WELL LOG ANALYSIS AND WELL TESTING IN THE HEBER GEOTHERMAL FIELD

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Detailed studies of the reservoir performance and operating conditions of the Heber geothermal field have been completed. These studies indicate that a minimum development at the Heber site would be 200 MW utilizing a two-stage flash process. This paper summarizes part of the investigations which have occurred with attention given to log analysis and well performance.

Geology

Nine wells have been drilled to date. The deepest wells penetrate to 6,000 feet and have encountered alternating sand-shale sequences. Structural markers have not been encountered thus far. Representative core has been retrieved from seven to the nine wells drilled. Porosity from core analysis has been correlated with available density logs. The combination of core analysis and logs has permitted the assignment of both porosity and permeability to each foot of sand which was drilled.

Individual sand members had permeability changes between one and two orders of magnitude as sands were traced from well to well. A vertical layering approach was used to calculate an average permeability over 4,000 feet of section.

The log correlations showed that permeability deteriorated with depth (characteristic of increasing overburden), but that the reservoir still had favorable porosity and permeability at a depth of 6,000 feet.

Well Tests

A total of 19 drill stem tests, two 48-hour tests and three 90-day tests were conducted to evaluate reservoir performance. The drill stem tests were performed over a net sand interval which varied from 48 feet to 156 feet. All the drill stem tests are characterized by essentially instantaneous buildup after shut-in. Therefore, permeabilities could not be calculated by buildup analysis. From a qualitative standpoint, the rapid buildup to final pressure and low drawdowns suggest a reservoir of very high quality.

The two wells which were tested for 48 hours achieved high flow rates. The buildup was complete for both these wells within 45 seconds of shut-in and did not permit a calculation to be made.

Three wells were tested for a minimum of 90 days. Two of these wells were producers, with the third well operating as an injector for fluid from the two producers.

Injection well permeability was calculated from a falloff curve. A density log was not available for this well, so no comparison can be made. However, the composite layered geologic model gave close agreement to the falloff test over the same interval.

Two buildup tests were analyzed for one of the producers. Calculated permeabilities compared favorably with indicated permeabilities from density logs. Calculations on this well suggested significant wellbore damage.

Permeabilities determined using multiple rate tests on the third well were compared with log calculated values and steady state flow rate data.

The long-term pressure history of the three wells followed the pressure calculated theoretically by assuming an infinite aquifer with no influx at the outer boundary. It is possible that the real data might fit an aquifer of some finite size with a constant pressure boundary.

All the buildup data was characterized by a single straight line. This would suggest that boundaries were not encountered by the pressure transients and corroborates the producing pressure history.

The injection well was completed in a lower interval than the two producers. The producing and injecting wells (separated by one mile) were isolated from each other by continuous shales (conjecture). The long-term pressure history corroborates this picture as injection did not influence the producing well pressure. The two producers were completed in the same interval and were also one mile apart. The pressure history at the producers shows some minor slope variations which occur when rates are changed, but these are only qualitative indications of well interference. Rate changes were made frequently at both wells, and these tend to mask any interference effects which may have occurred.

During the well testing, wellhead temperatures were recorded. For all flow rates which were encountered at the producing wells, flow was single phase water from approximately 3,000 feet deep. It was observed that wellhead temperatures approached equilibrium very quickly. At flow rates between 5,000 and 10,000 B/D, wellhead temperatures were within 7°F of the average bottom hole temperature after only 7 days. At flow rates above 15,000 B/D, surface temperatures were only 2°F below bottom hole conditions after 5 days, and 1°F after 25 days. It can be concluded that heat loss in the wellbore in single phase flow will be negligible during actual production operations. Geothermal well production rates are expected to be generally in excess of 30,000 B/D.

Conclusion

The geology and information gained from well testing was used as the foundation for a reservoir simulation to predict reservoir performance. The rationalization of information gained from these two sources plays a very important role in giving reliability to performance predictions. In the case of the Heber field, the log data, core data and well test data correlate satisfactorily. The reservoir performance prediction of 200 MW is therefore realistic.

The observation of negligible heat loss in the wellbore during norma production operations in water systems is significant. Wells may be direc tionally drilled such that a larger percentage of the total flow path is covered in the wellbore, rather than in surface flow lines.

It is worth noting that the overall analysis used for this geothermal reservoir was similar in nature to that used to predict oil reservoir response. The data gathering procedure, analysis and overall method of approach used for many years in evaluating oil reservoirs have direct applicability to geothermal reservoirs.