PROCEEDINGS, Twenty-Second Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, January 27-29, 1997
SGP-TR-155

Productivity of a Recent Three-well System at Hijiori HDR Test Site

Norio TENMA, Terumichi IKAWA and Masahiro NAGAI

New Energy and Industrial Technology Development Organization
(3-1-1 Higashi Ikebukuro Toshima, Tokyo 170)

ABSTRACT

Since 1985, the New Energy and Industrial Technology Development Organization (NEDO) has continued the development of Hot Dry Rock power generation in Hijiori Hot Dry Rock test site, Yamagata prefecture, Japan, as part of the Sunshine Project and succeeding New Sunshine Project sponsored by Agency of Industrial Science and Technology (AIST), a branch of the Ministry of International Trade and Industry(MITI). The objective of this project is to identify the feasibility of a Hot Dry Rock power generation system in Japan.

In 1992, hydraulic stimulation was conducted at a depth between 2150 and 2205 m to create a deeper reservoir. Two wells were deepened to a depth of about 2300 m to intersect the deeper reservoir, and a three-well HDR system was established in 1994. Two circulation test were conducted in 1995 and 1996 to estimate the deeper reservoir characteristics for a future long term circulation test. In this paper, we report productivity of the three-well system during the circulation test in 1995. We compare the connectivity of both the shallow and deeper reservoirs. We find that the connectivity of the deeper reservoir is smaller than that of the shallow reservoir.

INTRODUCTION

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

The Hijiori HDR system has two reservoirs (a shallow reservoir and a deeper reservoirs) and four wells(SKG-2, HDR-1, HDR-2 and HDR-3) as shown in Fig.1. As noted in Fig. 1, the characteristics of this system are one injection well in the artificial reservoir and two

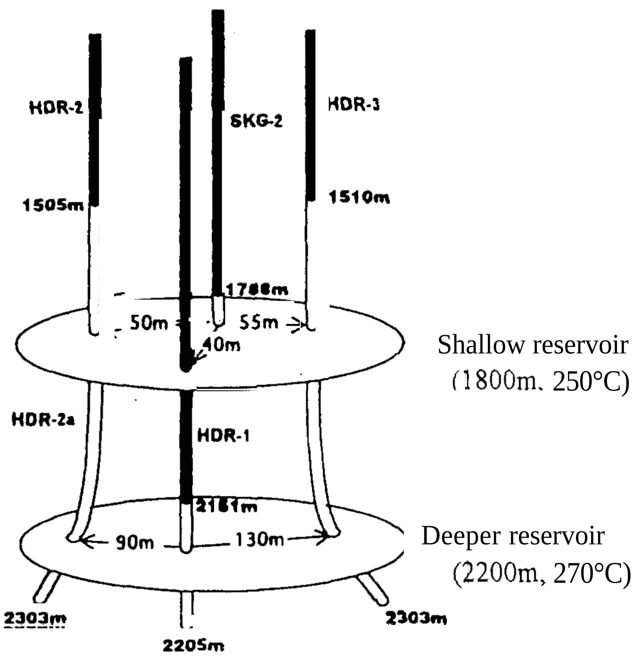

Fig. 1 Concept of Hijiori HDR system
(Black zone shows casing)

production wells, HDR-2 and HDR-3, whch also intersects the shallow reservoir.

The history of technical development carried out at Hijiori HDR test site, as noted in Fig. 2, is divided into two phases. The first phase was conducted from 1985 to 1991, when the shallow reservoir was created at a depth of about 1800 m and three circulation tests were carried out(Yamaguchi et al, 1995). In a 90-day circulation test 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).

In the second phase, aiming at the creation of a larger scale and hgher temperature reservoir, a deeper reservoir was formed by hydraulic fracturing at depth of about 2200 m in 1992. And a larger-scale circulation system was created until 1994.

	FY86	FY87	FY88	FY89	FY90	FY91	FY92	FW3	FY94	FY95	FY96
1,800-m-deep reservoir depth ; ± 1,800 m temperature ± 250℃	Hydraulic fracturing created a man-made reservoir	Drilled HDR - 1 to 1,805 m communica-ted to the SKG - 2	Circulation test for 2 weeks Deepen HDR - 1 to 2,205 m Set PBR	Drilled HDR - 2 to 1,910 m Circulation test for 29 days 40 % 4.5 MW thermal	Drilled HDR - 3 to 1,907 m communica-ted to the SKG - 2	Circulation test for 90 days 78 % 8.5 MW thermal					
2,200-m-deep reservoir depth ; ± 2,200 m temperature ± · 270℃							Hydraulic fracturing created a man-made reservoir	Deepen HDR - 3 to 2,303 m communica-ted to the HDR - 1	Sidetracked & Deepen HDR - 2 communica-ted to the HDR - 1	Preliminaly circulation test for 25 days 40% 8~9 MW thermal	Circulation for reduce the flow impedance

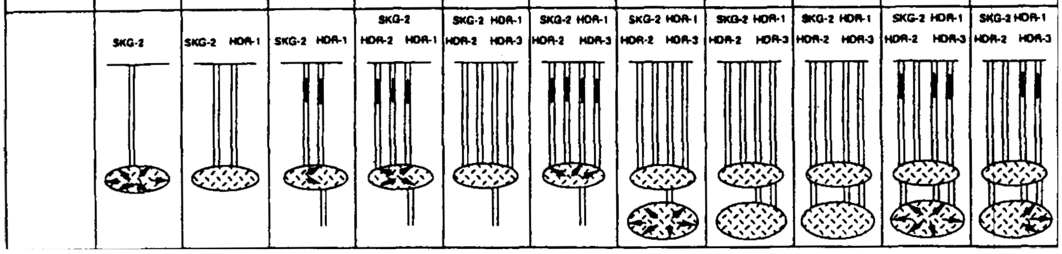

Fig.2 History of the Hijiori HDR test site

PRELIMINARY CIRCULATION TEST IN 1995

In 1995, a short-term circulation test was conducted with an injection well HDR-1, and two production wells HDR-2 and HDR-3(Sato et al., 1995). The purpose of the test was to evaluate the deeper reservoir characteristics for a long term circulation test and to improve the connectivity of the deeper reservoir between the injection well and production wells. The period of the test was from August 6 to 30. The injection and production flow rate is shown in Fig. 3(a)-(b). At the beginning of the test, water was injected under high pressure to improve the connectivity at a maximum flow rate of about 60 kg/s as shown in Fig. 3(a).

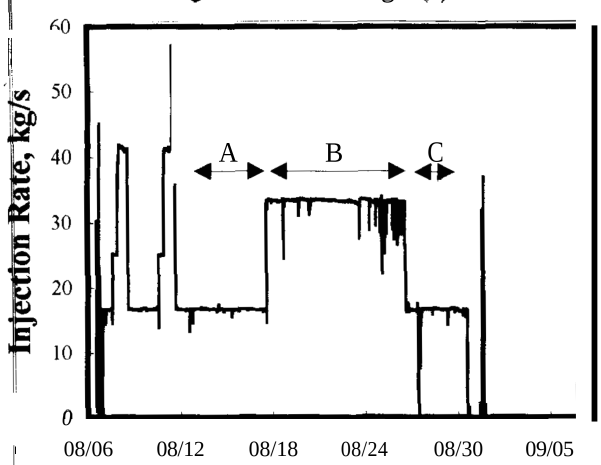

Fig. 3(a) Records of injection rate obtained during a preliminary circulation test in 1995

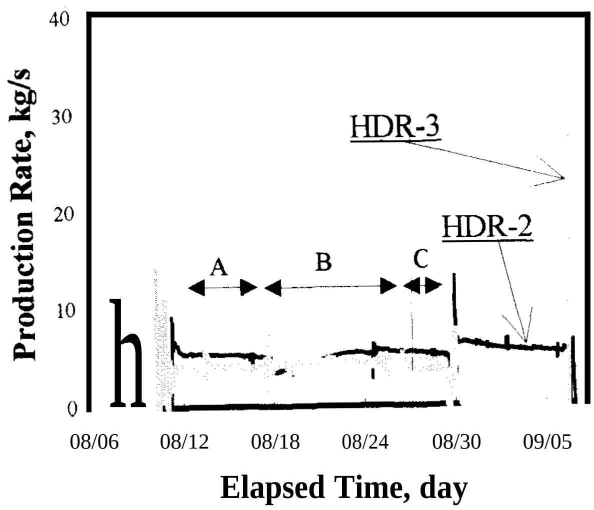

Fig. 3(b) Records of production rate obtained during a short-term circulation test in 1995

After initial high flow rate injection, the pumping was done at rate of 16.7kg/s(segment A and C) or 33.4 kg/s (segment B) during the test. As noted in Fig. 3(b), the mark of A, B and C indicate the period, when steam and hot water was produced from the two production wells. The result of these segments is shown in Table 1.

Productivity of two wells in segment A and segment C were almost equal. Production from HDR-2 was higher than that of HDR-3. The ***summary*** of the test is shown in Table 2. The total recovery rate of the test was about 40 %, and the amount of hot water and steam from HDR-2 was larger than that from HDR-3. Thus, we think that the productivity of HDR-2 was higher than that of HDR-3. But, the total production measured in wellhead included the water loss from the shallow reservoir(Tenma et al, 1995). Therefore, we compare with the shallow reservoir and the deeper reservoir using data from several PTS(Pressure - Temperature - Spinner) logs.

Table 1. Production of HDR-2 and HDR-3 during a contact flow test of the preliminary circulation test in 1995

	Segment	A	B	
Injection (HDR-1)	Flow Rate(kg/s)	16.7	33.4	
	Total Flow(ton)	8565	25838	
Production (HDR-2)	Steam (ton)	625	844	
	Hot Water (ton)	2066	2939	
	Recovery (%)	31.4	14.6	
Production (HDR-3)	Steam (ton)	564	939	
	Hot Water (ton)	1442	2368	
	Recovery (%)	23.4	12.8	23.6

Table 2 Summary of short-term circulation test

Period	Aug. 6-30, 1995	25 day
Injection(HDR-1)	Total Flow (ton)	51500
Production	Total production (ton)	13200
(HDR-2)	Recovery (%)	25.6
Production	Total production (ton)	6900
(HDR-3)	Recovery (%)	13.4

COMPARSION BETWEEN THE SHALLOW RESERVOIR AND DEEPER RESERVOIR

As the Hijiori HDR system has two reservoirs, PTS logging was carried out to evaluate the characteristic of the deeper reservoir(Miyairi et al., 1996). Also, PTS logging was periodically conducted in 90-day circulation test, 1991. The pressure, temperature and flow rate were measured along the production well. Thus, we obtained pressure and flow rate from both the shallow and the deeper reservoirs.

Also, we calculated bottom-hole pressure of the injection well using the WBHT code(Cremer et al., 1979). In 90-day circulation test, bottom pressure calculated by WBHT and wellhead pressure are shown in Fig. 4. As shown in Fig. 4, bottom pressure is almost about 21 MPa. And we calculated bottom pressure of injection well in preliminary circulation test, too. Thus, the relationship of differential pressure and flow rate measured using by PTS logging on both the shallow and the deeper reservoirs are shown in Fig. 5. Here we have differential pressure, we subtract measured pressure from calculated bottom pressure. In case of the shallow reservoir, we used data of the main fracture(Tenma et al., 1994). And, we used measured pressure at 1900 m depth in the deeper reservoir. The result are as follows.

1) The connectivity of main fracture of HDR-2 is almost equal to that of HDR-3 in the shallower reservoir.
2) In the case of the deeper reservoir, the connectivity of HDR-2 is higher than that of HDR-3.
3) the connectivity of the shallower reservoir is hgher than that of the deeper reservoir.

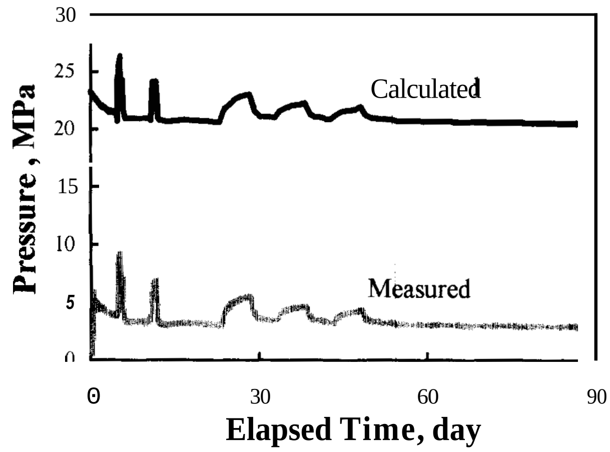

Fig. 4 History of calculated bottom pressure of Injectipn well(SKG-2) and measured pressure in 90-day circulation test , 1991

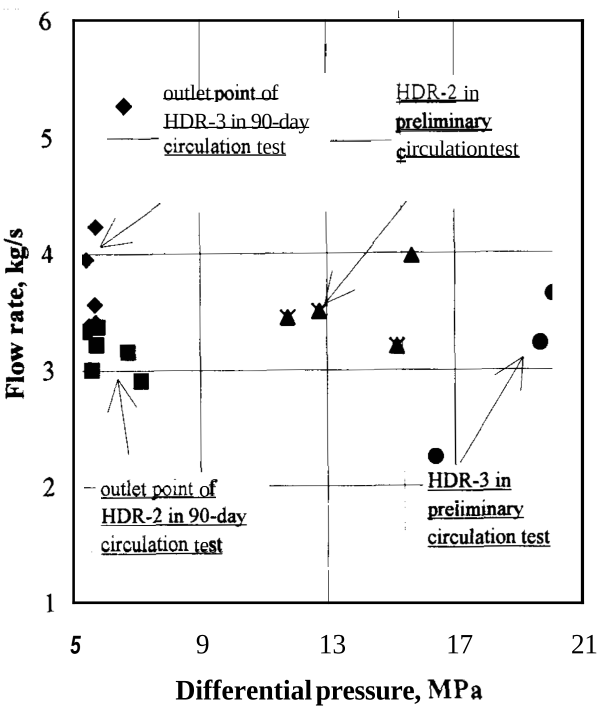

Fig. 5 Comparison with shallow reservoir and deeper reservoir

FUTURE TASK

In 1996, a one-month circulation test was carried out with HDR-1 as an injection well and HDR-3 as production well. The purpose of this test was to improve the connectivity of fractures between HDR-1 as the injection well and HDR-3 as the production well, because performance of both HDR-2 and HDR-3 were different. Data were obtained to evaluate the behavior of the deeper reservoir from these tests. Thus, we are planning a long-term circulation test of the Hijiori HDR system to confirm the feasibility of Hot Dry Rock power generation from the autumn of 2000 until the autumn of 2002.

REFERENCES

Cremer, G. et al. (1979) Hot Dry Rock Geothermal Energy Development Program, Annual Report FY 1979 (LA-8280-HDR), 136-137, Los Alamos National Laboratory

Mirairi M. et al.(1996) "Characterization of Effective Fractures by Downhole Measurements at Hijiori HDR Test Site", Proceedings of 3rd International HDR Forum

Sato, Y. et al.(1995) "Stimulation of the 2200-m-deep Reservoir at Hijiori HDR Test Site", Geothermal Resources Council TRANSACTIONS, Vol.19, 275-278

Tenma, N. et al.(1995) "Model study of the reservoir character at Hijiori HDR test site", Geothermal Resources Council Trans., 18, 475-478

Tenma, N. et al.(1995) "Interference of production between two wells during a one month circulation test at the Hijiori Hot Dry Rock test site", Proceedings of 21st Stanford Workshop on Geoth. Res. Eng.,295-298

Yamaguchi, T. et al.(1992) "90-day Circulation Test at Hijiori HDR Test Site", Geothermal Resources Council TRANSACTIONS, Vol.16, 417-422

Yamaguchi, T. et al.(1995) "Hydraulic Thermal Behavior of the Hijiori HDR Upper Reservoir", Geothermal Resources Council TRANSACTIONS, Vol.19, 279-285