GEOTHERMAL RESERVOIR ENGINEERING IN
THE EPRI GEOTHERMAL PROGRAM

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Early optimism about the rate at which geothermal energy might be developed in the United States appears to have diminished over the past two years, and the formula for accelerating the development of geothermal energy has proven elusive both for industry and the federal government. Certainly, the geothermal resource base has not changed, and several of the liquid-dominated fields have been better defined by continuing drilling programs. The technical problems have not changed significantly and progress has been made in the art of handling geothermal brines, notably the work with the hypersaline brines of the Salton Sea deposit. More applied research is underway and beginning to yield results. Why, then, has optimism diminished?

One of the main reasons is that power is not yet being generated in the United States from geothermal energy outside of The Geysers. Furthermore, there still are no firm plans to construct power plants at hot water-dominated resource sites. The nearest thing to a planned commercial size generating facility of this type is the Heber 50 MWe demonstration plant project initiated by EPRI and conceived for completion in 1980 with broad support from EPRI, the San Diego Gas and Electric Company (the lead utility), a number of other participating utilities, Chevron Oil, and ERDA. Many of the details of cooperation must be resolved in the next few months if the project is to remain on schedule. Including the possibility of another 10 MWe at the Geothermal Loop Experimental Facility at Niland and 10 MWe at East Mesa in California, the hydrothermal growth rate is far from impressive. If this slow trend is to be reversed and the commercialization of hydrothermal resources is to accelerate, more geothermal power plants must begin to appear in utility construction plans. In order for this to happen, the industry needs more precise estimates of the commercial potential of hydrothermal reservoirs both from the standpoint of energy production and energy conversion.

Although there are few firm plans, several utilities have tentative plans to use hydrothermal resources providing: (1) they have access to commercial quality resources; (2) the cost of geothermal power is competitive with other available energy sources; (3) that regulatory approval for such plants is forthcoming; and (4) environmental acceptance of geothermal power is achieved.

Although several of the known resource sites appear to have the potential for satisfying all of these conditions, the truth is that we have not yet satisfied all of these conditions at any of the sites. This, then, is one of the main reasons that utilities are cautious in regard to making firm commitments to plans that include geothermal power plant construction. A further cause for reluctance is that the potential of geothermal energy to displace other energy sources on a large scale has not been demonstrated. We do not yet know how much geothermal power we can depend on for electrical power generation.

The present status of geothermal development is somewhat disappointing, but may not be quite as grim as it seems. It appears to be a case of a young industry wanting to grow somewhat faster than could reasonably be expected. Both the potential and the challenge are still there and efforts should continue to establish the credentials of hydrothermal energy in the market place.

Importance of Reservoir Engineering

Aside from technology adaptation, verification of commercial viability and environmental acceptance, one of the most crucial efforts in the commercialization of hydrothermal resources will be reservoir assessment. It seems reasonable to speculate that as reservoir production and geothermal fluid characteristics are defined with better accuracy and greater confidence, geothermal power plants will begin to appear with increasing frequency in the future plan of utilities.

A decision on the part of a utility to construct a geothermal power plant naturally involves a host of considerations, but most relate one way or another to the results of reservoir assessments. Overall reservoir capacity, rate of sustained production, fluid heat content, fluid purity and the amount and species of non-condensible gases, are important considerations, particularly as they relate to power needs, selection of appropriate conversion processes and environmental controls. Reservoir assessment is one of the most important links in the development of geothermal energy, and reservoir engineering is an exceedingly important part of reservoir assessment.

Rationale for Including Reservoir Assessment Projects in the EPRI Program

For all practical purposes geothermal energy is a sole source commodity. It cannot be transported except over short distances; therefore, power plants must be sited near the source. Once a commitment is made to a particular reservoir, the commitment is irreversible in that fuel substitution is not a likely possibility.

Geothermal power plants must be designed to operate with low enthalpy fluids, making it unlikely that higher grade fuels could be sacrificed to continue operation of geothermal plants, if the reservoir fails to produce as expected. In such an event, the utility could experience capital losses associated with the plant as well as loss of generating capacity required to meet public need. The inherent nature of this type of arrangement suggests that the utility seek assurances that the reservoir will sustain production of fluids with consistent purity and energy content for the life of the power plant prior to commitment of funds to construct a plant.

Assurances of reservoir production may conceivably be obtained in two ways. The first would be for the resource company to assume all of the risk by guaranteeing the flow of energy, and indemnification against capital loss and loss of generating capacity. This could be achieved only by guaranteeing alternate fuels that could be used at other plants to make up any lost capacity, should the reservoir fail. However, such a complete guarantee is not likely. A more probable approach would be for the utility to share some of the risk, in which case it would want to participate in reservoir assessment either directly or through qualified consultants. In either case, the utility would have a need to be conversant with the technical disciplines of reservoir assessment, as they reflect reservoir reliability and longevity, fluid purity, long-term temperature stability, production capacity and the capacity of the reservoir formation to accept injected supersaturated brines. For the foregoing reasons and EPRI's emphasis on acceleration of geothermal development, EPRI has an interest in advancing the art of reservoir assessment and reservoir engineering.

Scope of EPRI's Current Effort

Several of the projects in the current EPRI geothermal program are loosely related to reservoir assessment. Only one is directly related. The brine chemistry project is intended to improve the capability to analyze the performance of brine systems as a function of the chemical and thermal properties of geothermal brines and the thermodynamics, hydrodynamics and chemical kinetics of the brine processing system. Although the project is oriented toward power plant analysis, the analytical techniques are expected to be useful in assessing the economic value of different geothermal brines for electric power generation. Two heat exchanger tests at Heber, one completed last year and a second almost complete, were conducted to develop data on heat exchanger performance as an aid in developing design criteria for commercial size heat exchangers. Here again the results should be useful in making first order approximations of the economic worth of brines, particularly brines similar to those found at Heber. In our feasibility study for the 50 MWe low salinity hydrothermal demonstration plant project, a significant portion of the effort was devoted to reservoir analysis. The mobile laboratory project is intended to increase and improve the information base on geothermal brine properties and their economic potential through standardized field testing.

Reservoir Assessment Guideline Manual

This project is more directly related to reservoir assessment. Its purpose is to develop a guideline manual on reservoir assessment primarily for use by utilities; however, the intent is to include sufficient information to make it useful to practicing reservoir engineers as well. The objective of the effort is not necessarily to advance the state-of-the-art, but to consolidate the existing body of information into a central source. The need for the manual stems from the fact that many techniques presently used to assess geothermal reservoir potential are not well documented in the open literature and have not been standardized by the industry.

For the purpose of this effort, reservoir assessment is viewed as that spectrum of activities and technical displines that, when combined into a logical sequence, are expected to lead to optimum choices regarding: (1) where to search for geothermal energy; (2) where to locate exploratory wells; and (3) assessment of the commercial potential of reservoirs. The relative role of reservoir assessment in the electric power development cycle is illustrated in Figure 1.

Since some assessment techniques are new and others are expected to emerge from current research, standardization of techniques is probably premature: however, the absence of standardization makes it difficult to compare results obtained by one group with those obtained by another, and a common reference may be useful in this context. Some standardization would be beneficial to the power generating industry in that it could serve to remove some of the ambiguities that arise from different sets of assumptions, different computational procedures, and sometimes different standards of measurement, test and data interpretation. It could increase the level of confidence placed on projections of reservoir power potential and lower the perceived risk of investment in geothermal power plants.

The approach is to include the following sections or chapters in the manual:

Geothermal Reservoir Assessment Philosophy and Rationale
Prospecting
Exploration
Reservoir Development
Production Facilities

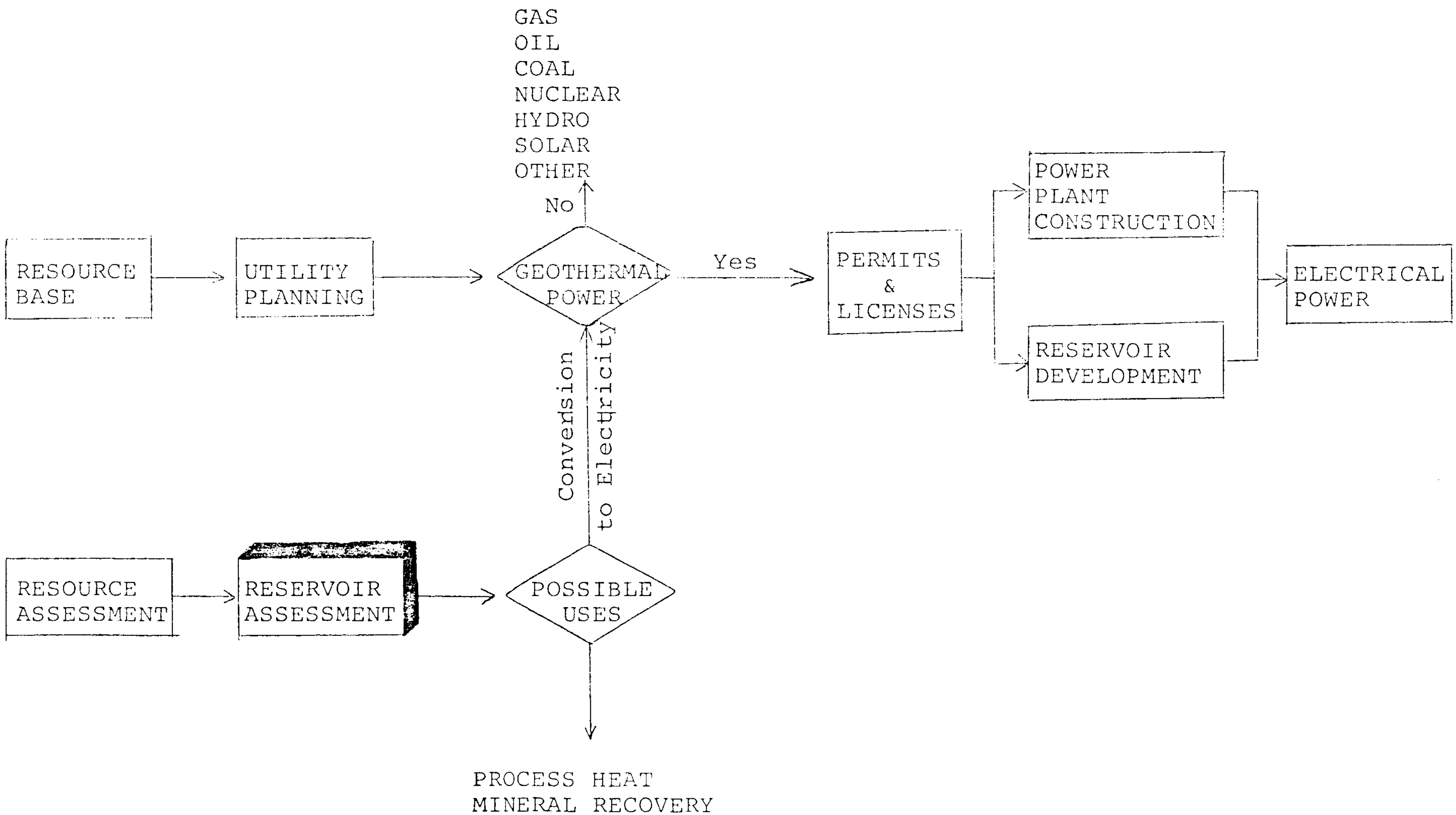

FIGURE 1. GEOTHERMAL ELECTRIC POWER DEVELOPMENT CYCLE

Production Test
Reservoir Management
Case Studies

The major emphasis will be on:

Geophysical Data Analysis
Geochemical Data Analysis
Well Log and Core Analysis
Well Test Data Analysis
Reservoir Performance Prediction
Well Bore Engineering

The text will contain concise descriptions of scientific principles and calculation procedures. Each calculation step will be illustrated by practical examples. The number of calculations required of the user will be minimized by making use of parametric charts covering the range of expected values. The charts will be developed using dimensionless variables so that a relatively small number of charts can be used for a large range or reservoir conditions. Direct readings from tables, charts, and nomograms, supplemented by a few calculations on a small calculator, should be sufficient for rough assessments. The manual will include conversion tables, tables of relevant mathematical functions, and a selected bibliography.

Gross Heat and Fluid Reserves: Common geophysical exploration techniques will be described. Examples of simplified, approximate techniques of deriving useful reservoir information from geophysical data will be included. Some examples include areal extent of the reservoir, subsurface geological structure, depth to the geological basement, presence of faults, fault activity and, in some cases, the reservoir temperature and salinity of the water. Inferences about locations of active faults can indicate the seismic risks. The techniques of estimating reservoir temperature from chemical analysis of water will be discussed. A brief account will be given of the principles of assessment of corrosion, scaling, and environmental pollution potential from chemical analysis of the water.

Recoverable Energy: Acquisition of qualitative and quantitative information on reservoir thickness, rock type, pay zones, porosity, permeability, water quality and temperature, will be discussed. Common well logs will also be discussed.

Flow Rates, Well Stimulation Pumping: Techniques of deriving important reservoir information from well tests will be reviewed. The information that can be derived from such tests include reservoir pressure, well productivity, reservoir boundaries, continuity and interconnection of various producing layers, expected flow rates, the need for well stimulation and pumping requirements.

Temperature Performance: Simplified techniques for predicting pressure, temperature, and flow behavior of a reservoir for at least 30 years will be discussed. Temperature decline will dictate increased production with corresponding escalation of operational costs. Temperature performance of a reservoir is almost as important as the heat reserve. Techniques for estimating temperature, pressure, density, and quality (proportions of steam and water) of the fluid as it flows up the well bore will also be presented in the manual.

The first issue of the Reservoir Assessment Manual is planned for completion by the end of this year.

Conclusion

Modest progress has been made in the definition of hydrothermal resources and development of the geothermal information base. The reluctance to build hydrothermal power plants thus far is a function of many factors but one important factor is the need for more complete and more accurate reservoir assessments for hydrothermal fields. EPRI's geothermal program has a small effort in reservoir assessment at this time, but a strong interest in advancing the art, and hopes to be in a position to expand the effort in the future.