Evaluation of the Pumping-Injection Tests Conducted at the Raft River Geothermal Plant in 1980

1. INTRODUCTION

Several pump-injection tests were conducted during 1980. The main objective for these tests was to test a down hole pump, geothermal water supply for 5MW plant and injection system. The data obtained during these pumping-injection tests may be used for the reservoir parameters evaluation; however, none of these tests was specifically designed for the reservoir testing. The data from two long-term pumping-injection tests conducted in May-June and August-September are used for the reservoir parameters evaluation. The results of these two tests are summarized in this report.

2. PREVIOUS REPORTS SUMMARY

During 1979 several pumping-injection tests were conducted at the Raft River site. The results of these tests are described in the following EG&G internal technical reports:

"Results at RRGI-6 During January, 1979, Injection from RRGE-2",
"Pump/Injection Test - Well RRGE-2 to Well RRGI-7, August, 1979",
and "Results of RRGE-2 to RRGI-6 Pump/Injection Test, March, 1979".

The results obtained from the tests in term of Q/S_{10} are listed in Table 1. The ratio of a pumping rate to the slope of semi-log plot represents a hydraulic properties of the aquifer (higher the number, more favorable aquifer properties).

3. PUMPING-INJECTION ACTIVITY AT THE RAFT RIVER IN 1980

On March 27 through 30 pumping from the RRGP-5 was conducted at the rate of 40.95 lps. The geothermal water was pumped into the lined pond for 61 hours, 19 minutes. Primary purpose of this pumping was to remove sand from the RRGP-5 wellbore after the November 1979 fracture simulation. The data collected during this pumping is not sufficient for the aquifer parameters evaluation.

Several short-term pumpings for pumps checkout were performed during April and May prior to the planned integrated flow test. The integrated flow test FET-1-80 was originally planned to include pumping geothermal water from RRGE-1, RRGE-2 and RRGE-3 wells and injecting water into RRGI-6 and RRGI-7 wells. Because of the pump failer in the RRGE-1 and RRGE-2 wells, test was limited to pumping water from RRGE-3 well and injecting into RRGI-6. At the test ending injection was switched into the RRGI-7 well. The May-June test is described and analyzed in the separate section of this report.

Several short-term cold water injection tests were conducted during June and July, 1980. The cold water injection into RRGI-7 was performed between June 26 and July 2. On July first cold water was injected for seven hours at an average rate of 26.65 lps. On July second cold water was injected for 11 hours, 26 minutes at an average rate of 26.08 lps. The maximum well head pressure was about 924 kPa. The water temperature was about 25^{o}C. Calculated specific injectivity is 0.028 lps/kPa. Injection tests from the pond number 4 into RRGI-6 were conducted between July 16 and August 6. Injection rate was about 30.97 lps and 23.34 lps respectively. The well head pressure reached 827 kPa for 30.97 lps injection rate and 689 kPa for 23.34 lps injection. Calculated specific injectivity is 0.037 lps/kPa for 30.97 lps injection and 0.034 lps/kPa for 23.34 lps injection. The data obtained from these cold water injection tests may not be further evaluated because of the changing pumping rates, interruptions and incompleteness of data.

Long-term pumping injection test was conducted in August-September, 1980. The pumping well was RRGE-1 and injection was switched between RRGI-7 and RRGI-6. The results of August-September test are discussed in a section of this report.

Short pumping from the RRGE-1 and injecting into RRGI-7 was performed on September 14. Purpose of this pumping was to flush 5MW plant geothermal water supply system. No sufficient data was recorded to evaluate aquifer hydraulic properties.

The integrated pumping test started on October 10, 1980. Three pumping wells, RRGE-1, RRGE-3 and RRGP-5 were in operation for approximately 18-20 hours, with a total pumping rate of 126.31 lps. All of the 126.31 lps flow was going through the 5MW(e) plant for a part of the pumping time. Technical difficulties and personnel injury prevented collection of data necessary for reservoir evaluation. The pumping activity at the Raft River site during 1980 was designed to check pumps and piping system. However, some data obtained during these tests may be used for reservoir evaluation purposes. Two pumping-injection tests conducted in May-June and August-September will be discussed in this report in more detail.

4. DATA LIMITATION AND METHODS OF DATA EVALUATION

There are several factors limiting use of the data obtained during the pumping-injection tests. The factors limiting use and accuracy of the data are as follows:

a. The test procedures and pump shutdowns
b. Instrumentation and lack of measurements
c. Thermal effects

a. The test procedure required to preheat the pumping injection system. The beginning of the pumping-injection tests had a lot of interruptions due to pipe plugging, pressure buildups and pump failures. The pumping rate was difficult to stabilize at the constant rate during the first minutes of the test. Frequently the pumping rate used at the beginning had to be reduced to meet a capacity of the pumping-injection system. Because of these, the early time data are not accurate and almost impossible to analyze.

b. The measurements taken during the 1980 tests are the well head pressure temperature measurements and the bubbler readings for the pumping wells. All well head pressure measurements were done using digiquartz pressure transducers. This record is relatively accurate, but an exact time of the pump shutdown or startup was missing on several occasions. There are several cases that after the power fails pressure transducers were not programmed and

were not recording time or pressure. The bubbler measurements, especially during the early recovery, are not accurate due to the perging problems. Switching the injection from one well to another may have an influence on the injection data. These interference effects are not possible to evaluate within the data from the conducted test.

c. The thermal effects may be divided into two categories: (1) effect on a measurements taken, (2) effect on the well and aquifer performance.

Because of the complexity of a problem and lack of data, no attempt was made to evaluate the thermal effects.

The analysis of a data will be limited to the evaluation of semilog plots of the residual pressure versus time ratio for recovery and some time pressure buildup and time draw-down plots for the pumping-injection part. These methods are described in references 1, 2, and 3.

5. RESULTS OF RRGE-3 TO RRGI-6 PUMP-INJECTION TEST, MAY JUNE, 1980

The May-June pumping-injection test was designed as the integrated test including pumping from the RRGE-1, RRGE-2 and RRGE-3 wells and injecting into RRGI-6 and RRGI-7 wells. The pumps at RRGE-1 and RRGE-2 failed during the checkout pumping. The test had to be modified to the single pumping-injection. The pumping started on May 14 and was continued until June 17, 1980. During the pumping, pumps went off seventeen times for a total of over 700 minutes. On June 12 injection was switched from the RRGI-6 to RRGI-7 well.

5.1 Pumping Well RRGE-3 Evaluation

The recovery data was used to evaluate reservoir properties for the pumping well RRGE-3. The semilog plot (Figure 1) of the residual draw-down versus t/t' ratio indicates kH value of about 1050 md-m and Q/S_{10} value of about 0.03 lps/kPa/log cycle. This value was obtained from the

late time recovery, early time recovery data is assumed to be not valid because of the inaccurate bubbler readings. The late recovery plot forms regular straight line, and results obtained from these data may be assumed as a representative for the RRGE-3 well.

No sufficient data for the pumping part of the test is available.

5.2 Injection Well RRGI-6 Evaluation

The data from the injection part of the test is not adequate for reservoir evaluation. The pressure falloff (recovery) data was plotted on the semilog plot (Figure 2). The straight line formed by the plot has distinctive change in the slope between early and late recovery data. The early recovery part of the plot indicates Q/S_{10} value of 0.29 lps/kPa/log cycle and kH value of about 10,700 md-m. The late recovery part of the plot indicates Q/S_{10} value of 0.17 lps/kPa/log cycle and kH value of about 6,300 md-m. The break in the slope of the straight line plot occurred about 200 minutes after injection stopped. The nature of the change is not fully understood, it appears to be a boundary type change. In previous reports (References 2 and 3) changes in the slope were described as a result of the temperature changes within wellbore. Correlation between the temperature changes and pressure falloff may not be made since temperature data from the borehole or wellhead were not recorded during recovery part of the test.

6. RESULTS OF RRGE-1 TO RRGI-6, AND RRGI-7 PUMP-INJECTION TEST AUGUST-SEPTEMBER, 1980

The long-term pumping injection test was conducted in August-September 1980. The pumping from RRGE-1 well and injecting into RRGI-7 started on August 19. On August 20 injection was switched into RRGI-6 well, because of trouble with a pump at RRGI-7. The injection into RRGI-6 continued until August 28, and was switched back into RRGI-7. The pumping-injection terminated on September 10, at 8:58. The recovery data was recorded until September 11.

Several short-term interruptions were experienced during the test. Pumping rate started at 66.15 L/sec and dropped to final steady rate of 56.70 L/sec after about three hours of pumping.

6.1 Pumping Well RRGE-1 Evaluation

The pumping part of the test was evaluated by plotting time drawdown data on a semilog paper (Figure 3). The early time part of the plot was not analyzed because of the effects of the pumping rate changes, interruptions and preheating flow. The latetime part of the plot forms relatively uniform straight line. The reservoir parameters calculated from this portion of the plot are: Q/S_{10} = 0.28 lps/kPa/log cycle and kH at about 10,500 md-m. The recovery data was analyzed by plotting residual drawdown versus t over t' ratio (Figure 4). The early time data for recovery is believed to be invalid because of the inaccurate bubbler readings. The late time part of the semilog plot indicates a Q/S_{10} value at about 0.24 lps/kPa/log cycle and kH value at about 9,000 md-m.

The values obtained from the pumping and recovery part of the test are relatively consistent and are believed to represent reservoir hydraulic properties within RRGE-1 well.

6.2 Injection Well RRGI-6 Evaluation

The injection into RRGI-6 started by converting part of the injected geothermal water from the RRGI-7 well. The injection flow was gradually increased from 7.56 lps to 22.05 lps for about three hours. All system shut down after the final switch-over attempt. The pump was restarted after about 20 minutes break and pumping-injection was continued at the 56.7 lps pumping rate.

During the injection, wellhead pressure was building up gradually to the maximum of 2164 kPa. The pressure buildup versus time plot (Figure 5) was used to evaluate reservoir parameters. The straight line plot has

distinctive change in the slope with a break point after about 60 minutes of injection.

The early time plot indicates a Q/S_{10} value of 0.12 lps/kPa/log cycle and kH of about 5,800 md-m. The late time plot (after 60 minutes) indicates Q/S_{10} value of 0.28 lps/kPa/log cycle and kH value of about 11,600 md-m. Two factors are believed to have significant influence on the early time plot: (1) preheating flow and interruption during the beginning of the test; (2) changing temperature of the injected fluid within the wellbore volume. The late time part of the plot is less influenced by these factors. The results obtained from this portion of the graph are believed to be more representative for the RRGI-6 injection well.

The recovery (pressure falloff) plot of the data (Figure 6) has much less distinctive slope change between the early and late portion of the plot. The early part indicates Q/S_{10} value of 0.24 lps/kPa/log cycle and kH of about 9,750 md-m. The late part indicates Q/S_{10} value of 0.16 lps/kPa/log cycle and kH of about 6,600 md-m.

It is believed that RRGI-6 recovery plot illustrates a temperature effect on a data recorded at the wellhead. The plot has a gradual change in a slope deviating from the straight line. Slowly cooling water in the borehole is gradually increasing pressure falloff measured at the wellhead.

6.3 Injection Well RRGI-7 Evaluation

The injection part of the test may be analyzed only for the first 60 minutes of the injection. The late data is influenced by the injection rate changes and injection interruptions. The early time plot (Figure 7) indicates Q/S_{10} value of 0.256 lps/kPa/log cycle and kH value of about 10,450 md-m. The plot forms not a very good straight line; however, obtained values are consistent with values obtained from the recovery plots.

The recovery was evaluated using data obtained after injection pump shutdown on August 20 and after termination of the pumping-injection on

September 10.

The plot for August 20 recovery (Figure 8) shows a change in straight line plot after about 200 minutes of the recovery. The early time data indicates Q/S_{10} value of 0.30 lps/kPa and kH value of about 12,450 md-m. The late time data indicates Q/S_{10} value of about 0.17 lps/kPa and kH value of about 7,100 md-m. The change in slope is gradual and most likely reflects effects of the slow cooling of the fluid within the wellbore.

The data plot for the September 10 recovery (Figure 9) shows less distinctive slope change in the straight line plot. This change is observed after about 340 minutes. The recovery after long-term injection shows slower and less distinctive response to the wellbore water cooling. The results obtained are as follows: early time, Q/S_{10} = 0.30 lps/kPa and kH = 12,450 md-m; late time, Q/S_{10} = 0.19 lps/kPa and kH - 7825 md-m.

7. MONITOR WELLS AND RRGP-4 WELL RESPONSE

Monitor wells 3, 5, 6 and 7 showed no evident response to the injection. Both long-term injection tests were conducted during irrigation season and the monitor wells were strongly influenced by irrigation pumping.

Monitor well 4 showed substantial water level rise in response to injection. The monitor wells record and discussion are provided in the separate report.

The wellhead pressure at RRGP-4 well was measured during both pumping-injection tests. During the May-June test no apparent interference on well-head pressure at RRGP-4 was observed. The wellhead pressure was basically steady at about 1013 kPa level.

During August-September test, RRGP-4 well responded to pumping. The wellhead pressure dropped from about 1040 kPa to 951 kPa level. The response

is not a typical observation well response and the data obtained does not qualify for the aquifer properties evaluation.

8. DISCUSSION OF TEST RESULTS

The results obtained from 1980 pumping-injection tests generally confirm these from previous tests, references 1, 2, and 3.

Injection capacity estimated at over 60 lps for both RRGI-6 and RRGI-7 wells, references 2 and 3, are within reasonable safety margin. This safety margin is needed to accommodate interference effect between injection wells. The interference effect has not been evaluated because of the data limitation. The RRGI-7 well has slightly higher injection capacity than RRGI-6 well.

The injection impact on the upper aquifers is not fully understood, but it is believed to be localized within limited areal extend.

REFERENCES

1. Allman, D. W., L. B. Nelson, and W. L. Nienis, "Results at RRGI-6 During January 1979 Injection From RRGE-2" EG&G Idaho, Inc. Internal Technical Report GP-AP-004, February, 1979.

2. Nienis , W. L., "Pump/Injection Test - Well RRGE-2 to Well RRGI-7, August, 1979" EG&G Idaho, Inc. Internal Technical Report PG-G-80-030, February, 1980.

3. Callan, D. M., "Results of RRGE-2 to RRGI-6 Pump/Injection Test, March, 1979" EG&G Idaho, Inc. Internal Technical Report PG-G80-035, September, 1980.

TABLE 1

Summary of the Q/S_{10} Values (lps/kPa/log cycle). January 1979 Test RRGI-6 Injection Well.

Falloff Calculations[1]	Buildup Calculations[1]
0.19[2]	0.13
0.20	0.19
0.19	0.23
0.28	0.16
0.20	0.14
0.19	0.19

March 1979 Test

RRGE-2 Production Well	RRGI-6 Injection Well
0.13 early drawdown	0.35 Buildup data intermediate time
0.09 late drawdown	0.46 Buildup data late time
0.11 recovery	0.29 Falloff data early time
	0.14 Falloff data late time

August 1979 Test, RRGI-7 Injection Well

Falloff Calculation		Buildup Calculation	
WHP	HP[3]	WHP	HP
0.36	0.22	0.31	0.59
0.35	0.31	0.28	
0.33		1.71	
0.13		0.30	
0.37		0.51	
0.34		0.59	
0.32			

1. Results from several short-term tests.
2. Rounded numbers.
3. The HP (Hewlett-Packard) downhole probe was installed at 1132m.

TABLE 1 (cont'd)

May-June 1980 Test

RRGE-3	RRGI-6	
0.03 recovery	0.29 early recovery	
	0.17 late recovery	≈ 0.3

August-September 1980 Test

RRGE-1	RRGI-6	RRGI-7
0.28 late pumping	0.12 early time injection	0.25 early injection
0.24 late recovery	0.28 late time injection	0.30 early recovery
	0.24 early recovery	0.17 late recovery
	0.16 late recovery	0.30 early recovery
		0.19 late recovery