Peggy Brookshier  
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Idaho Operations Office  
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Re: Grant No. DE-FG07-90ID12934

Dear Peggy:

Enclosed is the Quarterly Technical Report for January - March, 1991, for the above Grant.

Sincerely yours,

Jean W. Cook  
Program Manager

Enc.
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Progress Report for Winter 1991

Stanford Geothermal Program
Stanford University

May 13, 1991

1 Introduction

Over the quarter (January-March 1991), progress has been good on several fronts. The adsorption work has proceeded in all three tasks, namely the experimental, theoretical and field projects. The reinjection task is now nearing completion of the work on optimizing injection into the Palimpinon geothermal field in the Philippines. Well test analysis research has been expanded with the initiation of a new project on multiwell interference test interpretation.

2 Optimizing Reinjection Strategy Based on Chloride Data

This study on optimizing reinjection strategy in Palimpinon, Philippines, by research assistant Elena Urbino and Professor Roland Horne, is now nearing completion. The study has two objectives. The first aims to use available tracer test results in the Palimpinon Geothermal field to allocate production and reinjection rates employing the algorithms developed by Operations Research and modified by James Lovekin (1987). The second objective seeks to find another parameter that would relate injector to producer and be used as an arc-specific weighting factor for the optimization routine. These

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two objectives have been accomplished in the last quarter. Allocation of production and reinjection rates in the field was based on the ranking of the wells depending on the injection wells' potential to do damage and the producing wells' potential to suffer premature thermal breakthrough. For the second objective, the reservoir chloride value of the producing wells was successfully used as a parameter that would indicate the strength of the relationship between the injection well and the producing well. The basis behind this is the fieldwide observation that though the general trend of chloride values of the producing wells is increasing due to the return of injected fluid, the rate and magnitude of reinjection fluid returns are dependent on the combination of wells used for injection and production at any given time. Four methods were used to get the correlation between the chloride value of a producing well and the flowrate of an injection well. The first seeks to find the correlation between the chloride and the injection flowrate; the second determines the correlation between the chloride value and the cumulative flowrate of the injection well. The third method fits a linearly regressed line to the increasing trend of chloride, and the deviation of the chloride from this best fit line was then correlated to the chloride value. Finally, the last method expresses the chloride value as a linear combination of the flowrates of the injection wells on service at the same time.

For the last quarter, the applicability of the chloride method has been demonstrated using as test cases the results of the actual tracer tests. Producing wells which had positive returns during the tracer tests, had high positive correlation with the injection well when all concerned were on line. It has also been determined that of the first three methods, the second method fails to illustrate definitive injector/producer relationship. In conclusion, the chloride-flow coefficients of correlation can be used as cost coefficients for the optimization of production and injection well utilization scheme. A paper was presented for the Stanford Geothermal Workshop, and a talk was given for the Stanford Geothermal Affiliates meeting. Figures 1 and 2 illustrate the methods.
3 Experimental Investigation of Adsorption

This work, by research assistant Michael Harr and Professor Henry J. Ramey, Jr., has been focusing on experimental measurements of steam adsorption on geothermal reservoir rocks. During the quarter, the investigators have continued becoming familiar with the equipment being loaned to Stanford by the USGS. A diagram of this apparatus is shown in Figure 3. Two steam runs have been made with the equipment on the unconsolidated sample used by Herkelrath et al in their earlier experiments. The equipment was to have been moved in late March but will not arrive until after the first of April.

With the equipment on campus, the first goals will be to return the equipment to working order. Once working, the plan is to resize the core holder for the sample sizes now available to the Stanford Geothermal Program. It is also planned to add a system by which the total mass desorbed can be measured for each run.

4 Estimation of Adsorption Parameters from Experimental and Field Data

This project is being performed by research assistant Ming Qi, together with Professors Roland N. Horne and Henry J. Ramey, Jr.

When developing a mathematical model such as the model of steam adsorption in geothermal reservoirs, there exists some parameters which can not be derived directly from analysis (such as the parameters of the adsorption isotherm in this case). Field data and laboratory data are needed to determine these parameters. By matching the model with field data we can get good estimation about those parameters. One commonly used method is nonlinear regression.

By combining nonlinear regression programs with the ‘One Dimensional Steam Flow in Porous Media Under Desorption’ model which was developed by Cuong Phu Nghiem and Henry J. Ramey Jr., the plan is to match the model with field and laboratory data to get a good estimation of those
parameters needed for the model.

As the first step of testing, the simulation result was used as the "field data" during the regression and it gave a good match, as would be expected. So the next step will be use laboratory data and field data to do the estimation. To do this, modification of the model is also needed so that the model can be used to simulate a real field. This will finally lead us to obtain a better understanding of the effects of adsorption-desorption phenomena in geothermal fields.

5 Interpreting Multiwell Transient Pressure Data

This is the beginning of a new well testing project performed by research assistant Deng Xianfa and Professor Roland N. Horne. The objective is to investigate procedures for processing data from multiwell tests. Such tests are a common part of early analysis of geothermal reservoirs during development. The objective of multiwell interpretation is to avoid inconsistent results between different data sets, by identifying which data set has negative influence on the overall interpretation. After this determination, the technique will use as many sets of data (or information) as possible to obtain more confident estimation of the parameters.

The idea has been tried successfully in interference analysis for anisotropic reservoirs where seven well drawdown pressure data sets were used simultaneously. Figure 4 shows a typical match to all seven data sets at the same time.

Other cases under study include composite flow situations and matching pressure data at the same time as other information such as tracer data.

6 Theoretical Study of Adsorption Isotherms

This study by research associate Cuong Phu Nghiem and Professor Henry J. Ramey, Jr., has been focussed on the development of theoretical models of
steam adsorption in geothermal environments. Over the quarter, the project investigated the nature of the adsorption isotherms that are included in the mathematical model.

Five types of isotherm for gas adsorption on solid are encountered in practice (Brunauer, 1943). The adsorption isotherm for dirty sandstone (Herkelrath, 1990) and the isotherm for unconsolidated material containing sand, silt and clay (Herkelrath and Moench, 1982) were found to be both of type two. However, they differ from each other by the curvature of the isotherm shape.

Type two isotherm is generally attributed to multimolecular adsorption. However, when the curvature of the isotherm does not change than the Langmuir theory may be applicable. In the other case the BET theory is needed to describe the change in curvature which is the case of the unconsolidated material.

This observation is important for eventual piecewise approximation of adsorption isotherms.

7 References


Herkelrath W.N.: private communication with H.J. Ramey Jr..

Figure 1: Chloride - Flow Correlation Method for OK-7/PN-9RD
Figure 2: Correlation of Cumulative Injection Flowrate with Chloride
Figure 3: (Herkelrath and Moench, USGS Report, Jan. 82)
Figure 4: Type-curve Match for Multi-well Transient Data

Match Data Sets of
Well 1-E  Well 1-D
Well 5-E  Well 9-C
Well 5-C  Well 9-D
Well 9-E
Kxx  Kyy  Kxy
13.96  18.60  3.56
Figure 5: The five isotherm types in physical adsorption.