THE RESULTS OF NEDO'S DEVELOPMENT OF GEOTHERMAL RESERVOIR EVALUATION TECHNOLGY " PROGRAM.

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1.INTRODUCTION

In order to promote the development of geothermal energy resources, it is important to understand how to estimate reservoir capacity and to alleviate the risks associated with each proposed development project. It is furthermore essential to estimate the generation capacity of the reservoir prior to full scale committment so that the power plant design may be formurated. Since FY 1984, the New Energy Development Organization (NEDO) has been developing the technolgy for geothermal reservoir evaluation. NEDO completed Phase I of this program in FY 1987, and undertook Phase II beggining in FY 1988; the purpose of the new effort is to devise techniques to deal with more complex reservoirs. The results of the Phase I studies will be published during FY 1988.

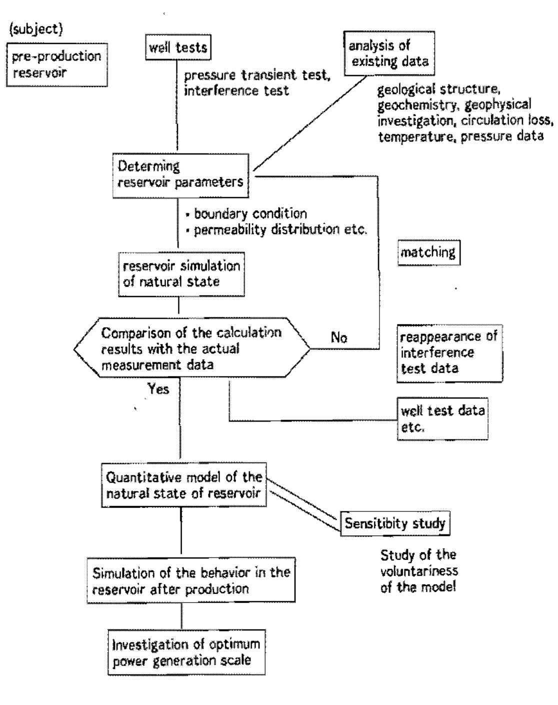
2.EVALUATION OF GEOTHERMAL RESERVOIRS

Figure 1 outlines NEDO's general approach to reservoir evaluation. For fields in which long-term fluid discharge tests have taken place and in which several survey wells have been drilled, NEDO is carrying out studies of the following types:

(1) Well Tests: In each field, single-well pressure transient tests (as well as several interference tests) are performed to obtain information concerning the reservoir permeabilty distribution and locations and types of reservoir boundaries.

Table 1. Phase I project schedule

	1984	1985	1986	1987	coment
1. Development of reservoir simulators					· I-phase, II-phase reservoir simulator (SING-I, SING-II) and wellbore simulator(WENG).
2. Drilling of observation wells	(Kirishima - field) 1500m×1	1500m×1; (Sumikawa - field) 1600m × 1	1700m × 1		
3. Well tests		(Kirishima - field); (Sumikawa - field)			· Injection test · Interference test
4. Reservoir simulation					· Reservoir simulation of Kirishima and Sumikawa field



Flow of evaluation of geothermal reservoir

Figure 1.Pre-exploitation procedure for geothermal reservoirs.

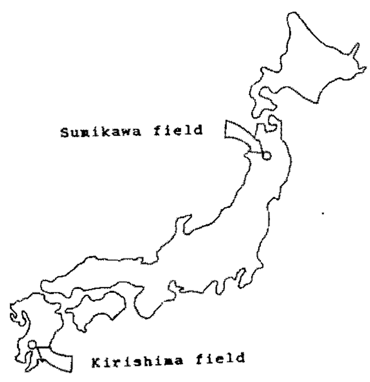


Figure 2. Location of two model field.

(2) Natural State Reservoir Simulation:Numerical reservoir simulations are carried out, based on available analyses of well-test measurments, geophysical survey results, geophysical data, and other relevant infomation. These simulations are performed repeatedly in an iterative manner, varying the various unknown parameters in the mathematical model to maximize agreement between measurements (such as pressure, temperature distributions) and computed results. These calculations are time-dependent in character, but are carried forward for long periods of time so that a nearly steady natural-state representaion is obtained. The unknown parameters are adjusted until a consistent model of the reservoir's natural condition results which is in adequate agreement with the available field measurements.

(3) Simulation of Reservoir Response to Production: Once an internally consistent natural-state model is obtained which is in resonable agreement with measurements, changes in reservoir conditions(pressure, temperature, steam saturation, etc.) with time are computed based on a variety of scenarios concerning various reservoir development strategies (principally locations and flow rates of production and reinjection wells). Sensitivity studies are carried out to estimate the reliability of the resulting predictions, and an optimum reservoir development plan is devised.

3.NEDO'S PROGRAM FOR EVALUATION TECHNOLOGY DEVELOPMENT

The schedule of NEDO's four-year project is indicated in Table 1. This prject has four main goals:the development of numerical reservoir simulators. the drilling of observation wells, the performance of pressure-transient and flow tests on wells, and reservoir simulation studies. Progress to date along these lines is as follows.

(1) Development of Reservoir Simulators: NEDO is developing two general-purpose three-dimensional unsteady geothermal reservoir simulators. SING I is restricted to single phase flow, while SING II is also capable of treating two phase water/steam systems.In addition, NEDO has developed the WENG code, which treats the steady flow of single phase and two phase (water/steam) mixtures up a borehole, including such effects as heat transfer through the casing, frictional effects,and slip between liquid and gaseous phases. This code permits the prediction of wellhead conditions based on downhole conditions.

(2) Drilling of observation wells: Two fields (Kirishima and Sumikawa geothermal fields) have been selected for study(see Figure 2). The Kirishima field is situated in southeastern Japan,in the southern part of Kyushu island. Since 1972, Nippon Steel Corporation and Nittetsu Mining Company have been jointly engaged in survey work in the area with the ultimate objective of constructing a geothermal power plant. These companies have carried out a variety geological and geophysical surveys in the Kirishima area, and have drilled a number of fairly deep wells in the field. The Sumikawa field, on the other hand, is located in the northeastern Japan, in northern Honshu. Mitsubshi Metal Corporation has been exploring this area since 1965, and has drilled several deep wells. Substantial regions characterized by extensive underground two-phase (water/steam) flow have been identified at Sumikawa.

NEDO has drilled two deep observatoion wells in each field to measure the reservoir pressure, and other pertinent reservoir properties. At Kirishima, wells KZ-1 and KZ-2 each reach 1500m depth; the wells at Sumikawa are KY-1 (1600m) and KY-2 (1700m); (see Figure 3 and 4). Repeated downhole pressure and temperature surveys during subsequent heat-up have been carried out in these wells. The wells have also used as observation wells for pressure interference experiments.

(3) Well Tests: Pressure transient tests, including both single-well tests and pressure interference tests, were carried out in each model field using both existing wells and the new NEDO wells. For these tests, down-hole pressure were measured using gauges of the capillary tube type.

The Kirishima field study started in 1984. Table 2 outlines the two-year test program which began in April 1985 at Kirishima. A total of five production wells were involved at one time or another during the test period. Figure 5 shows the total discharge rate from the flowing wells (KE1-7,17,19S and 22) as a function of time during the test period. Also shown is the recorded down-hole pressure history in observation well KE1-13. The average total discharge rate was about 170 tons per hour for the first eighteen months of the test; thereafter, however, the discharge increased gradually, reaching 670 tons

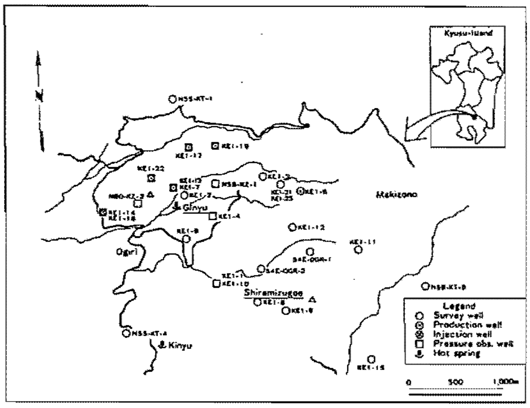


Figure 3. Location of wells in Kirshima field.

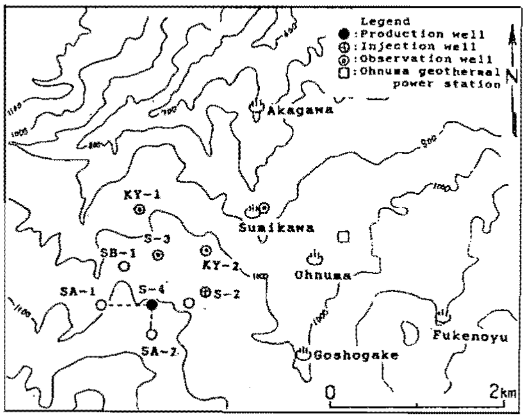
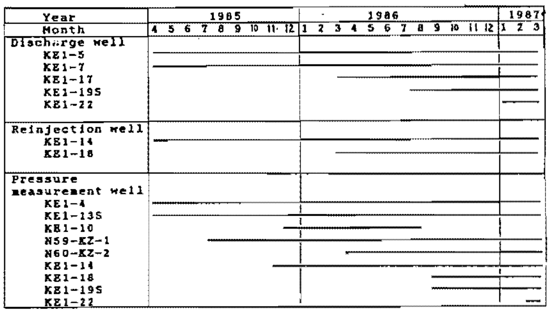


Figure 4. Location of wells in Sumikawa field.

Table 2. Interference test schedule in Kirishima field.



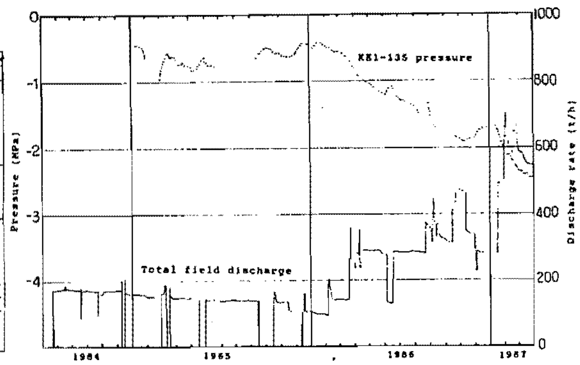


Figure 5. Total field discharge rate,and pressure history in well KE1-13S.

per hour in March,1987. As Figure 5 clearly shows, this increase in discharge rate resulted in a significant pressure decrease in observation well KE1-13, amounting to about 0.2MPa. The correlation between discharge rate changes and down-hole pressure changes is seen to be very good, both on the overall time-scale and shorter time-scales(one to two months ;associated with short-term fluctuations in discharge rate). Similarly, Figure 6 shows the pressure histories recorded in other observation wells (KE1-13S, 19S and 22) from April, 1986 to March,1987. The signal recorded in well KE1-13S shows a very clear response to the changes in discharge from the various flowing wells. These pressure signals were analyzed to try to establish the permeability distribution and other relevant properties of the reservoir.

NEDO's study of the Sumikawa field was initiated in 1985.In 1986, a two-month discharge of well S-4 was carried out; well S-2 was used to dispose of the discharged fluid. During this test, NEDO monitored changes in down-hole shut-in pressures in the new observation wells (KY-1 and KY-2) and also in two other wells (O-5T and S-3) previously drilled by the field developer. These four observation wells are situated to the north and northeast of the discharge well (S-4), as shown in Figure 7. Briefly, the results were that no signals attributable to the S-4 discharge were observed in wells O-5T, S-3 or KY-2, but a substantial interference signal (exceeding three bars in ampletude) was detected in well KY-1. Interpretation of these results suggests the pressure of a deep high-permeablity zone at Sumikawa confined by flow barriers with a north-south orientation. (See also, Maki et al., INTERPRETATION OF A PRESSURE INTERFERENCE TEST OF THE SUMIKAWA GEOTHERMAL FIELD, in this abstract volume)

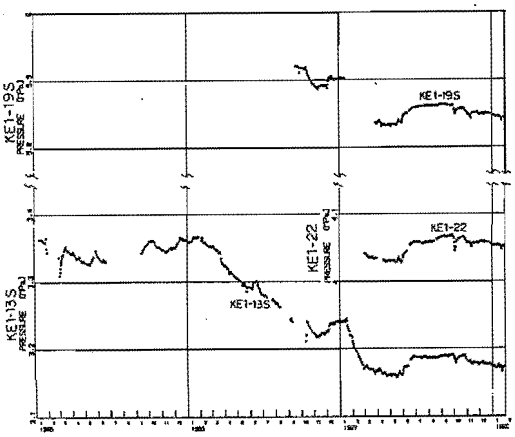


Figure 6. Pressure histories in wells KE-13S,19S and 22 from April 1986 to March 1987.

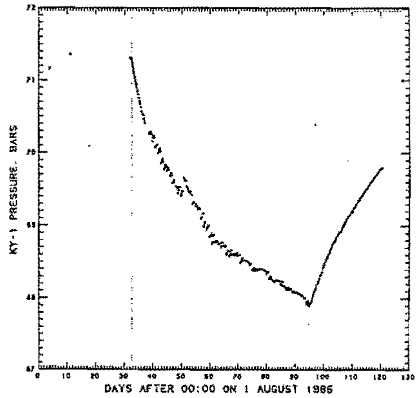


Figure 7. Measured interference signal in well KY-1.

(4) Reservoir Simulation: Reservoir simulation studies of the type outlined above, involving both natural-state and production calculations, were carried out for each field,using the SING I and SING II numerical reservoir simulation programs developed by NEDO.

The results of these simulation studies are discussed at greater length in two papers by Maki et al.(A STUDY OF NATURAL STATE MODELING OF THE KIRISHIMA FIELD and A STUDY OF NATURAL STATE MODELING OF THE SUMIKAWA FIELD)in this abstract volume.

4. ACKNOWLEDGEMENTS

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