GEOTHERMAL RESERVOIR ENGINEERING RESEARCH

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Before discussing reservoir engineering research, it is useful to consider the place of reservoir engineering within the broad field of study of petroleum engineering. Petroleum engineering includes the major specialties of drilling, production, and reservoir engineering. Other specialties important to development and production include petroleum geology, geophysics, geochemistry, fluid transmission, marine operations, refining, natural gas production and processing, computer science and reservoir simulation, and economics. Although petroleum engineering is frequently involved in planning the drilling of an exploration target, the main activity actually begins upon completion of an exploratory well.

Unfortunately, the objectives of the three major petroleum engineering specialties of drilling, production, and reservoir engineering are often antagonistic. The drilling engineer has a responsibility to complete the well as rapidly as possible with due regard for safe procedures and low drilling costs. The production engineer has the responsibility of maintaining high producing rates from wells and is frequently involved in the well completion phase of the drilling. He must analyze well logs and drill stem tests and make decisions concerning the running of pipe and completion of the well. He must determine whether the well is damaged and when and how to stimulate the well. In addition, he will be involved in the completion design of the well and will decide which portion of the interval to complete. The reservoir engineer is interested in the total reservoir-producing well system. He seeks such information as the permeability, porosity, and fluid content within the entire reservoir volume and the condition of the well. The reservoir engineer will be involved in planning the development of the entire reservoir, and will decide the number of wells required for a given reservoir, which well pattern should be used and what recovery process should be used. He usually establishes the potential producing life and oil recovery of the system. Generally, all three branches of engineers employ economics in making engineering decisions.

Obtaining necessary engineering data frequently involves extended periods of testing during the drilling of a well. In this respect, the drilling objectives of fast, low-cost completion are diametrically opposed to production and reservoir engineering objectives to obtain reliable data. On the other hand, the production engineer also is reluctant to expose the formation to drilling fluid for extended periods of time. This may result in formation damage and a poor producing well. Often, the technology employed by drilling, production, and reservoir engineers is compartmentalized or segregated. The specialty of formation evaluation is often considered to be involved with the drilling and completion of a well only, although important information useful in reservoir engineering may be obtained during this phase. This specialty should cross all three engineering specialties.

Fortunately, there are three good reference books available describing the functions of drilling, production, and reservoir engineering. Good examples include the text Drilling and Well Completions, by Carl Gatlin, Principles of Oil Well Production, by P.E.W. Nind and Applied Reservoir Engineering, by B. Craft and M. Hawkins. The text by Nind is a McGraw-Hill publication. The other two are Prentice-Hall publications.

In the light of important cross-purposes in the three major petroleum engineering specialties, it is imperative that engineering data not be taken for frivolous reasons. Engineering data should be gathered with firm objectives in mind. Data-taking procedures should be carefully planned so that the desired information will be obtained, and proper interpretive techniques established. Thus it is basic to review the principles involved in sound reservoir engineering research.

Reservoir Engineering Research

Reservoir engineering generally follows a specific pattern. First, field performance is observed and data obtained. From the observed performance, it is possible to generate a hypothesis as to the nature of the system. The hypothesis is then tested either by operating physical models in the laboratory or by computer investigation of mathematical formulations describing the hypothesis. From these results the physical laws involved in the operation of the reservoir can be formulated. It is also necessary to collect physical and thermodynamic data for the reservoir rock and fluids. These steps frequently involve running well tests. Pressure transient information and fluid samples may be obtained. The fluid samples can be used for pressure-volume-temperature studies in the laboratory, or used to select correlated properties from the literature. Using this information, one can write and solve pertinent equations describing the reservoir system. The mathematical model solutions are usually compared with field behavior to establish the validity of the simulation. Given a reasonable correlation between the mathematical model and the field performance, it is then possible to study the effect of various development and production plans for the system. Final decisions as to development plan are usually based on comparative economics of various operating schemes.

One danger in the preceding method lies in searching for field performance data to match a preconceived notion about important reservoir mechanisms. It is difficult to differentiate between a sound hypothesis and an incomplete mathematical model which includes only selected fact. One good example which occurs often in geothermal reservoir production is the idea that precipitation from geothermal fluids will plug the producing sand face of a well and result in declining production rates. The fact that all geothermal wells do appear to decline in productivity over short periods of time is sometimes thought to prove that precipitation is responsible for rate decline. However, many other factors may cause declining production rates in wells. One is declining formation pressure causing a decreasing driving force to move fluids into the wellbore. Often this is the factor responsible for declining geothermal well production rates rather than precipitation from geothermal fluids.

It is therefore important to keep an open mind. A proper reservoir engineering study searches for the hypothesis derived from all known facts. It is not valid to select only facts that substantiate a preconceived concept. The researcher should observe facts, then produce a hypothesis to explain field behavior and from this test the hypothesis with physical and mathematical models.

Geothermal reservoir engineering research is currently similar to oil and gas reservoir engineering research performed during the first quarter of this century. At that time workers were trying to decide the true nature of gas and oil reservoirs. Almost every scientific discipline made a contribution. There were many debates as to the essential behavior of oil, water and gas within the pore space of rock. Incorrect theories were offered and defended vigorously. Debate often gave way to rancor and personal animosity. Scientific reputations crumbled. There exist many scientific textbooks written during 1900-1925 which are now only historical curiosities. The final result, however, was a sound technology presently heading into a second generation of accomplishment and discovery.

Gas and oil reservoir engineering flourished immediately after World War II. The return of servicemen from war-time duties provided a new pool of engineering talent needed for the rapidly growing oil industry. The modern geothermal industry also dates essentially from the end of World War II. However, application of reservoir engineering to geothermal systems essentially began in the early 1960's. Geothermal reservoir engineering has come a long way in the last ten years. We have reached a stage of development that is comparable to the early 1950's in gas and oil reservoir engineering research. This can be seen in the report on the first geothermal reservoir engineering workshop held at Stanford in December of 1975. Perhaps the greatest reason for rapid advance has been development of field studies recently. The concept of jointly funded field studies supported by federal funding and combining the talents of private industry, university staffs, and the U.S. Geological Survey, has permitted rapid strides in the field of reservoir engineering research.

Geothermal reservoir engineering research is destined to blossom and bear significant fruit for the nation's energy appetite. We confidently forecast that the December 1977 workshop will reveal that geothermal reservoir engineering research has finally reached the decade of the 1970's.