

A STUDY OF THE PRESSURE-FLOW RESPONSE OF THE SHALLOW RESERVOIR AT THE HIJIORI HDR TEST SITE

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ABSTRACT

In 1996, a one-month circulation test (flow enhancement test; Exp.9601) was carried out with HDR-1 as an injection well and HDR-3 as production well at the Hijiori HDR site in Yamagata prefecture, Japan. There are two reservoirs (a shallow reservoir and a deep reservoir) in high temperature granite at the site. The shallow reservoir was located at the depth of about 1800 m with an injection well SKG-2 and the deep reservoir at the depth of about 2200 m with an injection well HDR-1. Both reservoirs were connected with HDR-2a and HDR-3 as production wells.

In 1995, we observed that water injected into HDR-1 flowed into the shallow reservoir from the deep reservoir at the initial period of a preliminary circulation test (Exp.9501)(Tenma et al., 1995). To examine this characteristic of the multi-reservoir system, the pressure of the shallow reservoir was monitored using SKG-2 during Exp.9601. Also, PTS (Pressure - Temperature - Spinner) logging was periodically carried out in production well HDR-3. Thus, we got the pressure and flow rate between SKG-2 and HDR-3 of the shallow reservoir.

Prior pressure and flow rate of the shallow reservoir were acquired both from PTS logging in the 1991 90-day circulation test (Exp.9102) data and the 1994 injection test (Exp.9403) for wells HDR-2a, HDR-3 and SKG-2.

With the combined data from Exp.9102, Exp.9403 and Exp.9601, we attempted to study the pressure - flow response between SKG-2 and HDR-3 of the shallow reservoir.

INTRODUCTION

Since 1986, a R&D project of Hot Dry Rock geothermal energy has been carried out at Hijiori in Yamagata prefecture, Japan. Presently, the Hijiori HDR system has two reservoirs (a shallow reservoir and a deep reservoir) and four wells (SKG-2, HDR-1, HDR-2a* and HDR-3) as noted in Fig. 1. The characteristics of this system are one injection well in the artificial reservoir (SKG-2 in the shallow reservoir, HDR-1 in the deep reservoir) and two production wells, HDR-2a and HDR-3, which also intersect the shallow reservoir.

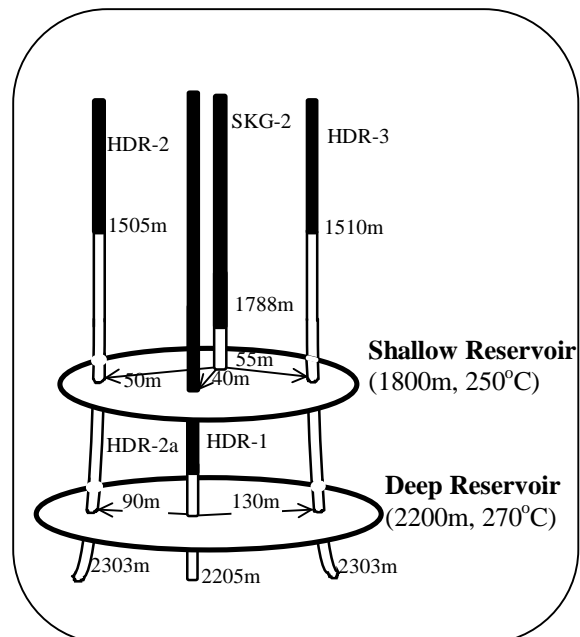


Fig. 1 Concept of the recently Hijiori HDR System
(Black zone shows casing)

(Note *) In 1994, HDR-2 was plugged back down to a depth of about 1600m and deepened to. To avoid confusion, the deepened HDR-2 is referred to as HDR-2a.

The Hijiori HDR test site is located on the southern edge of the 2km-diameter Hijiori caldera, which was formed about 10,000 years ago. Topographic effects extend underground, and the prevalence of fracture groups has a strike in the east-west direction and a dip to the northern side with high angle.

The history of the Hot Dry Rock geothermal energy R&D project is divided into two phases. The first phase was conducted from 1985 to 1991, when a shallow reservoir was created and various technological development works were carried out. In Exp.9102 in 1991, the recovery rate of hot water and steam was about 78 % and extracted heat energy was about 8.5 MW thermal (Yamaguchi et al., 1992, Kruger and Yamaguchi, 1993).

Based on results of the shallow reservoir, to create a larger volume, higher temperature reservoir. A deep reservoir at depth of about 2200m was formed by hydraulic fracturing in 1992. Two wells were deepened to a depth of about 2300 m to intersect the deep reservoir, a Hijiori HDR system was established in 1994. In 1995 and 1996, two short-term circulation tests (Exp.9501 and Exp.9601) were conducted to evaluate the deep reservoir characteristics for a long-term circulation test. Preparation for a long-term circulation test was started in 1997 (Nagai and Tenma, 1997).

PRESSURE - FLOW RESPONSE BETWEEN SKG-2 AND HDR-3 IN SHALLOW RESERVOIR

It is important for the long-term circulation test that the flow distribution in the multi-reservoir system is examined during the preparatory period. We observed the phenomenon that fluid within the shallow reservoir flows toward production wells by the pressure distribution. In this paper, we discuss the pressure-flow response between SKG-2 and HDR-3 of the shallow reservoir.

To examine the pressure - flow response, we arranged varied the pressure in the injection/production wells as noted in Fig. 2. We suggest that the differential pressure of the inlet/outlet point is the amount of $P_{injection}$ and $P_{production}$. And, the initial downhole pressure subtracted from the calculated pressure leaves $P_{injection}$, the calculated downhole pressure subtracted from the initial pressure leaves $P_{production}$. If we did not get the downhole pressure, we calculate the downhole pressure (Tenma et al., 1995) using by wellbore heat transfer (WBHT) code (Cremer et al., 1979). Also, as the Hijiori HDR system has two

reservoirs, PTS logging was carried out to evaluate the characteristic of the multi-reservoir system (NEDO, 1991, 1994 and 1996). Thus, as the pressure, temperature and flow rate were measured along the production well, we applied the PTS pressure instead of the calculated data.

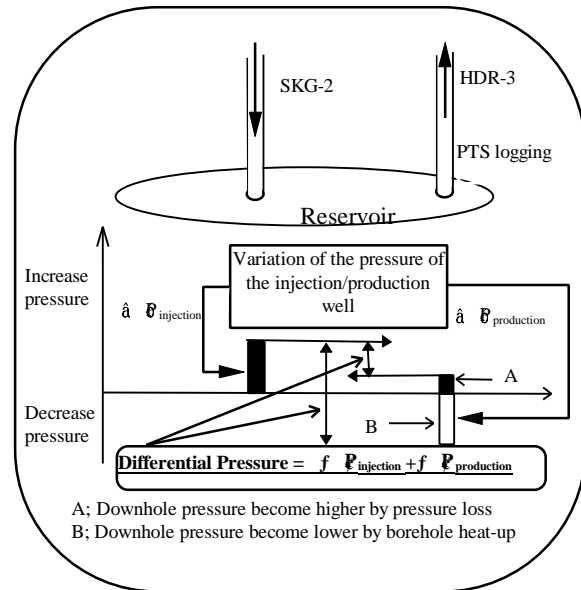


Fig. 2 Idea of the Differential pressure

The data related to the shallow reservoir were PTS logging of Exp.9102, data of Exp.9403 and measured pressure of the shallow reservoir during Exp.9601. A summary of these tests and the data of the shallow reservoir are described in the paper.

90-DAY CIRCULATION TEST IN 1991(Exp.9102)

Exp.9102 was a three-month circulation test with injection well SKG-2, and three production wells HDR-1, HDR-2 and HDR-3 as shown in Fig. 3. The purpose of Exp.9102 was to estimate the flow distribution of the shallow reservoir at 1800 m depth.

At the beginning of the test, water was injected at the maximum flow rate of about 50 kg/s to improve the connectivity as shown in Fig. 4(a). After injection at this large flow rate, single production tests were conducted to evaluate the productivity of each well. In this test, one production wellhead valve was kept open, while the other two were closed. Therefore, the flow rate of each production well was decreased to zero as shown in Fig. 4(b). After single production tests, production was continued from the three wells until the end of the test.

PTS logging was carried out in the three production wells once a week during Exp.9102. Therefore, PTS

data are used the pressure and flow rate of HDR-3. The solid lines of the arrow show the date of PTS logging. Also, we calculate the downhole pressure of SKG-2

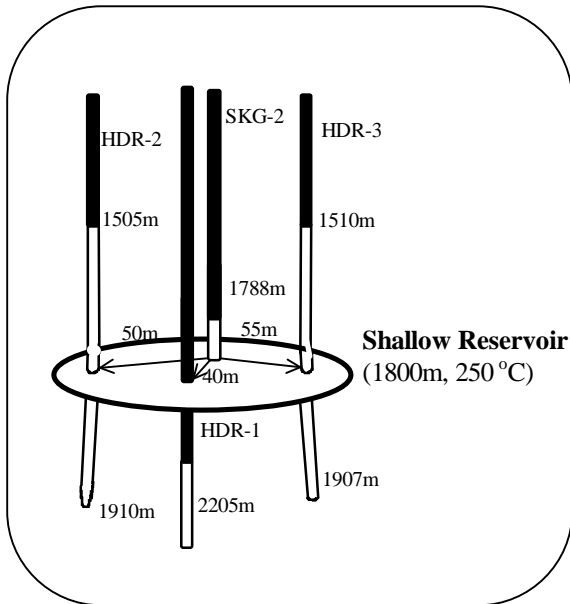


Fig. 3 Concept of the Hijiori HDR System in 1991 (black zone shows casing)

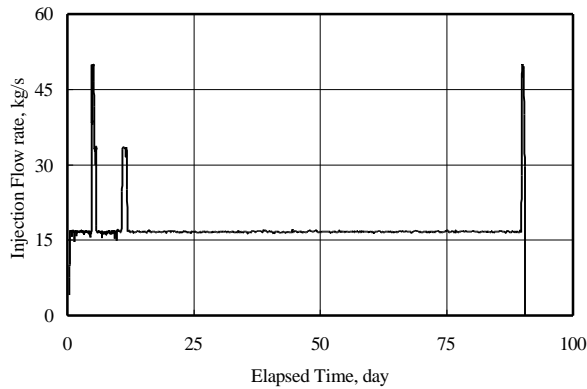


Fig. 4(a) History of Injection flow rate(SKG-2)

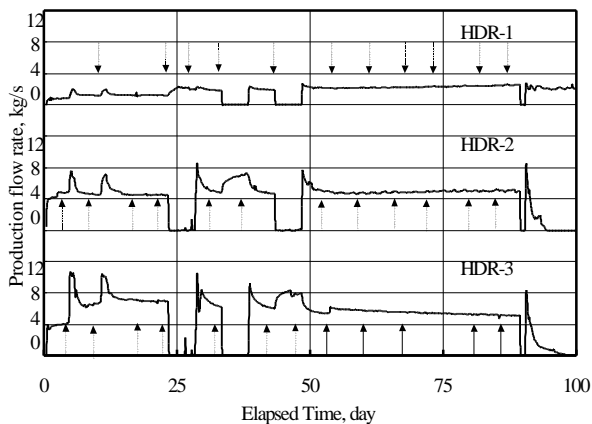


Fig. 4(b) History of production flow rate (HDR-1, HDR-2 and HDR-3) (Lines of allow show the date of PTS logging)

using by WBHT code. The dotted lines show the date of PTS logging, too. As the injection/production system was changing (Tenma et al., 1994), we do not apply the data in this term.

INJECTION TEST FROM HDR-2a IN 1994 (Exp.9403)

In 1994, HDR-2 was deepened to intersect the deep reservoir, and establish the current HDR system. After boring of HDR-2a, two injection tests from HDR-1 (Exp.9401-02) and one injection test from HDR-2a (Exp.9403) were conducted to estimate the connectivity of reservoir between HDR-1 and HDR-2a. During these tests, the pressure, flow rate and water level were measured on the surface. As shown in Fig. 5, water level of SKG-2 and HDR-3, injection flow rate and pressure of HDR-2a were measured in the Exp.9403. PTS logging was also, conducted in Exp.9403. As the results of PTS logging, it found that 90 % of the injected water was flowed into the shallow reservoir. Therefore, we assume that the change of water level is a response of the shallow reservoir. And, we converted a rise of water level to the flow rate, and calculated the downhole pressure of SKG-2 and HDR-3.

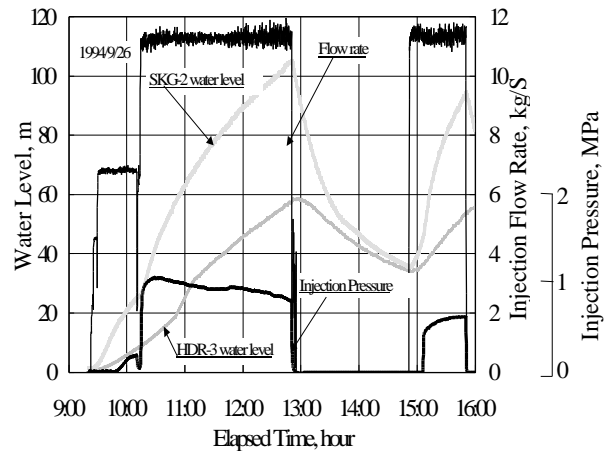


Fig. 5 History of Water level, Injection flow rate and Pressure (SKG-2, HDR-2a and HDR-3)

FLOW ENHANCEMENT TEST IN 1996 (Exp.9601)

In 1996, Exp.9601 was carried out with HDR-1 as an injection well and HDR-3 as production well. The purpose of the Exp.9601 was to improve connectivity of fractures between HDR-1 as the injection well and HDR-3 as the production well, because performance of both HDR-2a and HDR-3 were different (Tenma et al., 1997). The injection flow rate was constantly 16.7 kg/s during Exp.9601. As noted in Fig. 6, the pressure of the shallow reservoir was monitored using SKG-2 during Exp.9601. We measured the variation of pressure in the shallow reservoir during the test.

PTS logging was also carried out in HDR-3 during Exp.9601. Therefore, PTS data are used for pressure and flow rate of HDR-3. The solid line of the arrow shows the data of PTS logging. We used also the downhole pressure that was monitored in well SKG-2.

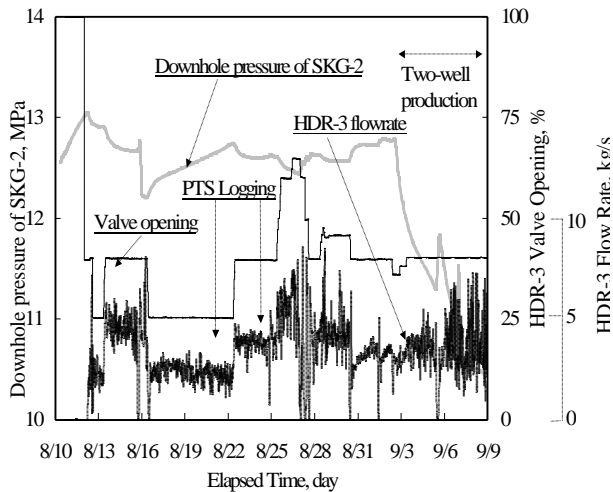


Fig. 6 History of downhole pressure, Valve opening and flow rate

CONCLUSION

Using the result of the Exp.9102, the Exp.9403 and the Exp.9601, we assumed the pressure - flow response between SKG-2 and HDR-3 of the shallow reservoir as shown in Fig. 7. The approximate curve is indicated the solid line. I think this curve will converge the optional differential pressure. Thus, I think that the pressure-flow response of the shallow reservoir will be measured, when the reservoir will not extend. In the future, we plan to examine the pressure - flow response between SKG-2 and HDR-2 of the shallow reservoir and the pressure - flow response of the deep reservoir. We will make a model of the multi-reservoir using by these results. And we will attempt to simulate the long-term circulation test.

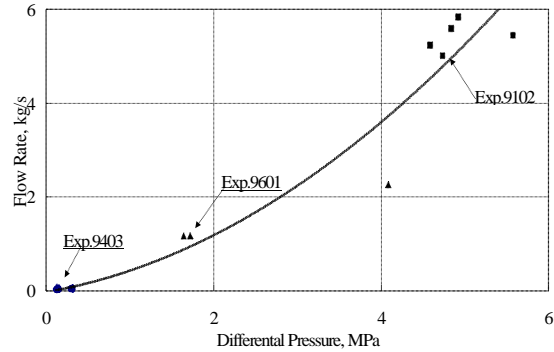


Fig. 7 Response of the shallow reservoir

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