical parameter will be monitored during effluent injection is the concentration of monomeric silica. Then the silica saturation index (SSI) which is defined as the ratio of monomeric silica to the pseudo equilibrium solubility (Cx) could be calculated using Fleming model (1986).

The equilibrium amorphous silica solibility (Ce) will be calculated from the equation of Fournier and Rowe (1997), which is valid from 0 to 250 °C, or the equation of Fournier and Marshall (1983) which is valid from 90° C to 340° C.

The retention time for waste brine within EDS prior to re-injection also will be measured through each section of the system. This should be done for an extensive baffling arrangement.

EDS Efficiency Test

Tests will be conducted to determine the efficiency of the EDS in reducing concentrations of monomeric silica prior to injection of waste brine, and silica polymerisation rates. This test will assess three scenarios: scenario-1 consisting of pond 1 without baffels: scenario-2 consisting of pond-2 without baffles; scenario-3 consisting of pond-1 with buffles.

CONCLUSION

The silica supersaturation of discharged water from SBY-3 and SBY-4 wells seem to be very high (500 ppm in brine flashed to atmosphere).

Adopting the amorphous silica kinetic model of Fleming (1986) it could be concluded that the silicic acid depositions (at pseudo equilibrium) of the Sibayak brine water have a relatively fast reaction rate.

The Effluent Disposal System does not support those above condition. The EDS have to re-design to maximise the amorphous silica supersaturation water and maximise the fluid residence time.

Monitoring in the EDS re-designed should be conducted for efficiency test. This should be done for an extensive baffling arrangement.

ACKNOWLEDGMENT

The outhors would like to thank PERTAMINA Management for allowing us to present this paper.

REFERENCES

Personal Communication, BATAN Preparatory Paper for Internal Report, 1997.

Ramonito P. Solis, Fidel S. See, Joselito R. Ruaya and Adriano C. Cabel, Low Temperature Waste Water Injection Experiments At The Bac-Man Geothermal Field, Philippines, Proceeding of the WGC 1995, Florence Italy.