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RESERVOIR VERIFICATION WORKSHOP PANEL REPORT

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INTRODUCTION

Before geothermal energy can be commercially developed for electric power, the utility companies need to have the assurance that the geothermal resource at a particular site can be produced at an adequate rate and with an acceptable quality over the life of the power plant, that is, over 25 to 30 years. Thus, the utilities need two basic assurances:

- That the reservoir has sufficient reserves and flow capacity to produce for 30 years at an adequate rate
- That the reservoir characteristics are such that the produced fluid will have acceptable quality as regards enthalpy, chemical composition, and so forth, over the 30 year period

The abovementioned assurances will have to be provided primarily by the reservoir engineer, who specializes in estimating the nature of a subsurface reservoir and the reserves it contains, as well as in forecasting its performance. Reservoir engineering is a well-developed discipline in the petroleum industry. However, in the geothermal industry the application of reservoir engineering is a relatively new development and is fraught with problems arising from the lack of a substantial data base and the inherent idiosyncrasies of a geothermal reservoir.

The lack of a substantial data base is a serious handicap. Worldwide, only three geothermal reservoirs have been produced for sufficiently long periods to provide case histories of major significance. These reservoirs are Larderello geothermal field in Italy (producing since the early 1900s), Wairakei geothermal field in New Zealand (producing since the late 1950s), and The Geysers geothermal field in the United States (producing since the early 1960s). Of these only Wairakei is a hydrothermal (hot water) system; the other two are dry steam reservoirs. Because of the inherent operational and economic advantages of dry steam wells and the two well-known case histories (Larderello and The Geysers), dry steam reservoirs are the most attractive sources of geothermal power. The Pacific Gas and Electric Company has been producing commercial geothermal power at The Geysers for over a decade and has thus developed, among the utilities, a sense of confidence in the viability of dry steam geothermal resource. The utility industry does not appear to have such confidence in the viability of hydrothermal resource. Hence, this workshop.

The other difficulty in applying reservoir engineering to geothermal reservoirs is the inherent complexity of geothermal systems. In the petroleum industry, the resource sought after (oil or gas) has a definite, assessable mass. In a geothermal system the resource is heat energy, the resource carrier being water and steam. Estimating the total amount of heat contained in the rocks and fluids in a

reservoir is relatively simple. However, how much of that heat is practically recoverable depends primarily on the amount of available water and how extensive the contact is between rock and water. The amount of available water depends on the water stored in the reservoir, artificial recharge (injection of power plant waste water), and natural recharge of water. It is relatively easy to estimate the water-in-place and the extent of artificial recharge, though not of natural recharge. Until a reservoir has produced for a number of years, the extent of recharge, or the absence of it, cannot be precisely estimated. As more case histories of geothermal reservoirs accumulate, inferences on the nature of natural recharge in geothermal systems can be drawn. However, a reservoir engineer can estimate the lower limit of available water by assuming no recharge. If any recharge takes place, the net energy recovery will be higher. Another uncertain factor is the degree of interconnection between pore-spaces in the reservoir. This aspect of a geothermal system sometimes cannot be precisely estimated from the state-of-the-art of well testing, well logging, and surface geophysical or geochemical methods.

The uncertainty of our knowledge of the nature of a geothermal system and the lack of case histories makes it difficult to estimate the reserve and flow capacity of the reservoir, or to forecast the performance of the reservoir with a high degree of confidence.

PURPOSE

A utility company will like to know with reasonable accuracy the answers to the following vital questions:

- Do we have sufficient reserve for a certain power plant capacity?
- Can the reservoir produce at an adequate rate to supply 'fuel' to the power plant for 25 to 30 years?
- How will the enthalpy of the produced fluid vary over the life of the power plant?
- How will the chemical composition of the fluid vary over the life of the power plant?
- How will the operational problems (amount of noncondensible gases, salinity, and corrosivity of the fluid, etc.) vary over the life of the power plant?

As discussed before, the answers to these questions are uncertain.

The purpose of this workshop was to bring together experts in geothermal resource assessment and representatives of geothermal resources producers, as well as the users (utility companies), with the aim of discussing the present uncertainties in geothermal resource assessment, its impact on the growth of the geothermal power industry, and the future trend. The participants consisted of representatives of the utility companies, EPRI, academia, government, and the service industry. An open and informal exchange of ideas took place between the panel of speakers and the other workshop participants.

DISCUSSION

This summary is followed by the transcripts of the talks presented by various speakers at the workshop. Transcripts have not been received from some of the speakers. The following outline summarizes the discussion at the workshop.

Exploration

H. T. Meidav pointed out both the assets and the shortcomings of the various geophysical and geochemical exploration techniques as they pertain to reservoir verification. He concluded that the risk in geothermal resource assessment can be reduced by judicious and synergistic combination of geophysical and geochemical survey techniques, tempered by local experience in an area. He pointed out that some failures in geothermal field development in the past were the result of undue reliance on any one survey or interpretation technique to the exclusion of others.

Laboratory Study of Rock Properties

A. G. Duba pointed out that the current state of knowledge of geothermal rock-fluid properties at elevated temperatures and pressures is limited. Yet such knowledge is indispensible in deciphering well log and test information and interpreting geophysical surveys, and in general reservoir assessment. He pointed out the need for some basic laboratory research into geothermal rock-fluid properties.

Well Logging

S. K. Sanyal underscored the urgent need for developing well logging tools that can safely withstand the hot, corrosive environment of a geothermal well; the existing tools are inadequate. He also discussed the inadequacy of the existing interpretation techniques for geothermal well logs. It was pointed out that in spite of these impediments, a reasonable assessment of geothermal reservoir fluid and rock properties can be made from the existing well logging techniques by innovative and synergistic analysis of data.

Well Testing and Reservoir Performance Prediction

W. E. Brigham discussed the various uncertainties in well testing and reservoir performance prediction. For example, he pointed out that while fairly reliable well test interpretation is possible in single-phase reservoirs (dry steam and hot water without any steam saturation), there is no simple analytical technique for well test analysis when both steam and water coexist in the reservoir. He pointed out that there are some basic uncertainties in reservoir performance prediction, because of the reasons mentioned in the Introduction section of this report. However, he did point out the advances made in geothermal reservoir engineering during the past few years and the consequent improvement in our confidence in geothermal reservoir assessment.

Use of Tracers in Reservoir Assessment

O. J. Vetter discussed how introduction of tritium tracer in the injected water and monitoring of the tritium level in producing and observation wells can be powerful tools in geothermal reservoir assessment. He concluded that the use of

tritium tracer in geothermal field operations can not only reveal some basic reservoir characteristics (flow patterns in reservoir; location, orientation, and extent of fractures, etc.) but also provide an early warning of breakthrough of cold, injected water in producing wells and allow time for prevention of coldwater breakthrough.

Use of Computer Simulation in Reservoir Assessments

T. D. Riney discussed the use of numerical simulation of a geothermal reservoir as a tool in various aspects of reservoir verification and development. He showed how various forms of reservoir and well bore simulators can answer some of the basic questions posed by utility companies. Thus, computer simulation can help reduce the uncertainty in geothermal reservoir assessment.

Resource Companies' Views

D. R. Butler and G. W. Crosby discussed the various aspects of the risks and uncertainties involved in the assessment and development of geothermal reservoirs as perceived from the point of view of the resource companies. Butler classified the risks to the geothermal resource producers into six groups: prospect risk, drilling risk, evaluation risk, sales risk, development risk, and reservoir risk. He described these risks and pointed out how the resource companies and utilities can work together with a reasonable amount of federal help to reduce their risks and develop a geothermal industry. Crosby pointed out that the resource operator makes every effort to reduce risks because he has to make a large investment in field development, just as the utility has to be concerned about the risks because of the large capital costs involved in power plants. He emphasized that both the utility and resource company should work in close cooperation to reduce these risks and that the time is ripe for decisive cooperation to build a geothermal power industry.

Utility Companies' Views

G. Lombard and A. Martinez voiced the dilemma of the utilities that while on the one hand they would like to promote a geothermal power industry, yet on the other hand it is difficult to make large financial investments in power plants based on a resource that is yet to be proved entirely reliable. They were concerned about the economic viability of the geothermal resource, as well as the assurance of adequate supply over the life of the power plant. In the near future they foresee the basic role of geothermal energy as a supplement to, and not a replacement of, the baseload capacity. However, as the geothermal industry matures, it is likely that geothermal energy may assume a significant portion of baseload supply.

Youngquist expressed the opinion that for the small utilities a small geothermal power plant (10 MWe) may be practical. Even wellhead generators can be used as supplements to the baseload capacity.

ERDA's Reservoir Engineering Management Program

J. H. Howard described the program now being planned that is to be implemented by Lawrence Berkeley Laboratory for ERDA for support of research in geothermal reservoir engineering.

CONCLUSIONS

The basic conclusions of this workshop can be summarized as follows:

- There are basic uncertainties in geothermal reservoir assessment:

  -- lack of data about the reservoir
  -- lack of a data base about geothermal reservoir assessment
  -- lack of knowledge about the "geothermal system" of a reservoir

- These uncertainties can be substantially reduced by proper engineering and basic research.

- Resource and utility companies can work together with some federal help to reduce the risks and uncertainties.

- While the utilities are interested in a geothermal power industry, they are yet to be convinced about the economics and the assurance of future supply of the resource.

- For the near future, geothermal energy will be a supplement to, not a replacement for, baseload energy.

- Small utilities may utilize small geothermal power plants, even though these may be uneconomical for large utilities.