DIXIE VALLEY SIX WELL FLOW TEST

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ABSTRACT

A six well flow test was conducted during 1986 at the Dixie Valley geothermal field. Flow duration lasted from 40 to 74 days with a maximum rate of 5.9 million pounds/hour. During the test, downhole pressures were monitored in eight surrounding wells. Downhole pressure and temperature surveys were run in each of the flowing wells, usually in conjunction with productivity tests. Results from the flow test and earlier interference tests indicate that six wells are capable of providing in excess of the 4.5 million pounds/hour required for a 62 mw (gross) power plant.

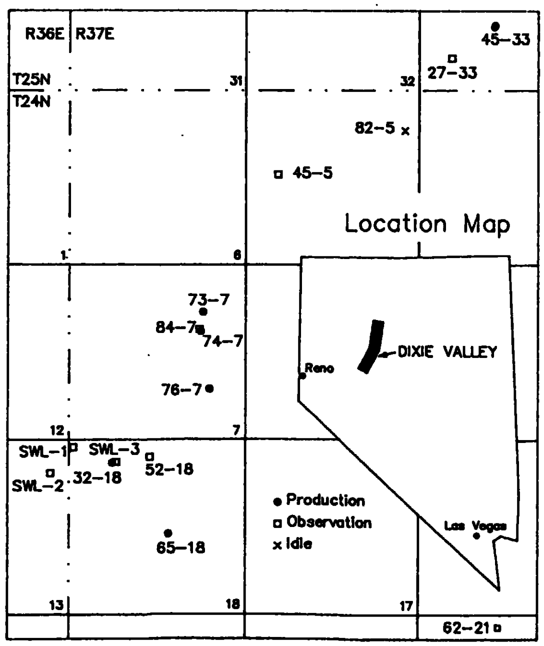
INTRODUCTION

During 1986, Oxbow Geothermal Corporation drilled four wells and reworked several existing wells at the Dixie Valley geothermal field in west-central Nevada (Figure 1). These wells are among the larger mass flow producers within the United States. Three of the new wells are each capable of initial production greater than 1,000,000 pounds per hour (1000 kph). Another new well and two of the workovers had initial flow rates of approximately 900 kph.

Drilling was completed during interference testing of two other wells. Due to the concurrent interference test, several new and reworked wells could only be flow tested for brief periods of time at non-stabilized flow conditions. During prior testing the Dixie Valley reservoir had not been stressed to a significant degree. The six well test was conducted because of the need to stress the reservoir and because of the backlog of virtually untested new and reworked wells.

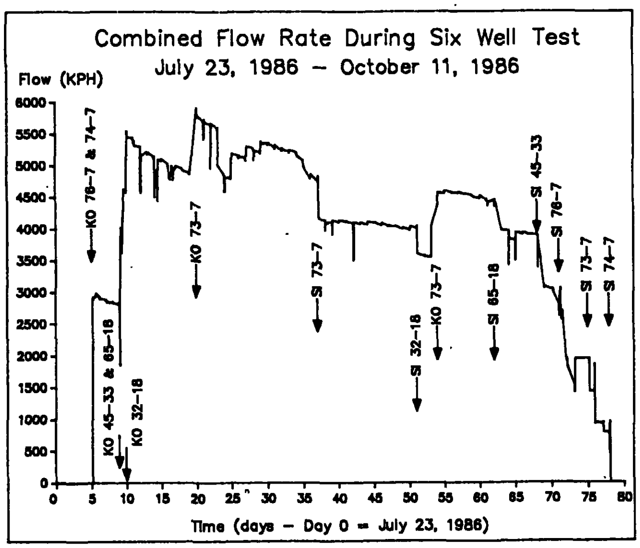
Six wells were concurrently flow tested between July and October of 1986. Maximum flow reached 5910 kph on day 20 as the sixth well came on line (Figure 2). The flow duration was 40 to 74 days with four of the wells flowing continuously. One well was briefly shut in for flowline modification and another well was shut in to repair collapsed casing. Observation well pressures and flowing well parameters were recorded every two to twelve hours with the closely spaced readings taken when wells were kicked off or shut in. Wellhead enthalpies were determined from downhole temperature surveys, then flow rates were calculated using the measured critical discharge pressure (James 1962).

FIGURE 1.



Dixie Valley is a northeast-southwest trending graben situated east of the Stillwater Range horst block. The geothermal wells (Figure 1) are aligned parallel to the range front about 1 1/2 miles out in the valley. The valley stratigraphy generally consists of Triassic marine sedimentary rocks overlain by a complex thrust sheet of Jurassic oceanic crust (Waibel, 1987). The Jurassic section, consisting of intrusives and marine sediments, has a thickness of 2000-4000 feet. Overlying the Jurassic sequence is about 1000' of Miocene lacustrine sediments which are overlain by up to 2000 feet of Tertiary basalt. The basalt is overlain by approximately 6000 feet of Quaternary-Tertiary alluvium and volcaniclastic rocks.

FIGURE 2.

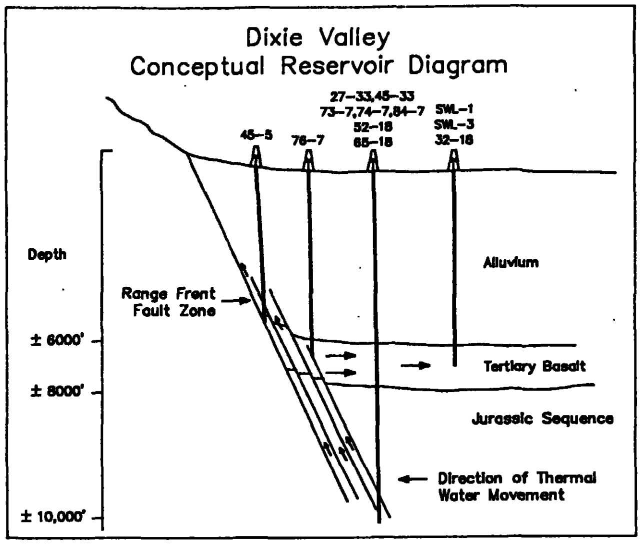


A conceptual reservoir diagram (Figure 3) shows thermal fluid movement up the range-front fault with leakage into the Tertiary basalt. The temperature decreases as fluid moves up the fault zone and into the basalt. The wells produce from the basalt or the fault zone. The basalt wells generally have equal static and flowing temperatures. Wells producing from the fault zone often have flowing temperatures greater than static temperatures. Static and flowing temperatures also vary along the fault decreasing from north to south.

The main producing formation is the Jurassic sequence where it is fractured by the fault zone at a depth of 8000-10500 feet (Figure 3). The producing zones in wells 76-7, SWL-1, SWL-3 and 32-18 are within the Tertiary basalt at depths of 7000-7500 feet.

The 76-7 production zone apparently is located where flow enters the basalt from the range-front fault, because the flowing temperature in this well is much greater than the static temperature. Production from well 45-5 is within the range-front fault zone but at a depth of 6000-7000 feet where fluids are substantially cooler (Figure 3).

Figure 3.



FLOW TEST RESULTS

Flowing Wells. The six well test began on July 23, 1986 with collection of background pressures in eight observation wells. Flow began on day five when wells 76-7 and 74-7 were kicked off. Total flow rose rapidly, to nearly 3000 kph, and then began to decline (Figure 2). The negative spikes on Figure 2 reflect rate decreases during productivity tests. Total flow had decreased to about 2800 kph by day nine at which time flow was initiated in 45-33 and 65-18. Total flow increased to greater than 4600 kph and barely had time to begin declining before flow was initiated in well 32-18.

By day 19 total flow had declined from about 5500 kph to 4900 kph. The following day flow was initiated in 73-7 and total flow rose rapidly to its maximum of 5910 kph. All six wells flowed for the next 18 days. Then 73-7 was shut in for casing repairs. Average flow during the 18 day period was 5358 kph. During the next two weeks total flow slowly declined from 4160 kph to 4040 kph. On day 51 well 32-18 was shut in for the remainder of the test resulting in a flow rate decrease to about 3500 kph.

Three days later flow was reinitiated in well 73-7. Total flow climbed to nearly 4600 kph then slowly declined to below 4500 kph during the following ten days. At this time well 65-18 was shut in. As the remaining four wells were shut in during the final 17 days of flow there was a stepwise decline (Figure 2). Total volume of fluid produced during the test was 7.22 billion pounds. The water was discharged into individual well sumps, and then diverted into ditches and creeks which drained into the Humboldt Salt Marsh.

The first well to be kicked off, 76-7, flowed for 67 days. Flow began on day five at about 1100 hours and within one hour increased to greater than 1600 kph. Maximum production of 1758 kph was attained ten hours later. Shortly afterwards the flow rate began a logarithmic decline over time. However, during the final 30 days flow decreased linearly at a rate decline of 3.0 kph/day. Initiating flow or shutting in the other wells had no obvious effect on the production rate. The multiple flowing well effect can not be determined because previous flow of 76-7 was limited to a one hour test. Well 76-7 the largest producer at Dixie Valley, produced 2.0 billion pounds of fluid during the flow period or 30.2 million pounds per day (Table 1).

TABLE 1. PRODUCTION RESULTS

	Six Well Test					Individual Test	
Well	Pounds (10^9)	Time (Days)	Pounds /day (10^6)	Maximum Rate (kph)	James I.D. (Inches)	Maximum Rate (kph)	James I.D. (Inches)
74-7	1.80	74	24.63	1266	12.00	1360	12.00
76-7	2.00	67	30.20	1757	13.25		
45-33	1.26	60	21.29	1020	9.76	904*	9.95
65-18	.72	54	13.60	786	9.75	801	8.10
32-18	.55	42	13.33	942	12.00	947	9.87
73-7	.90	40	23.54	1109	12.00		
Total	7.22		126.58				

*Unstabilized flow.

Well 74-7 flowed for 74 days, the longest flow duration of the six well test. Flow began on day five about four hours after well 76-7 started. Flow rose rapidly with a maximum rate of 1262 kph attained by the following day. The logarithmic flow rate decline was slower than the decline for the first 30 days in well 76-7. Well 74-7 flow stabilized as 73-7 was first shut in and later decreased after 73-7 began flowing again. Interference is also seen as the 74-7 flow stabilized after shutting in several of the larger wells during the last ten days of flow.

During an earlier single well test 74-7 flowed at a rate of 1360 kph or about 100 kph greater than during the six well test (Table 1). Well 74-7 produced the second largest amount of fluid, 1.8 billion pounds or 24.6 million pounds per day.

Well 45-33, kicked off on day nine, flowed for 60 days. Maximum production of 1023 kph was attained within six hours. Flow then declined linearly at about 2.75 kph/day during the remainder of the test. No obvious interference was seen in the production of well 45-33. The multiple flowing well effect can not be determined because maximum flow had not been attained during an earlier single well test (Table 1). Well 45-33 produced the third largest amount of fluid, 1.26 billion pounds or 21.29 million pounds per day.

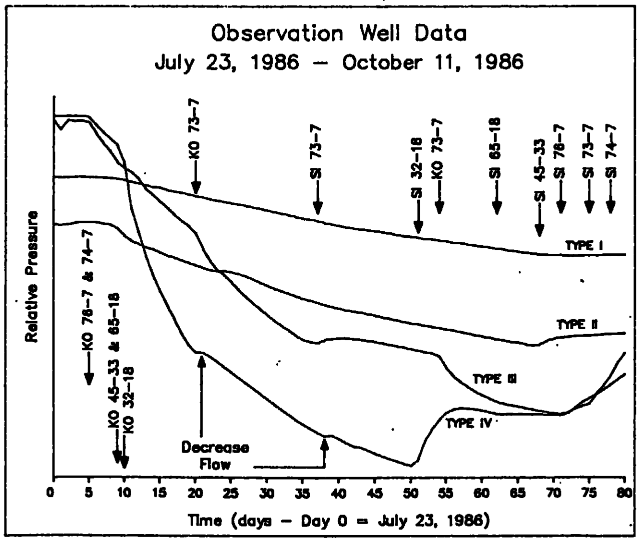
Well 65-18, kicked off about four hours after well 45-33, flowed for 54 days. Flow climbed rapidly to greater than 700 kph with a maximum rate of 784 kph attained by the following day. The decline is logarithmic with a non-stabilized flow rate at the end of the test. The decline during the last two weeks of flow was about 1.5 kph/day. Interference from the other flowing wells effects the 65-18 production rate, because during an earlier single well test a similar rate was achieved through a considerably smaller James tube (Table 1). Well 65-18 produced the second smallest amount of fluid, 719 million pounds or 13.6 million pounds per day.

Well 32-18 was kicked off on day ten with maximum production of 943 kph attained five hours later. The logarithmic flow rate decline is similar to that of well 65-18. The decline during the last eleven days of flow was about 2.9 kph/day. Interference from the other flowing wells effects the 32-18 production rate, because during an earlier single well test a similar rate was achieved through a considerably smaller James tube (Table 1). Well 32-18 produced the smallest amount of fluid, 547 million pounds or 13.33 million pounds per day.

The final well to be kicked off, 73-7, flowed for a total of 40 days during two flow periods. Flow began on day 20 with a maximum rate of 1111 kph attained on the following day. The flow rate decline apparently is logarithmic, however, the non-continuous flow pattern was difficult to interpret. On day 34 the flow rate began to decline drastically. After shutting the well in it was determined that the casing had collapsed. A workover rig was moved in and the damage was repaired. On day 54 flow in 73-7 was again initiated. Flow increased slowly with a maximum rate of 1071 kph attained by the following day. The rate slowly declined and stablized at greater than 1000 kph over the last ten days of flow. Initiating flow or shutting in the other five wells had no obvious effects on the production rate. Since 73-7 only flowed during the six well test, the multiple flowing well effect can not be determined. Well 73-7 produced 901 million pounds of fluid or 23.54 million pounds per day.

Observation Wells. During the six well flow test downhole pressures were monitored in up to eight surrounding wells (Figure 1). The pressures were monitored continuously in six of the wells, however, the fluid level dropped below the pressure chambers in two of the observation wells. The pressure responses (Figure 4) can be separated into five types: I. Low-magnitude smooth curve, II. Low-magnitude non-smooth curve, III. Medium magnitude response, IV. Higher magnitude response and V. No response. The zero pressure change, type V is not shown on Figure 4.

Figure 4



Seven of the eight observation wells responded to reservoir drawdown. The low-magnitude smooth curve, type I, reflects reservoir drawdown with only minor effects from flowing well rate changes. This observation well did respond to major changes in well 45-33, e.g. when 45-33 was kicked off and shut in on days nine and sixty-nine. The production zone of this observation well is in the shallow fault environment.

The three remaining response types more strongly reflect flowing well rate changes in addition to reservoir drawdown.

The low-magnitude non-smooth curve, type II, reflects flow rate changes mainly in well 45-33 (Figure 4). The production zone of this observation well is deep within the range-front fault in an area of the field where a relatively small volume of fluid was produced. After responding to initial flow the type II decline rate increased when flow in 45-33 began. Conversely, on day 23 the pressure stabilized during a five day productivity test of 45-33. On day 68 the pressure began to rise after 45-33 was shut in.

The medium magnitude response, type III, reflects flow rate changes throughout the field with strongest response to the Section 7 wells (Figure 4). The production zone of this observation well is deep within the range-front fault in the main part of the field where a large volume of fluid was produced. After responding to initial flow the type III pressure declined more rapidly when flow began in wells 45-33, 65-18 and 32-18 on days nine and ten. On days 20 and 54 the decline rate increased each time flow was initiated in 73-7. Conversely, on days 37 and 71 the pressure increased after Section 7 wells were shut in.

The higher magnitude response, type IV, reflects flow rate changes throughout the field, but mainly responds to the Section 18 wells (Figure 4). The production zones of these observation wells are within the basalt which is fed by the range-front fault. After responding to initial flow the type IV decline rate increased when flow began in 45-33, 65-18 and 32-18. Conversely, on days 21 and 39 the pressure increased after flow decreased in the Section 18 wells. The pressure increased and stabilized when the Section 18 wells were shut in on day 51 and 62. On day 71 the pressure began to rise rapidly after 76-7 was shut in.

DISCUSSION

All eight observation wells have produced fluid and several are capable of producing at commercial rates. The observation well pressure response or lack thereof provides a means of defining the relative position of these wells with respect to the geothermal reservoir. The easiest to categorize is type V which showed no response to the multiple well test. This well, 62-21, does not appear to communicate with the geothermal reservoir indicating that it is located outside the productive area. This lower temperature well is the only well located near the center of the valley (Figure 1).

The low-magnitude smooth-curve, type I response, appears to be hydraulically remote from the flowing wells. The low-magnitude non-smooth curve, type II response, presumably is due to this well being located in an area where a relatively small volume of fluid was produced.

The medium magnitude response reflects the large volume of fluid produced from the center of the field where this observation well is located. The production zone of this well is the main production zone deep within the range front fault.

The interpretation of the higher magnitude response is that these are "discharge" wells located within the reservoir but at the distal end furthest from the "source". The higher magnitude response of the basalt observation wells would likely occur until drawdown within the basalt equals recharge from the fault zone.

The flow patterns of the six flowing wells reflect the different production zones. The main distinction is whether the well produces from basalt or the range-front fault. The non-stabilized flow of the smallest producer, 32-18, is primarily due to this well producing from the Tertiary basalt. The other five wells produce from the range-front fault but at several different zones within the fault. The second smallest well, 65-18, produces from deep within the range-front fault but at a lower temperature than other wells intersecting this zone. The interpretation is that 65-18, the most distal production well in the field (Figure 1), is located in a "discharge" area. The remaining four wells produce from the range-front fault and are the most prolific in the field.

CONCLUSIONS

Results from the six well test and data from earlier interference tests have provided determination of total stabilized flow from the Dixie Valley geothermal field. Six of the Section 7 and Section 33 wells are capable of initially providing fluid at about 6 million pounds per hour, far in excess of the 4.5 million pounds per hour required for the 62 mw (gross) Dixie Valley power plant. The flow test provided the necessary parameters for power plant design. Power plant construction has begun and completion is scheduled for mid 1988. Interference testing has identified the overall extent of the geothermal field and the wells that are likely candidates for reinjection.

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