Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

SULFUR SCALE ABATEMENT SYSTEM USING A SURFACTANT IN GEOTHERMAL POWER PLANT CIRCULATING WATER

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Keywords: Sulfur Scale, Surfactant, Sulfur Bacteria

ABSTRACT

A lot of sulfur rich scale accumulates in the cooling water system of geothermal power plants, which markedly lowers cooling system efficiency.

Numerous sulfur bacteria were detected in the sulfur scale. It is thought that sulfur mainly originates from sulfur bacteria activity when oxidizing H_2S (gas) to S (solid) in the circulating water (geothermal steam condensed water).

In this study, we examined the prevention effect of surfactant on sulfur scale formation.

At the Sumikawa Geothermal Power Plant (50MW, Akita Prefecture, Japan), we injected surfactant into the cooling tower circulating water at 1ppm concentration, which reduced the sulfur scale to 40-50% of that before surfactant injection.

This chemical injection was successful to some degree in prolonging the plant inspection interval but the plant inspection interval is 1 year and still too short.

With 1ppm surfactant, the number of sulfur bacteria was less than 10 cells/l in the circulating water but 10^3-10^4 cells/g in the sulfur scale. This means that the bacterial activity was inhibited in the circulating water but not in the scale. This might be the reason why sulfur scale accumulates in the 1 ppm surfactant cooling water system.

Our laboratory and miniplant experiments showed that the bacterial activities were inhibited at concentrations over 0.5 ppm in the circulating water but not at concentrations less than 160 ppm in the sulfur deposit. Once the sulfur scale contacts over 160 ppm high concentration surfactant for a short time, signs of sulfur scale growth are no longer found.
Now we are preparing to apply this idea to the actual geothermal power plant.

1. INTRODUCTION

The Tohoku Electric Power Co., Inc., geothermal power plants have, conventionally, undergone periodic one month inspections every year. However, to improve efficiency at the geothermal power station operation, longer inspection intervals are required. To accomplish this, our current periodic inspection schedule is, provisionally, a one month inspection every two years and a one week simplified inspection mid-way.

We are now planning to omit the one week simplified inspection. If this inspection is not done, scale deposits cause clogging in the cooling water line, including the condenser, the turbine oil cooler, etc., and efficiency is reduced. Scale washing and removal is currently done every year when the plant is shut down for the inspections. When our inspection schedule is adjusted to omit the one week simplified inspection, anti-scale adherence measures will be required to maintain the efficiency of the cooling system.

The objectives of this study were to clarify the cause of scale production and to establish anti-scale adherence measures. This report describes the interim results of the study that will end in FY 2000.

2. SCALE

2.1. Scale composition

An analysis of samples of scale deposits from every part of the cooling water system indicated that the scale was 90% sulfur (Fig. 1).

The steam produced at the geothermal wells contains hydrogen sulfide (Table 1) and it is assumed that this hydrogen sulfide is oxidized in the cooling water system and precipitates as solid sulfur and forms scale deposits.

2.2. Mechanism of scale formation

The following reactions are deemed to occur in the cooling water system and the formation of the sulfur supposedly depends on the balance between the reactions.

$$2H_2S + O_2 \rightarrow 2S\ (solid) + 2H_2O \quad (1)$$

$$2S + 3O_2 + 2H_2O \rightarrow 2H_2SO_4 \quad (2)$$

Chemical and biological origins are considered to be involved in the above reactions. The production of sulfur from the chemical origin is governed by the oxidation-reduction potential and pH, while bacteria, such as sulfur bacteria, participate in the formation of sulfur from biological origin.

Experiments on solid sulfur formation were conducted in the laboratory to confirm the chemical origin of the sulfur by changing the pH of the cooling water and steam drain of the real plant. The result was that solid sulfur did not form. The relationship between the oxidation-reduction potential and pH in our measurements ruled this out as a source.

On the contrary, microscopic observation of the scale showed various kinds of bacteria (Photo 1). We detected sulfur bacteria from the scale with selective cultivation agar media for acidophilic sulfur bacteria.

As a result, it was judged that scale formation is mainly governed by a biological origin.

3. ANTI-SCALE MEASURES

3.1. Scale at the Sumikawa Geothermal Power Station

Scale deposits were significant at the Sumikawa Geothermal Power Station (50 MW, Akita Prefecture) of Tohoku Electric Power Company and periodic inspections every six months were required. It was decided to use a surfactant to suppress the sulfur bacteria. The surfactant was a common industrial, anti-bacterial reagent that has little effect on the equipment. The power plant cooling system was operated with an injection of 1 ppm surfactant.

The injection of the surfactant permitted operating Sumikawa continuously for one year. After one year, however, scale deposits must be cleaned up during the inspection and extending the inspection interval to longer than one year seemed to be difficult to achieve.

3.2. Confirming the surfactant effect at Sumikawa Geothermal Power Station

To confirm the scale deposit suppression effect of injecting 1 ppm surfactant, the cooling water and some of the scale deposits at Sumikawa Geothermal Power Station were sampled. The bacteria in the cooling water were found to be completely suppressed, without growth, while bacteria growth was detected in the scale.

This implies that the scale forming after injecting 1 ppm surfactant was attributable to the bacteria that had not been completely removed during inspection.

3.3. Determining the optimal concentration of the surfactant

The optimal surfactant concentration that suppresses bacteria growth varies with the environment surrounding the sulfur bacteria. To clarify this, individual experiments were conducted for the bacteria living in the cooling water and the scale.

The results showed that effective concentrations are over 0.5 ppm for bacteria in the cooling water and 160 ppm for bacteria in the scale (Figs. 2 and 3).

3.4. Miniplant experiments

The results of the optimal surfactant concentration tests led us to believe that the effect of scale suppression is feasibly maintained by first using surfactant over 160 ppm on the scale for a short time followed by a continuous injection of surfactant of about 0.5 ppm.

A miniplant model was installed at Sumikawa Geothermal Power Station to verify the effect.

This miniplant simulated operating the real plant with a surfactant injection of 1 ppm. The scales treated with a high surfactant concentration and untreated were placed in the miniplant, and compared one month after running the model with respect to the amount of scale deposit and the number of sulfur bacteria (Table 2 and Fig. 4).

When treated with a high concentration of surfactant, the amount of scale formed and the number of sulfur bacteria can be reduced by 80-90%.

However, bacteria activity is observed even in the scale treated with a high concentration of surfactant and is not completely suppressed. Further testing is required to confirm the continuity of the suppression effect.

4. CONCLUSION

The followings are FY 1998 accomplishments:

- The scale deposit detected in the cooling water system is sulfur scale and the surfactant is effective for suppression.
- When the scale is subjected to the surfactant at a high concentration over 160 ppm for a short time, followed by a continuous low concentration surfactant injection, scale formation is reduced by 80-90% compared to scale untreated with high concentration surfactant.

5. FUTURE TASKS

Aiming at practical use in a real system, studies on the followings are scheduled:

- Confirm the continuity of the effect of high surfactant concentrations.
- Clarify and resolve the problems that occur when treating with high surfactant concentrations.
- Investigate chemicals other than surfactants that are effective in suppressing scale formation.
- Other anti-scale adherence methods.

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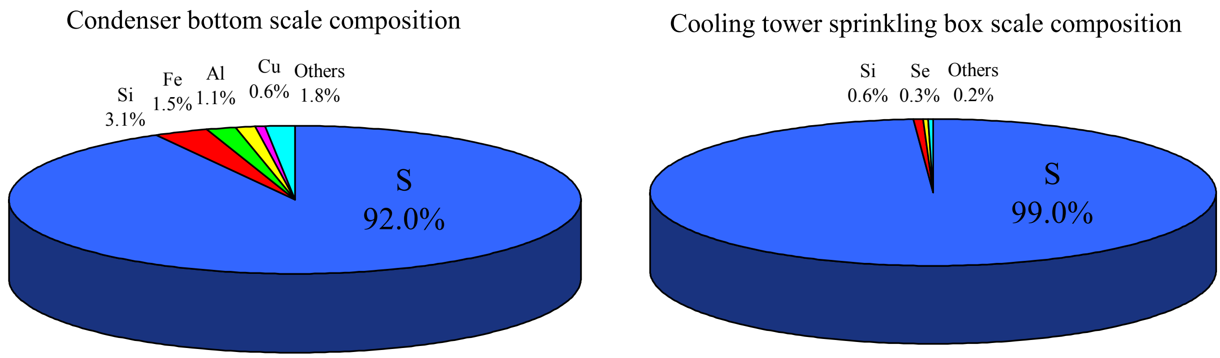

Fig. 1 Composition of cooling water system scale

Table 1 Steam composition

	Kakkonda			Uenotai			Sumikawa			Yanaizu-nishiyama		
Steam/gas composition (vol%)	Steam 99.97/ noncondensable gas 0.03			Steam 99.8/ noncondensable gas 0.2			Steam 99.93/ noncondensable gas 0.07			Steam 97.5/ noncondensable gas 2.5		
Gas composition (vol%)	CO_2	H_2S	Other	CO_2	H_2S	Other	CO_2	H_2S	Other	CO_2	H_2S	Other
	66.1	23.9	10.0	87.7	6.9	5.4	70.5	21.2	8.3	96.7	2.8	0.5

Photo 1 Bacteria in sulfur scale

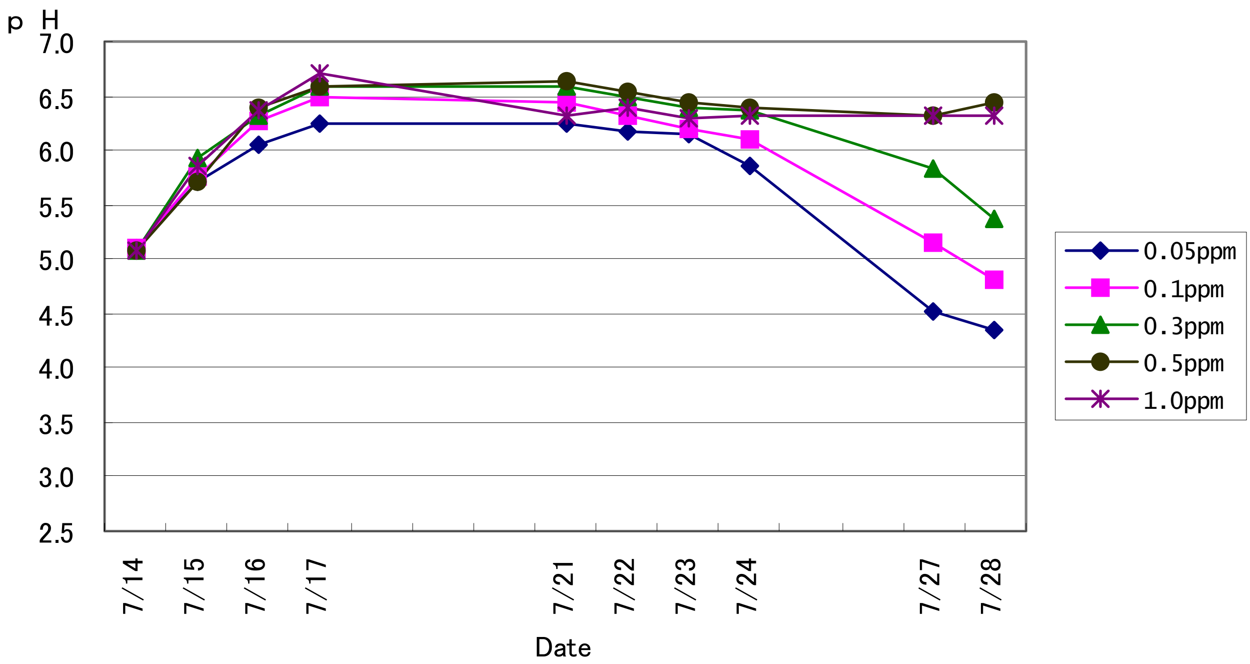

Fig. 2 Surfactant suppression of sulfur bacteria activity in the circulating water (low concentrations of surfactant)

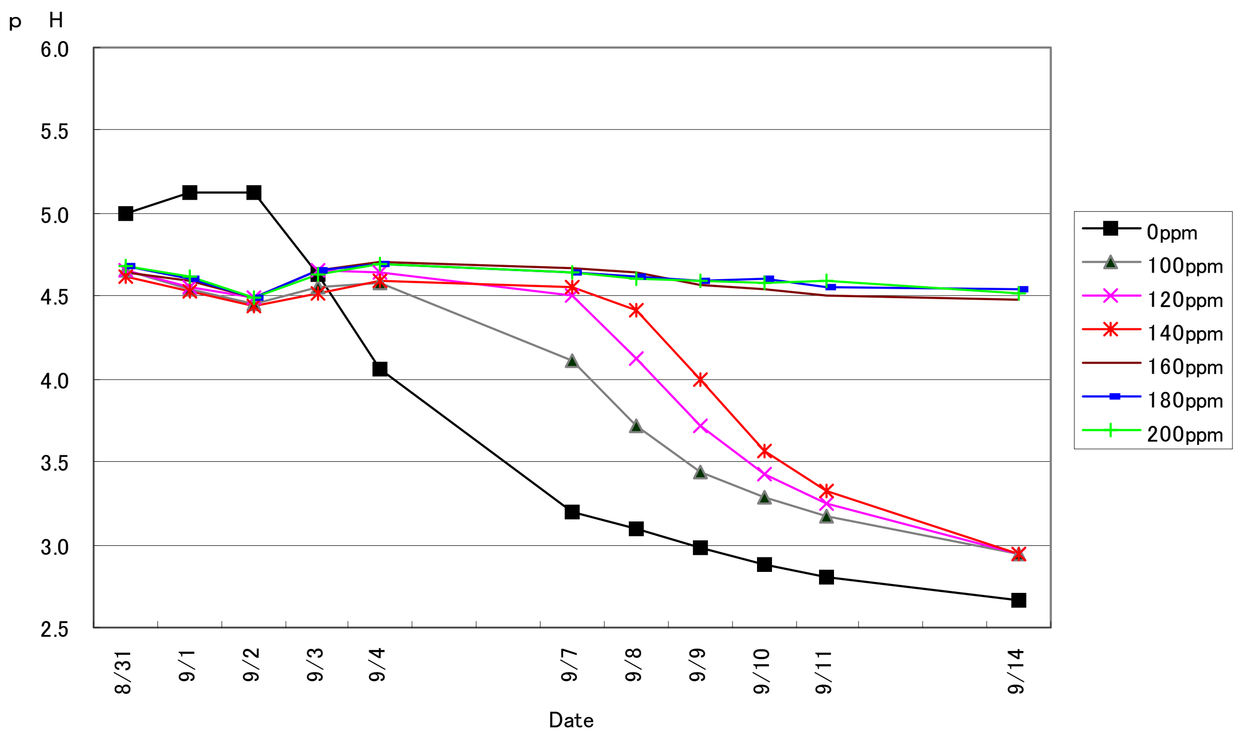

Fig. 3 Surfactant suppression of sulfur bacteria activity in sulfur scale (high concentrations of surfactant)

Table 2 Miniplant model test

		Scale untreated with a high concentration surfactant	Scale treated with a high concentration surfactant
Scale quantity (g)	Beginning of test	500g	500g
	End of test (31 days)	775g (+275g)	530g (+30g)

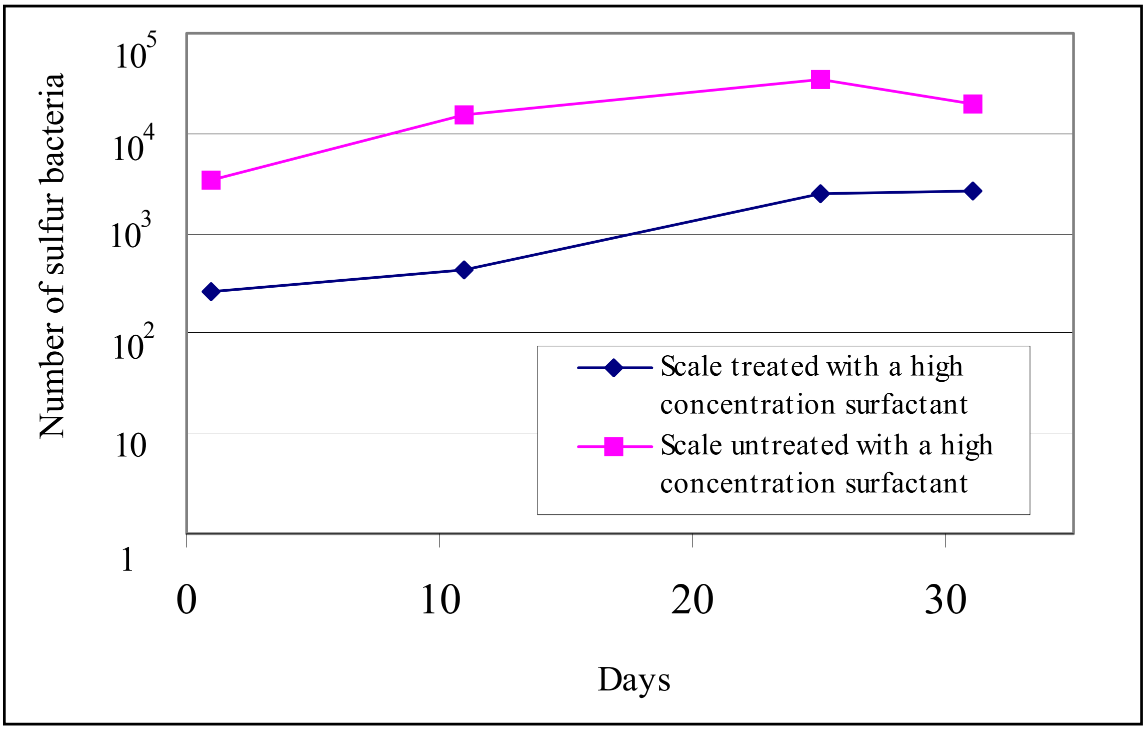

Fig. 4 Number of sulfur bacteria