COLLECTION AND ANALYSIS OF RESERVOIR DATA FROM TESTING AND OPERATION OF THE RAFT RIVER 5 MW POWER PLANT

Susan Petty
EG&G Idaho, Inc.

INTRODUCTION

The Raft River 5 MW power plant will be on-line some time this spring. During testing of the supply and injection system prior to plant start-up and during testing of the plant itself, data can be collected and used to calibrate computer models, refine predicted drawdowns and interference effects, monitor changing temperatures, and recalculate reservoir parameters.

Analytic methods have been used during reservoir testing at Raft River to calculate reservoir coefficients. However, anisotropy of the reservoir due to fractures has not been taken into account in these calculations and estimates of these coefficients need to be refined. From refined estimates of reservoir coefficients better predictions of interference effects and long-term drawdown in the wells can be made.

In conjunction with the USGS, Faust and Mercer's 3-D finite difference model has been used to simulate the Raft River geothermal field. Intera used a 2-D simulator to predict temperatures, pressures over 30 years and movement of dissolved solids in the reservoir. Data collected during production of the field will be compared to these simulations and the models refined.

Work suppored by the U. S. Department of Energy Assistant Secretary for Resource Application, Office of Geothermal, under DOE Contract No. DE-AC07-76ID01570.

DATA COLLECTION

Instrumentation

For collection of data during production at the field a permanently installed downhole pressure gauge was needed. During reservoir testing several types of downhole tools were tested, including a Hewlett-Packard downhole quartz pressure-temperature probe, continuous flow bubbler gauges, and bubbler gauges purged periodically when data are taken. The Hewlett-Packard probe failed frequently during testing. Continuous flow bubbler gauges used excessive amounts of nitrogen, possibly due to inaccurate flow metering devices. At present, stainless steel tubing strapped to the pump tubing extends to the total depth of the pump intake. The tubing is purged periodically with nitrogen and pressure read from a 0-6895 KPag Heise gauge. This gives fairly accurate relative measurements. Pressure at the injection well is recorded using a Paroscientific pressure transducer with a digital readout.

Temperature is monitored only at the wellhead to reduce downhole electronics prone to electric cable failure. A type K thermocouple is installed in the wellhead with a strip chart recorder readout. Temperature is also recorded manually with an in-line mercury thermometer as backup.

Flow is controlled at both the production and injection wells using automatic electrically-closed valves in the piping from the pump production tubing and in the piping after the injection pumps and strainers. Orifice plates with differential pressure transducers are used both to measure flow rates and to control the automatic valves at the injection wells. Line pressure is maintained by adjustment of valves at the production wells.

Collection Intervals

Although it was planned to automate data collection during operations, budget restrictions have prevented this so far. At present, data are manually collected from the bubbler gauges at the production wells and from pressure gauges and thermometers with no recorded readout. Data are collected on one minute intervals during the first 20 minutes of start-up or shut-down of any well and at increasing intervals thereafter.

INTERFACE WITH PLANT OPERATIONS

Testing of Pumps

During the past year an effort has been made to find a high capacity submersible pump suitable for geothermal operations. Line shaft pumps have been successfully used at Raft River with few problems in wells where deep drawdown is not encountered. However, deep setting depths for high production rates and large drawdowns require the use of large submersible pumps. It is planned to use various designs of geothermal submersible pumps during the coming year at Raft River to determine which design is most reliable. During this phase of wellfield operation much useful data can be collected if operations are planned with reservoir engineering in mind. For instance, no long-term, high rate test of RRGI-7 or RRGE-1 had been completed until this date. The recent need for a test of a newly installed REDA oilfield submersible pump at RRGE-1 allowed for planning of a high rate test of RRGE-1. Well RRGE-1 was produced for a total of 4 days at 66 lps with injection initially into RRGI-7. Due to high line pressures it was necessary to reduce the flow rate to 57 lps. The effect of this reduction is shown in Figure 3. The intrinsic transmissivity calculated from the late time data from this curve is 1.1×10^4 md-m, more than an order of magnitude lower than intrinsic transmissivities calculated from earlier low rate tests. The intrinsic transmissivity calculated from late-time recovery data is almost identical to this value (Figure 4). Due to pump failure at RRGI-7 the test could not be continued beyond 96 hours.

Testing of the supply and injection system at Raft River will for the most part involve wells RRGE-1, RRGE-2, RRGE-3 and RRGP-5. The geothermal reservoir at Raft River is highly fractured. Fracture direction is controlled by two major structural features: the Bridge Zone and the Narrows Zone. Prediction of interference effects is complicated by the differing directions of these two major structural trends. During testing of RRGP-5 prior to stimulation, wells RRGP-4, RRGE-1 and RRGE-2 were used as observation wells. (See Figure 1 and 2.) The response of well RRGP-4 is suggestive of drainage of a single, near vertical fracture of limited extent or production from a totally bounded system. The intrinsic transmissivity calculated from this observation well is 6.2×10^4 md-m while the storage coefficient is 2.9×10^3. The intrinsic transmissivity calculated using RRGE-1 as an observation well is 5.0×10^4 md-m which is close that calculated from RRGP-4. However, the storage coefficient is an order of magnitude larger, 3.1×10^4. Pump tests at these wells show that RRGP-4 has very low intrinsic transmissivity while RRGE-1 is around 2.0×10^4 md-m. Because the reservoir is in fractured rock it is not possible to determine whether these results are an actual indication of the intrinsic transmissivity and storage coefficients averaged over this area of the reservoir or if the methods used are inappropriate to the situation.

Faulting related to the uplift of the Jim Sage Range may also affect communication between wells. Predicted interference at RRGE-1 from production at RRGP-5 and RRGE-3 is of the order of magnitude of 200 kPa using the method of images. However, the total effect may be much larger given the suspected degree of communication between these wells and the anisotropy of this fractured system.

As data are collected during supply and injection system tests, numerical simulation of the system can be refined. A modeling effort by Intera for the injection aquifer assumed a single high conductivity fracture communicating with upper aquifers. This resulted in a perturbation of these aquifers with increasing pressures, temperatures and TDS over the 30-year life of the project. This modeling effort did not, however, simulate production. Further modeling efforts by EG&G in conjunction with the USGS using the Faust and Mercer's 3-D, single-phase code will be directed toward prediction of long-term pressure and temperature effects of production on the geothermal reservoir.

TESTING OF 5 MW POWER PLANT

All testing of the Raft River injection system to date has been accomplished using water at 140°C instead of the plant outlet temperature of 65°C. Because wellhead pressures will limit the injection rate it is necessary to predict pressure build-up at the wellhead in the injection wells. This will be affected by the temperature of the injected geothermal effluent from the power plant. Previous predictions of pressure build-up at the wellhead have been done using linear regression analysis of the semilog plot of pressure build-up during hot water testing. Assuming that the temperatures of the injected effluent will be 65°C, year pressure build-up was calculated using the equation :

$$\Delta P_{total} = P_{i\ 65°C} + \Delta P_{skin} + \frac{Q\mu}{2\pi kh} \ Ei \left(\frac{kht}{Sr^2\mu} \right)$$

where ΔP_{total} is the pressure build-up at the wellhead, Q is the flow rate, kh is the intrinsic transmissivity, t is time, S is the storage coefficient, P_i is the initial pressure, ΔP_{skin} is the pressure build-up due to skin effects, and μ is the viscosity at the temperature of the injected water. The pressure predicted from hot water injection was 2020 Kpa after 1 year of injection at 63 lps. After 1 year of injection of 65°C water at 63 lps the predicted pressure is 3510 Kpa. Data collected during testing of the power plant will provide data to validate this prediction.

As testing of the power plant continues turbine trips can be expected. In this binary system such trips will result in bypass of the geothermal fluid around the heat exchangers and hence an increase in the temperature of the injected effluent. This will allow for further comparison of the injection system response to cold and hot water injection.

As production of the reservoir continues during plant operation total volumes and reservoir pressures and temperatures will be closely monitored. These data will be used for constructing decline curves which can be used to predict future temperature and pressure declines. These predictions can then be checked against actual production records and predictions made using numerical simulation.

CONCLUSION

Through planning of testing of pumps and the supply and injection system at Raft River, data can be collected which will aid in calibration of commercial models and prediction of the long-term pressure and temperature response of the reservoir to production. Data collection and pump malfunction proved to be the major barrier to collection of reservoir engineering data during production of the well field. A fully automated data collection system would allow collection of high quality data without requiring excessive manpower. Predictions of wellfield behavior made by analytic methods, numerical simulation methods and decline curves can be compared to each other and to production data to ascertain the effectiveness of these techniques.