GEOTHERMAL RESERVOIR ENGINEERING IN INDUSTRY

Stephen C. Lipman
Union Oil Company of California
Santa Rosa, California 95406

The status of geothermal reservoir engineering in industry is highly encouraging. The "state of the art" has grown steadily over the years and has been accelerating rapidly in the last few years. Geothermal engineers in industry have had an advantage over their counterparts in research and government in that they have had actual reservoirs and producing wells on which to apply their engineering skills. This involvement with field testing and development has created an ideal environment for advancing the technology of geothermal reservoir engineering.

I tend to view geothermal reservoir engineering in a much broader context than the five general topics being discussed in this workshop. For reservoir engineers in private industry, a geothermal project begins when a potential geothermal prospect is being evaluated for leasing. The reservoir engineer must be involved with his exploitation and land acquisition groups so that the terms of the eventual lease are achievable within the framework of the existing stage of technology, regulatory control and appropriate economics.

Once the lease is consummated, the reservoir engineer must be involved in the exploration and initial drilling program. The exploration data acquired and evaluated by the exploration geologist is of vital importance to the reservoir engineer in his evaluation of the reservoir. He must work closely with the design and execution of the initial drilling program so that the maximum reservoir information can be obtained from the drill cuttings, coring, logging, bottomhole fluids, temperatures and pressures. The casing design and well completion program will be of important concern to the reservoir engineer, since they will play a large role in limiting or contributing to the productivity of the well.

Nowadays in the United States, very little new industrial development can occur without a thorough analysis of the environmental impacts of the operation. The reservoir engineer in industry must play a role in contributing necessary information in these analyses. He can provide details on the anticipated well testing and field evaluation programs and on the estimated extent of development and on the quantity and characteristics of the fluids which will be produced. The quantity of information required before these projects are well defined may seem unmanageable, but the reservoir engineer is the most qualified to supply much of this information.

There is another aspect of regulatory control in which the reservoir engineer should play an active role. The regulations which generally fall into the category of environmental protection have been in a general state of flux by local, state and federal agencies. Geothermal development is very new to these agencies, and there is an urgent need to educate them on the exact nature of the operations. Without this education, industry has and will continue to experience long delays in receiving governmental approval for future development.

While I am on the subject of delays, we should examine an important responsibility the reservoir engineer has in shortening the long lead time from initial discovery to commercial production. In an oil or gas reservoir, field production facilities can be installed shortly after the first few wells are drilled and tested. The reservoir evaluation proceeds concurrent with the development of the field. We are not provided with this luxury in geothermal development. Small geothermal power plants are not economically attractive, and it takes extenuating circumstances to justify their installation. We tend to view a 55 MW plant as the smallest economic size unit under normal circumstances. This means that a reservoir will have to contain close to 300 billion pounds of steam to support this plant for a 30-year life. Of course the required minimum reserve will vary depending upon the power cycle used and the nature of the fluids in the reservoir. If the reservoir fluid is hot water, the required fluid reserves may be four to five times as large. The challenge to the reservoir engineer in industry is to determine how large his reserves are within the shortest possible time and with the minimum amount of wells and testing.

It is toward achieving this goal that the reservoir engineer must constantly strive. I feel that the industry is moving rapidly in this direction. Well testing and evaluation techniques have been vastly improved in the last few years. In this respect, the bottomhole pressure measurement techniques are meeting our needs, but there is an obvious absence of equally sensitive temperature tools. We must find a way to measure temperature changes in the reservoir with greater accuracy.

There are considerable chemical data becoming available on existing geothermal reservoirs. I feel there is an urgent need to analyze these data with respect to what they are telling us on reservoir performance. I refer not only to ion concentration changes, but also to isotope chemistry. The performance of a geothermal field will be controlled by, among other factors, the hydrology of the area. Monitoring the changes of isotopes, such as H, O, C and S, will provide insight into how the hydrology of the area is responding to geothermal operations. The results of these chemical investigations need to be integrated with flow behavior and the physical properties of the reservoir fluids. We feel that the reservoir evaluation and prediction techniques will eventually have to account not only for the mass and energy changes during exploitation, but also for the chemical changes.

There has been considerable interest in the last few years on the consequences of cold fluid injection into geothermal reservoirs. Industry has been aware of this potential problem for a number of years, so it is gratifying that more research is being undertaken to determine the physical characteristics of its effect. Such research will aid in designing successful reinjection programs, but industry will have the responsibility of developing field trials and making the system work beneficially for additional heat recovery and not to detrimentally inhibit our producing wells. An unknown in calculating the heat recovered from the rock during water injection is the fracture intensity. In all the mathematical derivations, we use the assumption of instantaneous heat transfer from the rock to the fluid to achieve thermal equilibrium. This assumption has

to be verified in the laboratory using larger rock than in past experiments and also in the field by conducting pilot tests. The technology development for fluid injection into geothermal reservoirs should proceed much like the development of water-flooding in oil reservoirs. Theoretical and laboratory analyses went hand in hand with field testing.

I should point out that Union Oil has been involved in water injection at The Geysers since 1969, in New Mexico since 1973, and for over one year in Imperial Valley. These injection programs were initiated to dispose of the produced liquids in an environmentally acceptable manner. I anticipate that reinjection of produced liquids will become the only acceptable method of water disposal for geothermal operations in the United States. Therefore, it is mandatory that we develop techniques that minimize the detrimental effects. Our experience to date indicates that if the injection program is designed carefully, water injection can be carried out successfully.

Though we are confident in cold fluid injection, there is still a considerable amount of field data and experience needed. We intend to concentrate on reservoir analyses on the heat transfer characteristics in these operations in the coming year. We have experimented with the use of tracers in our injection water in the past, and we plan to expand this work in the future. It is our hope that the use of tracers will provide us with information on the orientation and intensity of the fractures and how effectively we are mining the heat from the rock.

In summary, I feel that geothermal reservoir engineering in industry is extremely important in advancing the development of these needed resources. The engineering going on in the field is highly complementary to the current research activity. There is considerable work ahead for both industry and research, but through information exchanges such as this workshop, we can shorten the time-lag in our knowledge about geothermal reservoirs.