Geothermal Resources Council TRANSACTIONS, Vol. 18, October 1994

OUTLINE OF OGACHI PROJECT FOR HDR GEOTHERMAL POWER IN JAPAN

Yoshinao Hori   Kouichi Kitano   Hideshi Kaieda

1) Associate vice president, CRIEPI, 1646 Abiko , Abiko city Chiba 270-11, Japan
2)Senior research fellow, CREIPI
3)Senior research engineer, CREIPI

INTRODUCTION

The Central Research Institute of the Electric Power Industry (CRIEPI) has been studying domestic natural resources that offer energy production which will provide greater diversity and compatibility with current environmental demands. Hot Dry Rock (HDR) geothermal energy production was singled out as an ideal method to expand the development of Japan's wealth of terrestrial heat resources. CRIEPI began studying HDR's economic use in 1990 to develop the technology essential for HDR application in the nearfuture.

Since 1989, experiments have centered on the site at Ogachi, Akita Prefecture where a research group of 20 geothermal engineers have been conducting research with a 1,000m well. (Figure 1) The following is a report on experiments at Ogachi resulting in the creation of two layers of fractures. Included are the results of the well boring and an evaluation of the fracture development.

THE EXPERIMENT SITE

Ogachi experiment site is located about 2.5 kilometers northeastof Akinomiya hot Springs area, in the southern part of Akita Prefectureshown in Figure 2. Investigative boring shows geological characteristics of composite features including ash, rock, gravel, etc. to a depth of 77m. The next 200m plus consist of a variety of pyroclastic rock, and from 300m, granodiorite, as shown in Figure 3. The ground condition shows a conductive slope and the temperature at the depth of 1,000 m is about 228 C.

Existing data on the rock from underground stress measurements of a core sample made in Kanagawa in 1981, at the depth of 900m, shows that the maximum principal stress along the horizontal plane went from northwest to southeast over an area of about 29MPa. The minimum principal stress went from northeast to southwest over an area of about 12MPa.

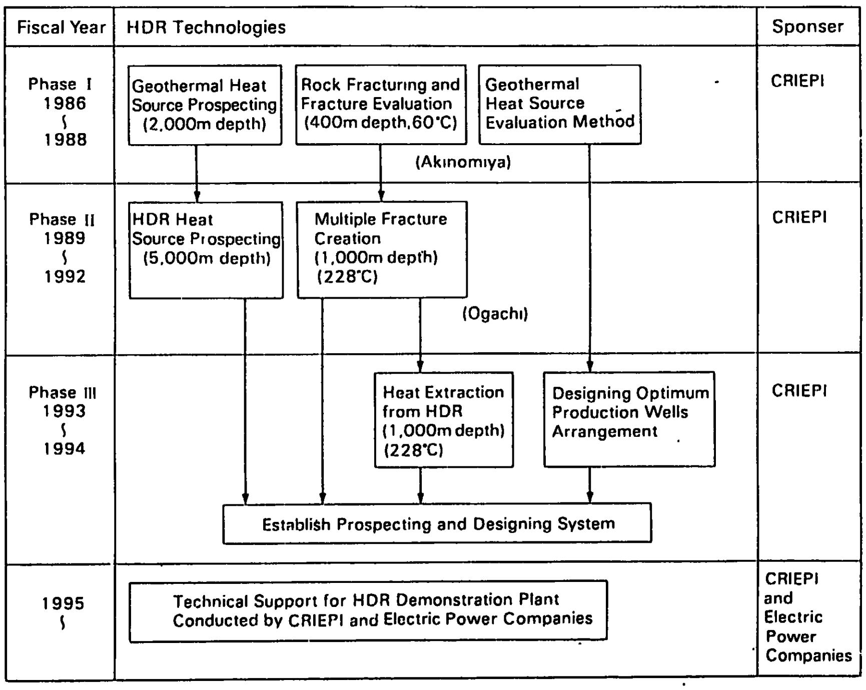

Fig. 1 CRIEPI's Plan for HDR development

MULTIPLE FRACTURING BY HIGH PRESURE HYDRO-FRACTURING METHOD

CRIEPI developed the high pressure hydro-fracturing multiple fracture method during early experiments in Akinomiya in 1988. With this method multiple fractures for water storage can be created at different depths along one well. Practical application of the method was tested at the Ogachi experimental site. A bore hole was drilled to a depth of 990m. A steel casing pipe was then placed at the bottom of the bore hole and cemented in a process called full-hole cementing shown in Figure 2. Further drilling was then carried out to the 1,000m mark, with the lower segment left open.

(1) The Lower layer Fracturing

During the period of 26 June to 6 July, 1991, the lower layer offractures was induced by application of high pressure water to the open part of the well at the depth of 990-1,000m. Water was first injected at a rate of 1 l/min. to determine the permeability condition of the rock. A second injection was made at 100 l/min. to effect initial fracturing of the rock. Finally, fractures were expanded by an injection of 600 l/min. Figure 4 shows the changes in water flow rate and well head pressure during the fracturing process. A total of 10,142m3 of water was injected continuously 24 hours a day for a period of 11 days.

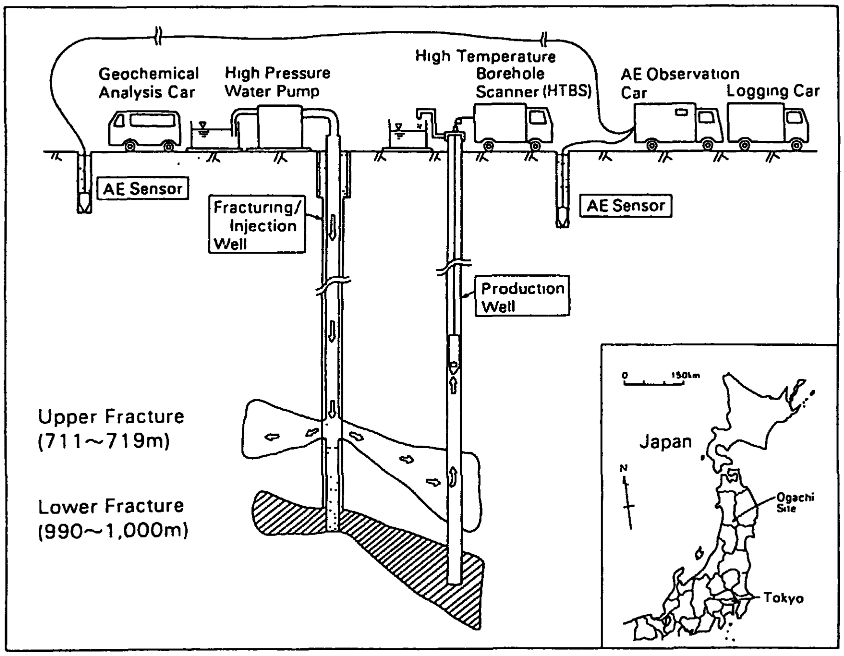

Fig. 2 Concept of Ogachi HDR Experiment

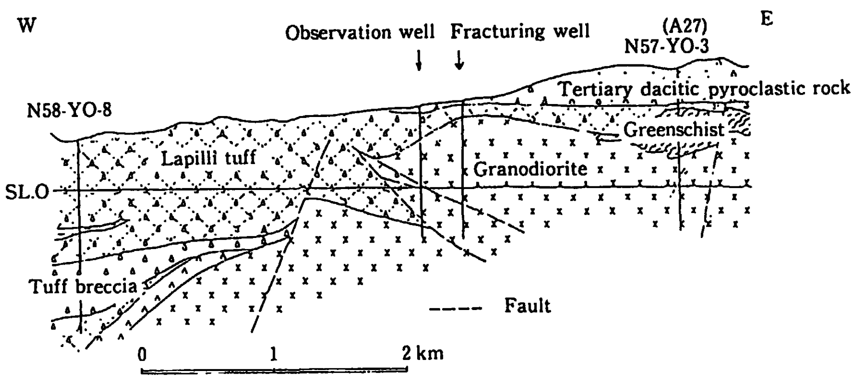

Fig. 3 Geological Cross Section

(2) The Upper layer Fracturing

Following creation of the lower layer of fractures, an 8m long window was milled in the well's casing pipe between the depths of 711m and 719m. The well below the window was then filled with sand, forming a Sand Plug. The upper portion of the well was left filled with water. A second permeability test of the lower fracture level was then made. The fracturing process was then repeated at the 711m to 719m level. Following initial fracturing of the rock, high pressure water was injected at the rate of 450 /min. to effect fracture expansion. Figure 5 shows the water flow rate and the well head pressure. A total of 5,440 m3 of water was injected continuously 24 hours a day for a period of 10 days.

EVALUATION OF FRACTURES

(1) Evaluation Methods

The progression of the fractures was evaluated by the following methods:

The water pressure at the well head and the amount of water flow per hour were measured during high pressure hydro-fracturing.

AE observation was carried out during hydro-fracturing. AE monitoring was conducted by three-component seismometers with a frequency of 5Hz set in 30m to 50m boreholes at nine points around the site.

The mise-a-la-mass method was applied using the fracturing well's casing as one of the current electrodes. Monitoring was done byapproximately 120 potential electrodes placed at 50m to 100m intervals in a radius of 400m around the borehole.

The AE and the mise-a-la-mass monitoring operations were conducted continuously for days before, during and after fracturing operations.

Injected water and returned water were subjected to repeated geochemical analyses. Samples of injected water were taken from a stream located next to the experiment site. Samples of returned water were taken from the well following completion of fracturing operations. Water density was checked hourly.

Testing for the permeability of the rock where fracturing was applied was accomplished by determining the average permeability coefficients of the fracturing interval before and after fracturing operations.

(2) Evaluation Results

The AE observations showed that AEs occurred at a rate of 20 to 30 per hour during the first fracturing as shown in figure 4. A total of approximately 1,700 AEs were located as shown in Figure 6.

These results indicate that the AEs were located south and west of the borehole just after the start of fracturing. The location then moved gradually to the north and finally was found at approximately 20 north-northeast of the borehole. The range of the AEs indicates that the fractures expanded in the form of a large ellipse with long axis of about 1,000m, a short axis of about 500m and a thickness of 200m.

During the upper fracturing AEs occurred at a rate of ten per hour, considerably less than with the lower layer, as shown in Figure 5. However, on July 6 and July 10, AEs occurred at a rate of approximately 200 per hour, with about 1,000 locations as shown in Figure 6.

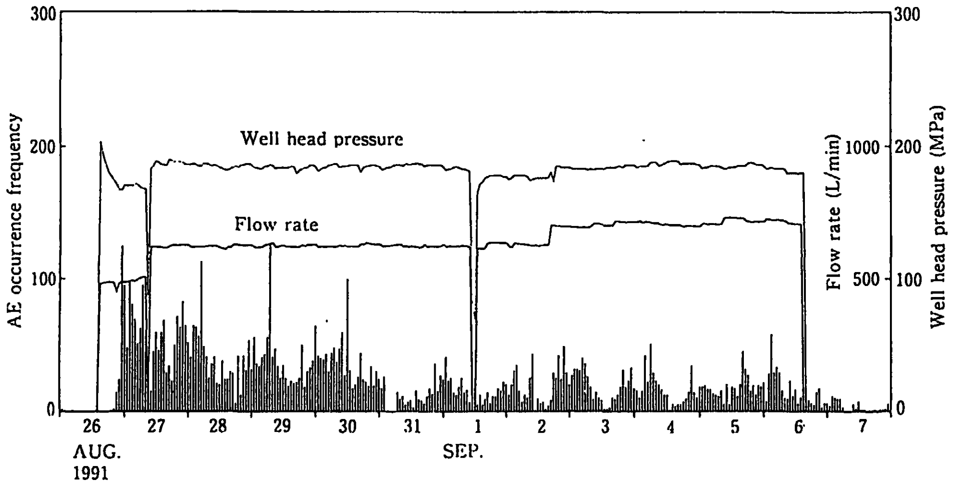

Fig. 4 AE Occurrence Frequency, Well Head Pressure and Flow Rate

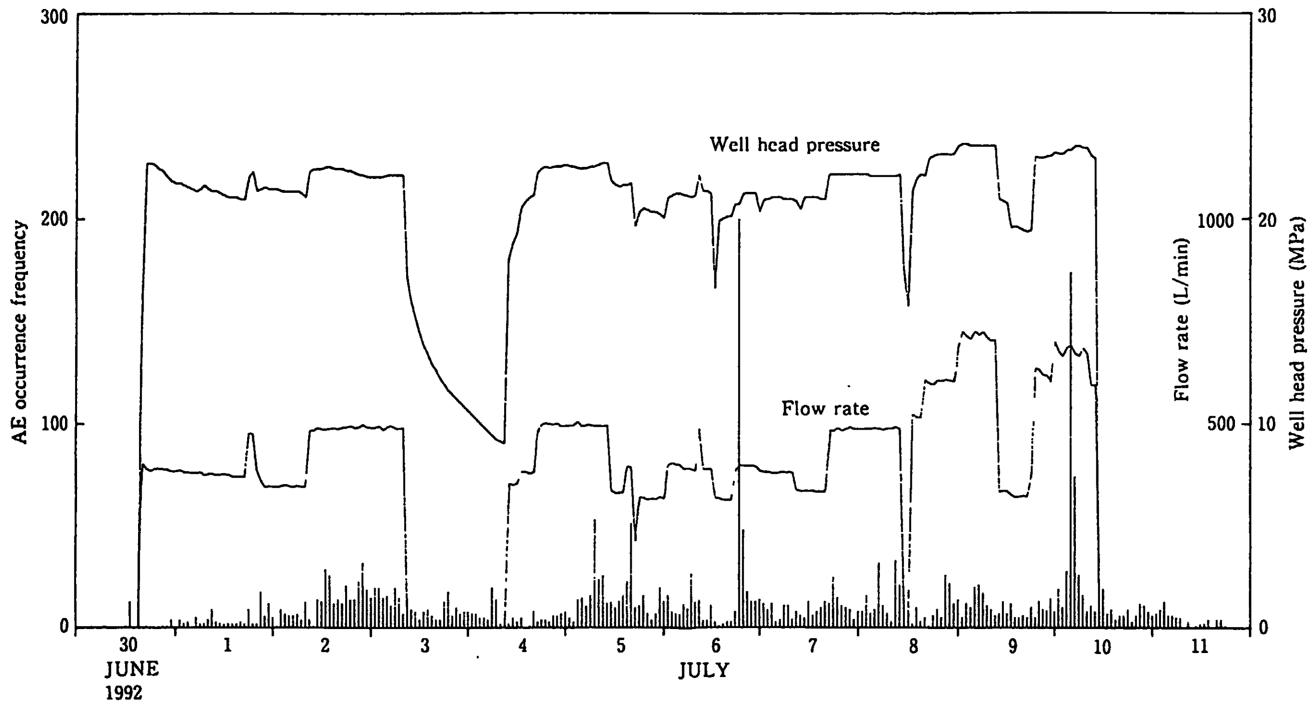

Fig. 5 AE Occurrence Frequency, Well Head Pressure and Flow Rate

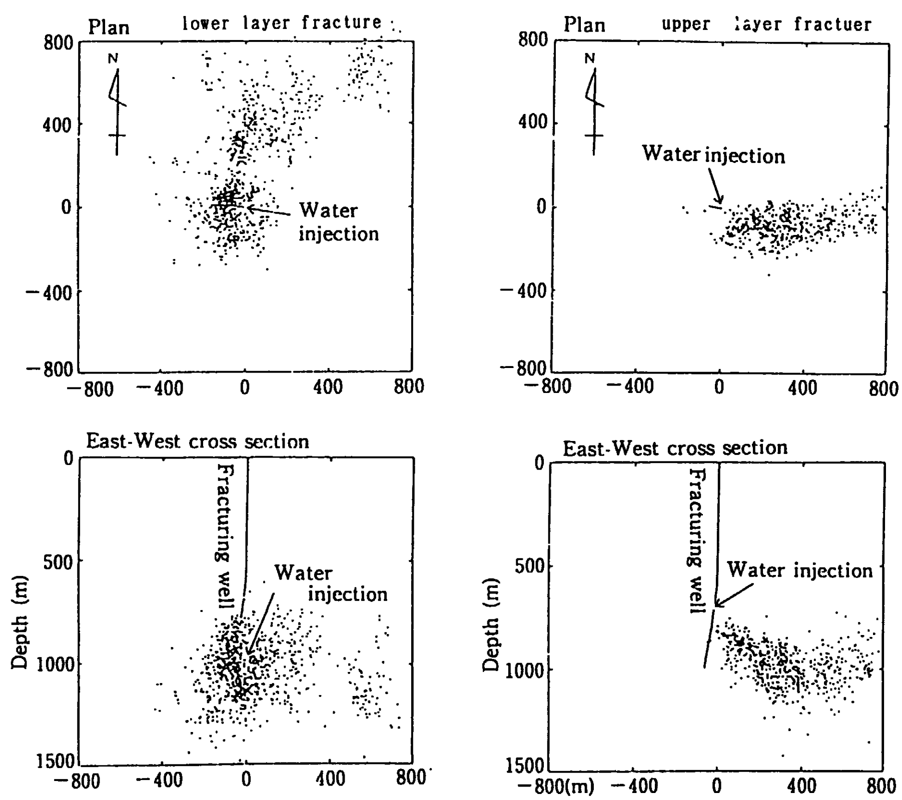

Fig. 6 AE Hypocenter Distribution

The AEs were located only on the east side of the borehole, indicating that the fractures progressed in an easterly direction. The estimated size of the upper fracture layer was similar to that of the lower layer, forming an ellipse with a long axis of about 800m, a short axis of about 400m and a thickness of 200m.

Measurements by the mise-a-la-mass method showed that the fractures progressed from west to north. This finding was supported by the AE observations, even though the measurement area was small in the first fracturing experiment. In the upper fracture layer experiment, alow rate of resistance of abnormality was evident around the well head itself. We assumed that the injected water flowed toward the abnormal area. This is also supported by AE observation.

The results of the geochemical study indicate that the concentration of Cl , which is an especially dissoluble component was 4.2 ppm in the injected water. The corresponding figure for the returning water was 63.2 ppm after the first fracturing. This large increase could be attributed to possible inadvertent mixing with preexisting hot water in the natural joints. Samples of returned water taken following the upper fracturing contained only 8.8ppm of Cl , which would indicate only minor influence from preexisting hot water in the natural joints.

The volume of water flow and the hourly temperature change data show a recovering rate of as low as 6% in the lower fracture layer and as high as 25% in the upper layer. This could indicate that the lower layer of fractures progressed by connecting with natural joints. While in the upper fracture layer the permeability coefficient of the rock was lower. Pressure during fracturing was high. The fractures progressed toward the direction of maximum principal stress. Cl concentration in the returned water showed little change. The rate of recovering water was high. This could indicate that the upper layer of fractures progressed not only by joining with existing natural joints, but also by the creation of new fractures. It was concluded that the two layers of fractures were not connected and could therefore be made independently.

DRILLING THE PRODUCTION WELL

Drilling of the production well was carried out on the basis of the above mentioned results. A drilling route that would enable one well to penetrate the two fractures layers was selected. The well head was set at a point east-south-east of the experiment site in order to penetrate the upper fracture layer at its most shallow point. An inclination was made to the north and it was planned to penetrate the lower layer of fractures at that point. The drilling of the production well was conducted according to the plan shown in Figures 6.

There was no indication of water leakage during drilling operations, except for some leakage at the rate of 20 liter/min. which was found at the depth of 1,063 m. This is presumed to indicate that the lower layer of fractures was intersected at this point. Confirmation of the intersection through the two fracture layers by the fracturing and production well were completed in 1993.

EPILOGUE

Two artificial reservoirs were created at depths of 719m and 1,000m by inducing fracture layers with lengths of 800m and 1,000m by the multiple fracturing method at the Ogachi experiment site. According to the results of the fracture evaluation, these reservoirs might not have interconnected, but might have been created independently. In 1993, a second bore hole which was drilled for the production well, penetrates both fracture layers enabling the flow of water down the injection well, through the fractures and up the production well inthe form of steam.

In 1994, we conducted "well stimulation experiments" to inject high pressure water into the production well, in order to improve permeability around the production well. A 5-months flow test has been conducted since end of June for the purpose of investigating the rate of temperature decrease and chemical components that dissolve from rocks into hot water, thereby completing the first stage of study prior to commercialization of this power generation system. For 1995 and after, long-term (2 year and more) circulation experiments will be planed based on the discussion in the "HDR power generation technology study committee" sponsored by CRIEPI with participant from industry, government and academia.

We will also investigate the possibility of establishing a 100-kw class pilot plant in Ogachi test site by way of a joint venture with electric power company.

Table 1 Results of Evaluation

		lower Fracture	upper Fracture
Water injection depth		990~1,000m	711~719m
Rock temperature at the above depth		228℃	165℃
Permeability of rock in fracturing section	Before fracturing	$3\times10^{-15}m^2$	$1\times10^{-16}m^2$
	After fracturing	$1\times10^{-13}m^2$	$1\times10^{-14}m^2$
Total injected water volume		10,160m³	5,440m³
Average flow rate		650l/min	500l/min
Average well head pressure		19MPa	22MPa
Fracture dimension estimated by AE hypocenter distribution		1,000×500×200m	800×400×200m
Fracture progression direction		N20°E	N100°E
Water recovery		6%(640m³)	>25%(1,349m³)
Max.temp. of recovered water		64.4℃	64℃
Final Cl concentration of recoverd water		63.2ppm	8.8ppm