EXPERIMENTAL STUDY ON RENEWAL OF THE REINJECTION WELL

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1. INTRODUCTION

In a water-dominated geothermal system, geothermal waste water is returned into the ground at a depth to maintain the reservoir pressure and also to avoid the environmental pollution caused by chemicals contained in the water. However, the decrement of injection capacity of wells occured in the reinjection system. For example, the injection capacity of wells in the Otake and the Hatchobaru fields decreases 20-30 % a year. Therefore, two to three additional wells have to be drilled annually to maintain the total injection capacity in Otake and Hatchobaru. Injectivity decrease of wells is probably caused by the silica scale deposition in a formation near wells.

In this paper, a couple of techniques to recover the injectivity of wells were presented.

2. Causes of decrement of injection capacity.

The reinjection has been started since 1972 in the Otake field. At the initial stage of reinjection, the cause of decrement of injection capacity was considered to be mainly physical factors.

2-1. Simulation test of reinjection well.

In order to clarify the mechanism of injectivity decrease of wells, the Otake and the Hatchobaru waters transmission tests using experimental equipment in both Otake and Hatchobaru and injection tests in Otake were carried out.

The injection simulation testing equipment was composed of five cylindrical columns, in which the various packing materials such as alumina balls and rock fragments can be packed.

The Otake and Hatchobaru geothermal waters were flowed into the cylindrical columns which correspond to the porous media in the reservoir, at a constant flow rate.

The adhesion of silica scale was concentrated at the first column and the permeability of the first column decreased to one hundredth compared with its initial value, when the pressure difference between the inlet ofthe first column and the outlet of the fifth column rose up to 5Kgf/cm^2 and then the water supply was stopped.

From these results, the numerical model was developed to study the decreasing phenomena of reinjection well.

The factors, which affect the rate of scale deposition from the geothermal water, such as ①silicic acid concentration ②temperature ③PH ④salt concentration, were evaluated quantitatively.

2-2. Numerical simulation of the reinjection well.

On the basis of the experiments on reinjetion it was understood that the decrement of injection capacity is mainly caused by silica deposition in the formation around reinjection well.

The numerical simulation on the decrease of injectivity for reinjection well was carried out with the use of the numerical model.

The simulation results show that the permeability decreasing range of the reinjectin formation is limited in the vicinity of the reinjection well.

Figure 1 shows one of the results of numerical calculation.

The change of measured water level

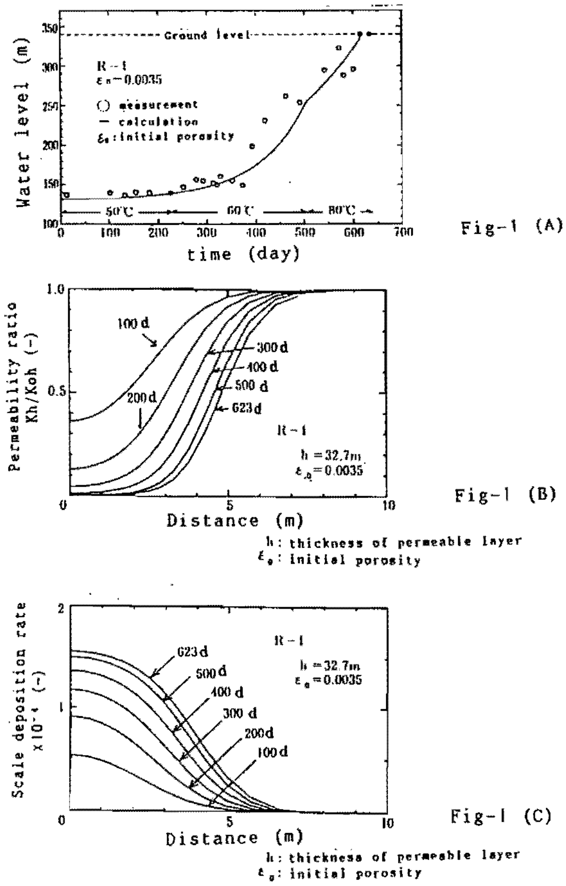

Fig-1 Change of reinjection capacity and distributin of permability ratic & scale deposition rate (R-1) with time in the well agreed with the calculated value from the numerical simulation (Fig-1(A)), and then the area distance from the well bore where declined permeability and concentrated scale deposition had occured, was limited near the well.

3. Countermeasures to prevent the injectivity decrease of wells.

Basically, the conceivable method to prevent a scale deposition which causes injectivity decrease of wells must be applied. However, it has not been developed yet.

The mechanical cleaning of scales and the hydro-fracturing have been tried at the wells in Otake and Hatchobaru to cope with the injectivity decrease of wells. However, these method showed little effect on the improvement of injectivity.

4. Experimental study on recorvering of injection capacity.

4-1. Chemical cleaning using HF solution.

(1) Selection of chemical cleaning solution.

A silica scale deposition can be dissolved by some chemicals such as HF, NaOH and NH_4HF_2+HCl : HF solution is considered to be more effective. But in case that chemical cleaning method is applied, an inhibitor should be used with it.

(2) Experimental results of chemical cleaning.

The experiment for renewal of the reinjection well by chemical cleaning was conducted to the silica deposited column under two conditions : the chemical cleaning solution is poured into the columns 1) under constant hydraulic head, 2) at a constant flow rate.

First, the chemical cleaning solution containing HF in the range from 0.5 to 5 % was poured into the permeability reduced column at a hydrostatic head of one meter. As the HF solution dissolve the silica scale in the column, the permeability of the column was recovered. Figure 2 shows a relationship between the flow rate of HF solution and the recovered permeability for different concentration of HF solution. The maximum recovery in permeability was attained when the HF solution of 5 % used; the permeability increased more than 90 % of the initial value.

In order to estimate the total volume of chemical cleaning solution for the optimum treatment, the chemical cleaning solution containing HF of 5 % was injected into the silica deposited columns (5 columns connected in a series) at a constant flow rate, 0.2 l/min. The columns reduced their permeability to 1 % of their initial values before injecting chemical cleaning solution. Figure 3 shows the change of silica concentration in the sampled water at the exit of the column. The maximum silica concentration was measured 15 to 20 minutes after the chemical injection. The optimum volume of

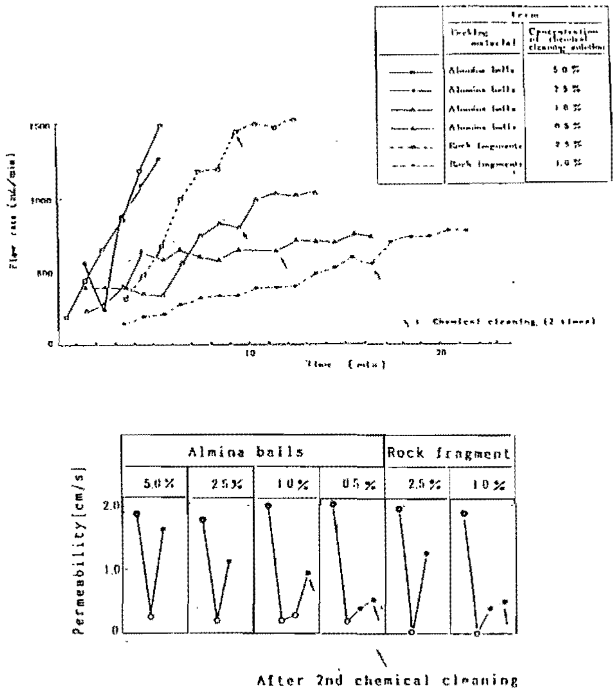

Fig-2 Results of the geothermal hot water transmission test before and after chemical cleaning

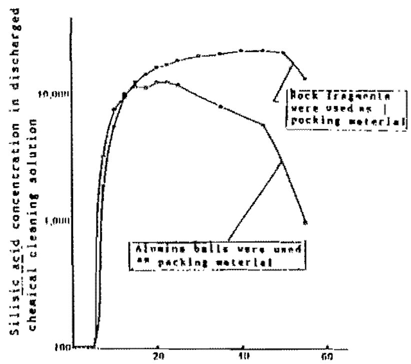

Fig-3 Change of concentration of silicic acid in discharged chemical celaning solution

the chemical cleaning solution in total can be estimated to be 3 to 4 liters. The chemically treated columns recovered their permeabilities to 94-99 % of its initial value when the aluminum ball was packed, and 76-92 % when the rock fragment was packed.
The results are shown in Table-1, Fig-4.

Packing material / Tube No.	Alumina balls: Permeability (m/s) Ⓐ Before geothermal brine transmission test	After geothermal brine transmission test	Ⓑ After chemical cleaning	Rate of recovery Ⓑ/Ⓐ×100 (%)	Packing material / Tube No.	Rock fragments: Permeability (m/s) Ⓐ Before geothermal brine transmission test	After geothermal brine transmission test	Ⓑ After chemical cleaning	Rate of recovery Ⓑ/Ⓐ×100 (%)
Tube 1	1.99	3.06 × 10[illegible]	1.87	94	Tube 1	1.56	3.85 × 10[illegible]	1.43	92
Tube 2	1.97	6.59 × 10[illegible]	1.90	96	Tube 2	1.50	9.89 × 10[illegible]	1.27	85
Tube 3	1.96	5.78 × 10[illegible]	1.93	97	Tube 3	1.61	2.08 × 10[illegible]	1.24	77
Tube 4	1.96	6.31 × 10[illegible]	1.96	99	Tube 4	1.53	8.26 × 10[illegible]	1.19	78
Tube 5	1.97	7.78 × 10[illegible]	1.94	98	Tube 5	1.57	1.11	1.19	76

Table 1 Results of the geothermal hot water transmission tests before and after chemical cleaning

(3) Subjects of chemical cleaning for field application.

When we apply the chemical cleaning method for actual field, the following subjects should be considered;

a) facilities to inject the chemical solution.

b) estimation of total volume of chemical solution.

c) extracting method of HF and SiF_4 gases from the well.

d) avoidance of environmental contamination due to chemicals.

4-2. SIDE-TRACKING OF WELLS

Field experiments of injecting geothermal waters into two wells were carried out in Otake. The decrease of well injectivity has been numerically analyzed to investigate the silica deposition in a reservoir near the well. The results indicate that the injectivity decrease of the well is due to the permeability reduction in the close vicinity of well(Fig-5)

On the basis of the numerical simulation results, side-tracking was tried at OR-7(350m deep) in the Otake field. The side-tracking was conducted as follows:

1) The casing pipe of 12 inches diam. was cut off about 25 meters by drilling machine.

2) A new bore hole was drilled aside through the cut off section keeping a certain distance from the original bore hole.

From the result of the side-tracking, it was confirmed that the new bore hole met a water loss zone at the same depth of the injectivity lost hole (original well) and the injectivity of the side-tracked hole was almost the same as initial value of the injectivity lost hole.

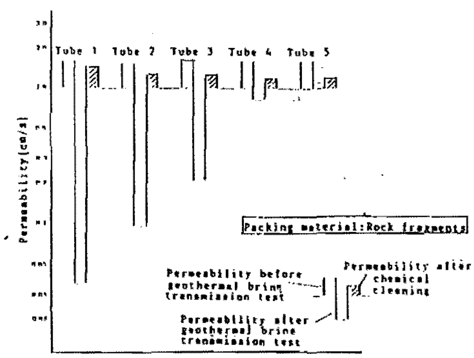

Fig-4 Composition of permeabilities between before and after chemical cleaning
(Packing material: Rock fragments)

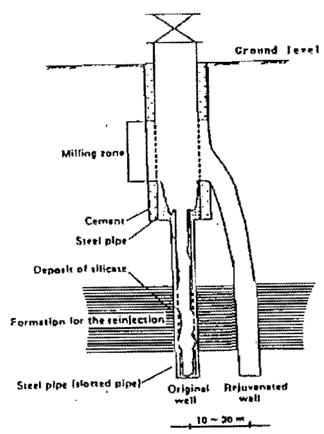

Fig-5 Model of the renewal of reinjection well by side-tracking

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