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Silica scale prevention effects of brine pH modification at Hatchobaru power station, Japan

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ABSTRACT

Hatchobaru power station started to operate with the first unit of 55MWe in 1977, and was expanded with another unit of 55MWe in 1990. Although high efficiency in power generation has been attained by adoption of a double-flash system, the low temperature (90°C) of separated brine yielded high silica-scaling potential. The retaining tank system was originally developed in the Hatchobaru-Otake power station as a countermeasure against scaling problems. This system aimed to reduce the silica-scaling rate in and around reinjection well by polymerizing silica in brine after retaining for about one hour, and had succeeded for long years. However, during the long period of operation, the installation of a number of make-up production wells that produces fluids exhibiting a variety of chemistry resulted in the change of chemical conditions of reinjection brine. This prevented silica polymerization of brine in the retaining tank, and raised the silica-scaling rate.

Consequently, pH modification system has been adopted as an alternative scale prevention method from 2003. The purpose of this method is to reduce the silica-scaling rate by adjusting brine pH with sulfuric acid. Although diluted sulfuric acid is generally utilized for pH adjustment in Japan, concentrated sulfuric acid is directly injected into brine in the Hatchobaru because of restriction of available clear water for dilution and limitation of space for water tanks in the field. From the results of silica polymerization experiments, it was confirmed that adjustment of pH at 5-6 brings sufficient effect for reducing silica-scaling rate. To date, the pH modification system has been successfully operated, and reduction of scaling rate and decrease of decline rate of reinjection capacity have been observed.

This paper introduces scale prevention effects under various brine chemical conditions based on the several kinds of monitoring data taken during the operation of Hatchobaru power station.

1. INTRODUCTION

The Hatchobaru power station is located in southern part of Japan. The total generation capacity is 110 MWe (55MWex2). It is well known that the first double-flash system in the world was adopted here. The brine of units 1 and 2 contained silica of about 700 mg/L and 800 mg/L as SiO_2, respectively. About 1,600t/h brine cooled around 90 °C downstream of flashers is reinjected. Over saturated silica as amorphous silica has tendency to react with silica scale. Therefore the brine of the Hatchobaru field has high scaling potential. The retaining tank method was originally developed in the Hatchobaru-Otake power station as a countermeasure against scaling problems in the brine containing over saturated silica (Yanagase et al., 1970). To date, the pH modification method has been adopted and proven to be successful as an alternative silica scale prevention method following changes in the chemistry of brine during long-term operation of the Hatchobaru power station.

2. RETAINING TANK METHOD

The retaining tank method aims to reduce over saturated silica as amorphous silica by polymerization. Polymeric silica has negative surface charge, therefore polymer is able to be suspended stably in water, and have lower tendency to react with silica scale than monomeric silica in low saline water. Monomeric silica concentration in brine decreases to amorphous silica solubility, after sufficient reaction time. Silica polymerization reaction is controlled by several factors such as silica concentration, temperature, pH, salinity and coexisting components of water. The Hatchobaru geothermal water which was alkaline and contained supersaturated silica did not need longer time than one hour to reduce monomeric silica concentration to amorphous silica solubility.

Figure 1 shows effectiveness of the retaining tank method at the Hatchobaru field. Molybdate active silica regard as monomeric silica concentration in the brine decreased while flowing in the retaining tank from inlet to outlet. At the same time, thickness of silica scale deposited on the tank wall also decreased (Yokoyama et al., 1987). Yanagase et al. (1970) reported that silica scale deposited on pipeline reduced to 10% by this method in the Otake field. This method had succeeded for long years. However, during the long period of operation, the installation of a number of make-up production wells that produce fluids exhibiting a variety of chemistry resulted in the change of chemical conditions of reinjection brine. For example, acid and slightly low temperature brine was mixed with reinjection water, reaction time of silica polymerization became longer. Figure 2 showed molybdate active silica concentration and scaling rate in the retaining

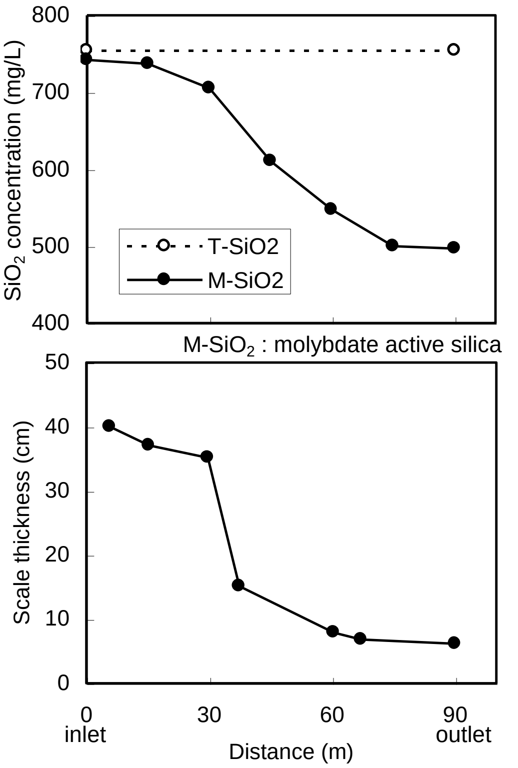

Figure 1: Variation of the silica concentration in the retaining tank water and thickness of scale deposited on the wall of the retaining tank for three years at the Hatchobaru field (Yokoyama et al., 1987).

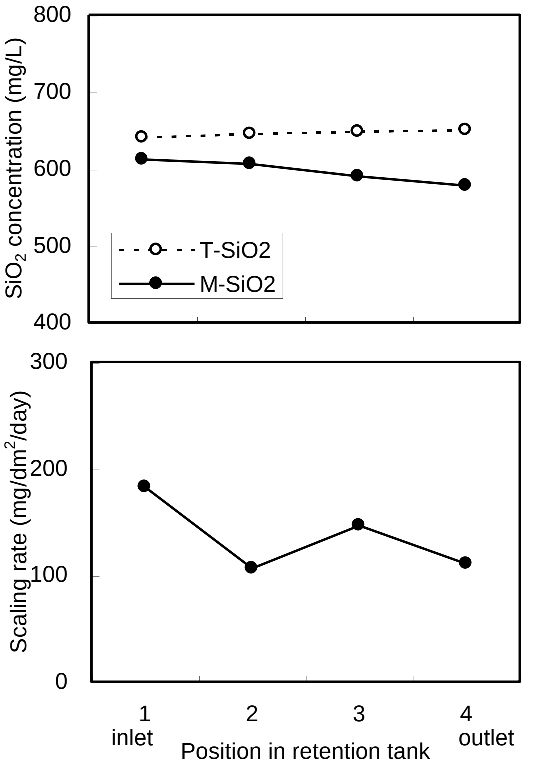

Figure 2: Variation of the silica concentration in brine and scaling rate from inlet to outlet in the retaining tank at the Hatchobaru field.

tank of Hatchobaru field at the time. Molybdate active silica concentrations of brine and scaling rate did not change at inlet and outlet of retaining tank. This suggested that silica scale was continuously depositing along the pipeline and within reinjection wells downstream of retaining tank and as a result the reinjection capacity decreased in a short period. Therefore, it became necessary to research alternative methods for scale prevention. A number of scale prevention methods have been proposed, and succeeded on each geothermal field. It is well known that keeping brine pH acid prevents silica deposition (Nishiyama *et al*., 1985). Gallup (1996) reported that scale deposition rates in brine transportation line were reduced and brine injectivity was also sustained by pH modification.

3. PH MODIFICATION METHOD

3.1 Retention Time

Silica scale formation is similar reaction with polymerization of silica, and this reaction is controlled by several factors. To determine effective pH values preventing silica scaling for each line waters, polymerization experiments were carried out using brines of the units 1 and 2 at the Hatchobaruand and Otake geothermal power plants. The molybdate active silica concentrations in those brines were from 605 to 722 mg/L, and original pH ranged 6.6-7.5. The brines were adjusted to target pH with sulfuric acid and packed in polyethylene bottles, which were retained at about 90°C for four hours. Aliquots of the brines were sampled and analyzed periodically for molybdate active silica and total silica concentrations.

Molybdate active silica concentrations are stable for some period of time and start to decrease. This induction period is thought to represent the time required to form polymers of critical size (Gunnarsson and Arnorsson, 2005). As shown in Figure 3, induction period becomes long depending on decline of pH and silica concentration of initial brine. It was confirmed that the polymerization of silica in the brines of the Hatchobaru and Otake fields were restrained at pH=5-6, and the brine of the Hatchobaru unit 2 containing high silica concentration is required to adjust lower pH.

3.2 Effect of pH Modification

The pH modification system has been adopted as an alternative scale prevention method in the Otake and Hatchobaru geothermal fields from 2002 and 2003, respectively. The brines derived from each wells are gathered in retaining tanks, in which sulfuric acid is injected. Figure 4 shows silica scale preventing effect of pH modification method at the Otake geothermal field. Before adoption of new silica scale preventing method, retention effect was already lost because of decrease of silica concentration in the brine. Scaling rate on test piece located at outlet of the retention tank for 28 days was reduced from 117 $mg/dm^2/day$ to

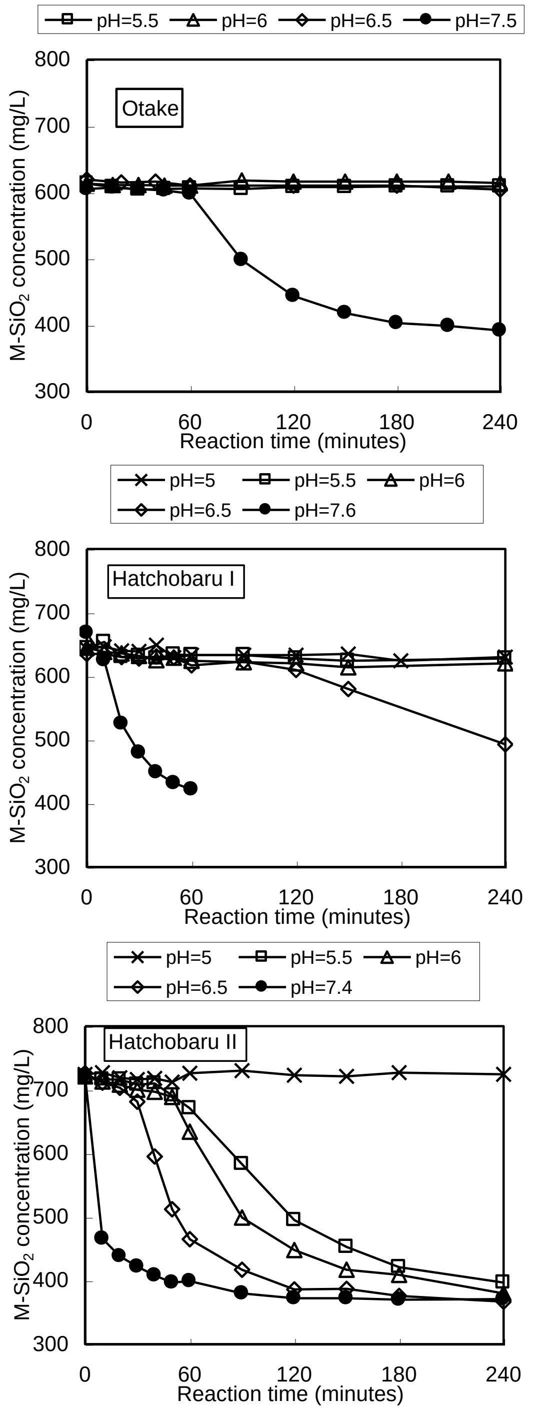

Figure 3: pH dependence on silica polymerization in the brines of the Otake and Hatchobaru power plants at 95°C.

0.9 mg/dm^2/day. Annual decreasing rate of injection capacity at reinjection wells were reduced about 30% compared before.

3.3 pH Modification Effect at Different Conditions

Figure 5 shows silica scaling rates and chemistries of brines sampled at the inlet and outlet of the retaining tanks in the Otake and Hatchobaru fields.

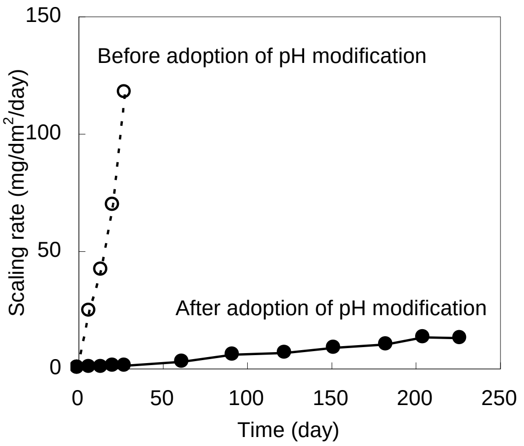

Figure 4: The effect of pH modification on scaling rate deposited on test piece settled at outlet of the retaining tank at the Otake power plant.

The brine of the Otake field containing low silica allowed minimum silica scaling rate. On the other hand, although the brine of the Hatchobaru unit 1 had low silica concentration as compared with the unit 2, scaling rate was higher. Furthermore, only the brine of the Hatchobaru unit 1 had higher scaling rate at inlet than outlet. There were no changes of molybdate active and total silica concentrations of brine during flowing in the retaining tank. This means that there was no retaining effect by silica polymerization. The difference was that the brine of the Hatchobaru unit 1 had higher total iron concentration than the brine of other tanks. That was because an acid well was used at the Hatchobaru unit 1. Admixing of acid brine containing metal ion with neutral brine raises silica-scaling potential (Abe, 1995). In the case of the Hatchobaru unit 1, high total iron concentration might yield silica-scaling risk.

3.4 pH modification effect at various SiO_2 concentration

After acid well stopped, silica-scaling rate and reinjection capacity decline were decreased. Silica scale prevention was successful for about one year in the Hatchobaru unit 1, but reinjection capacity drastically decreased. At the same time, a make-up well (well-A) started to production. The well-A had very big production capacity and contained high concentration of silica. By mixing of the brine of this well, total silica concentration of the tank brine increased by about 100mg/L. To reduce scaling rate, pH was modified slightly lower. However silica polymerization did not stop at the pH value, which indicated silica-scaling risk was high. Because it was difficult to lower the pH in terms of corrosion problems of equipments, the well-A was obliged to reduce its production rate. It caused reduction of total silica concentration in the brine of Hatchobaru unit 1 (Figure 6) and succeeded to reduce scaling rate. Scaling rate and reinjection capacity reduction were eventually controlled by changing the production rate at well-A.

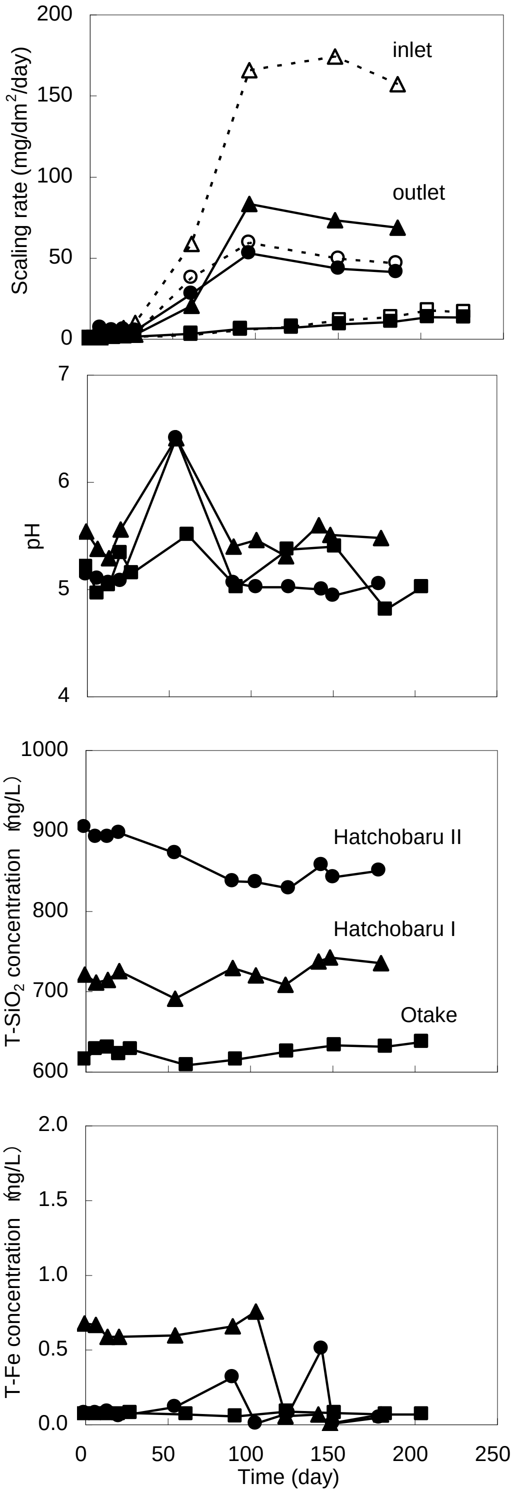

Figure 5: Variation of the scale prevention effect of pH modification with brine chemistries at the Hatchobaru and Otake plants.

4. CONCLUSION

The retaining tank system was adopted in the Hatchobaru-Otake power station as a countermeasure against scaling problems, which had succeeded for long years. However during the operation of long period, change of chemical conditions of reinjection brine caused preventing silica polymerization, and raised the silica-scaling rate. Consequently, pH modification system has been adopted as an alternative scale prevention method. To date, the pH modification system has been successfully operated, and reduction of scaling rate and decrease of decline rate of reinjection capacity have been observed. However, change of brine chemical condition affects scaling rate, even though the pH modification method is adopted. It is, therefore, necessary to continue monitor chemical composition of the brine to be injected.

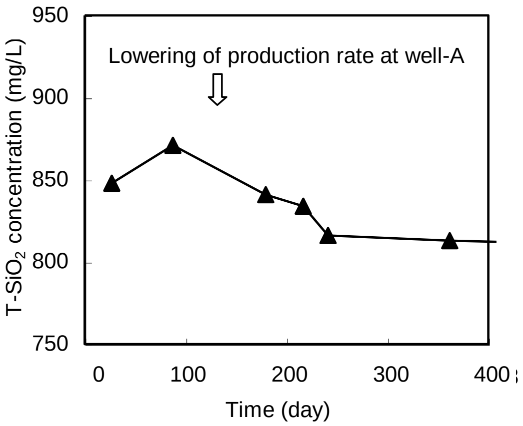

Figure 6: Total silica concentration change in the Hatchobaru unit 1 brine after make-up well started to production.

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