ROCEEDINGS, Twenty-Second Workshop on Geothermal Reservoir Engineering
tanford University, Stanford, California, January 27-29, 1997
GP-TR-155

GEOTHERMAL RESEARCH AND DEVELOPMENT ACTIVITIES OF THE DEPARTMENT OF ENERGY

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ABSTRACT

Working closely with the U.S. geothermal industry in cost-shared research allows the Department of Energy to multiply the effectiveness of Federal funding for geothermal research. Industry reviews of the Geothermal Research Program provide a focus for the scientific investigations and the technology developments. Education of the geothermal industry and the public is an important part of the Federal research effort, and the rapid transfer of newly developed technologies supports the industry's expanding use of geothermal resources worldwide.

INTRODUCTION

The Department of Energy (DOE) is committed to developing new technologies that can be used by the **U.S.** geothermal industry to lower the risk and the cost of geothermal development. The **U.S.** Congress appropriated approximately $30 million for the DOE Geothermal Research Program for Fiscal Year 1997, and the DOE Office of Geothermal Technologies is responsible for implementing the research program. With this funding, DOE works with industry to assist in solving the technical problems which slow the development of geothermal resources worldwide. In recent years, DOE geothermal research has benefitted greatly from the active participation and cost sharing of the **U.S.** industry. The Office of Geothermal Technologies continually solicits ideas and suggestions for research priorities that help focus on the needs of industry.

DOE funds several research programs to generate new technology in the areas of: exploration, drilling, reservoir management, energy conversion, chemistry and materials, and direct-use geothermal applications. This program has gathered experienced researchers in well equipped laboratories, and these experts continually provide DOE with innovative geothermal technology development. No mater how excellent the research group, there is a recognized need for industry collaboration to focus the research and to rapidly transfer new ideas to the development companies. At this workshop, you will hear about many research projects funded in whole or in part by DOE. Most of this research benefits from strong industry participation. The operational knowledge contributed by industry participation in this research is vital to working out practical solutions to many technical problems.

Education is an important part of the DOE Geothermal Program. Funding is provided for the education of graduate and undergraduate students working on geothermal degrees in order to assure that a well trained pool of scientists and engineers is available to assist the industry. DOE participates in education and training for the geothermal industry to make sure the latest research information is easily accessible. The Office of Geothermal Technologies also supports the preparation and distribution of educational materials to primary and secondary school science classes. The development of geothermal resources will benefit from an educated citizenry.

RECENT IC

In December 1995, the Geothermal Energy Association (GEA) provided an industry committee to review the DOE Hot Dry Rock research program. Based on this review, the industry committee presented suggestions to DOE for the future of the program. Key to the suggestions was the need to transfer the management and future direction of the research program to industry. The committee decided that a thorough industry assessment is needed to

expedite the rapid transfer of commercial technologies from the basic studies of a national laboratory to implementation by industry.

During 1996, GEA convened groups of industry representatives to participate in three reviews of DOE research programs. These reviews considered Drilling, Reservoir Production, and Subsurface Permeability Detection and Mapping. The goal of these reviews was to provide DOE with a ranking of industry priorities within each of the geothermal research categories. DOE is now working with the industry to implement these suggestions, and additional reviews are anticipated in 1997 for the Conversion Technology and the Chemistry and Materials programs.

In the recent reviews, the **U.S.** geothermal industry strongly suggested that DOE should concentrate its research efforts on a few of the most pressing technological problems. It was recommended that DOE research focus on both better drilling methods and better ways to detect fracture permeability in order to significantly reduce the cost and number of exploration and production wells that would be drilled in a geothermal project. Industry representatives advised DOE that geothermal reservoir simulation needed improvement by (1) quantifying the physical parameters that govern reservoir properties, (2) basing simulation on geologic reservoir models, and **(3)** incorporating fluid and rock chemistry in the simulation to reflect changes in reservoir permeability. The reviewers proposed a set of monographs, written by renowned experts in the field, to document the state of injection technology for geothermal systems and to describe the ongoing monitoring and evaluation of producing reservoirs. These monographs would delineate the state-of-knowledge for these technologies to provide industry with a compilation of the basic information now available.

ACCOMPLISHMENTS

In 1996, the laboratory phase of the hot dry rock program was successfully completed, and the final report is now in preparation. DOE plans to transfer this program to industry management for continued research into thermal energy extraction of low permeability rocks. Also in 1996, the East Mesa Test Facility, used for geothermal research since the 1970s by the Bureau of Reclamation and later by the Department of Energy, was restored to its natural state, and the land was returned to the control of the Bureau of Land Management.

The Geysers geothermal field is being used as a test area for several projects to reduce operating and maintenance costs of geothermal electrical generation. **A** cost-shared project, with funding from industry and DOE, has developed a prototype steam-driven gas compressor (for the removal of noncondensible gases) that will soon be tested at The Geysers. **A** three-dimensional, honeycomb shaped lattice has been constructed to increase the efficiency of steam condensation within a direct-contact condenser, and this design will be tested at one of The Geysers generating units. A jointly funded project with industry will soon be testing the use of specially cultured bacteria to remove mercury from sulfur produced by the Stretford process of hydrogen sulfide abatement.

Construction is nearly complete for the binary turbine test facility at the National Renewable Energy Laboratory in Golden, Colorado. This facility will use a gas-fired boiler to produce the large amounts of hot water necessary to test the operation of binary geothermal turbines.

RESEARCH IN PROGRESS

The geothermal industry is currently conducting geothermal exploration ventures in andesitic volcanic regions in several areas of the world, and the DOE-funded research in Fracture Characterization is examining technologies that will be useful in andesitic systems. The research goal is to develop techniques to more effectively locate producing fractures and to decrease the number of unproductive wells that are drilled. DOE-funded research is examining geophysical methods to determine anomalous electrical properties through magnetotelluric measurements from the surface and through electromagnetic measurements from well bores. Research is also being conducted to locate and characterize fractures through detection and interpretation of anomalous seismic signals. The phenomenon of shear-wave splitting from fractures is being investigated at The Geysers. Borehole receivers are being used to evaluate acoustic emissions from fractures in Dixie Valley and The Geysers. Plans are underway for a three-dimensional seismic survey to assess the geothermal application of this common oil and gas technique.

Reservoir Injection research still has a high level of activity in The Geysers geothermal field, where treated effluent will soon be used to augment the injection of condensate. Water injection is critical to maintaining the productivity of all geothermal reservoirs, and the DOE research is directed to determining the optimum flow rate and best location for injection into a reservoir. The Dixie Valley geothermal field has become another focus of injection-related research. Converging projects in tracer flow, state of stress measurements, and water chemistry studies are now producing preliminary results. This research is building a knowledge base to determine the factors that control the location of open and permeable fractures along the normal faults in the Basin and Range Province.

Drilling Research is focused on reducing the high cost of drilling geothermal wells. Methods to reduce the time involved in geothermal drilling, particularly the time needed to regain circulation after total loss, are considered key to cost reduction. Other time consuming activities, such as cementing, are being examined for possible reduction of cost. The need to provide a strong and stable cement bond between surface casing and the surrounding rock has led to the investigation of cement additives and coatings for the casing pipe. Development of a core barrel latching indicator for exploration coring operations is nearing completion, and a downhole fluid-sampler is ready for testing.

The long term research effort in reservoir simulation has greatly improved the predictions for reservoir response to production and injection. Laboratory studies have confirmed the significance of adsorption for the storage of fluid in a vapor-dominated reservoir, and this phenomenon has been added to some simulators. Research is underway to better characterize the physical properties of a geothermal reservoir and to incorporate those properties in reservoir simulation. Tracer testing has become a reliable tool in revealing the major paths of fluid flow through fractures. The examination of rock cores with nuclear magnetic resonance imaging (MRI) and computer assisted x-ray tomography (CT-scan) appears promising for the determination of the initial fluid saturation in a reservoir, and these methods have demonstrated the infiltration of drilling fluid into very low permeability rocks.

Experimental laboratory studies and computer simulation research used to investigate hydrothermal fluid-rock chemical reactions are producing important results. The basic thermodynamic parameters are now available to describe the formation of acid conditions in the "high-temperature reservoir" of The Geysers, and the isotopic shift due to salinity is now understood for the brine-vapor systems. More accurate equations of state and simulators based on ion-interaction parameters are being used successfully to model the point of gas breakout and the onset of scale formation in producing geothermal wells.

SOLICITATION OF NEW RESEARCH IDEAS

The Office of Geothermal Technologies worked with the DOE Idaho Operations Office to issue a solicitation for new and innovative research. This solicitation opened in November of 1995 and will close in October of 1997. Representatives from several geothermal companies are involved in the review of these research proposals, and they are asked to evaluate the proposed studies on the basis of industry needs. The more successful research proposals were discussed with industry prior to submittal to make sure the critical needs of geothermal development were met. The resulting projects have added some creative new research to the DOE-funded activities.

The Idaho Operations Office will soon issue a solicitation for the management of an industry-directed program to continue the hot dry rock research effort. It is expected that this new phase of research will continue to develop the technology necessary to commercially extract thermal energy from low-permeability rocks.

EDUCATION

The DOE Office of Geothermal Technologies supports geothermal education on a number of levels. You are all aware of the excellent reputation in geothermal education that the Stanford Geothermal Program has developed. For the past twenty years, Stanford has received funding from DOE to conduct geothermal research and to train graduate students in geothermal reservoir engineering. In order to stimulate scientific interests in younger students, DOE provides funding for the Geothermal Education Office (GEO) in Tiburon, California. GEO prepares and distributes educational materials on geothermal energy for the primary and secondary schools.

The continuing education of the professionals in the geothermal industry is one of the top priorities. DOE contributes indirectly to the Stanford Geothermal Workshop each year by encouraging DOE-funded

researchers to prepare and deliver papers on their latest investigations. The DOE Geothermal Technologies Office presents a yearly Program Review to provide the geothermal industry another opportunity to learn about the current research results, and DOE requests industry comments on the quality and direction of the research. In addition, DOE provides funding to the Geothermal Resources Council Annual Meeting to further the exchange of new technology between research institutions and the geothermal industry.

A growing number of education sites are available on the Internet as part of the World Wide Web. The following is a list of World Wide Web sites of geothermal interest that are funded by DOE.

1. "http://doegeothermal.inel.gov/"US DOE Geothermal Technical Site, is a site for technical information about the DOE Geothermal Research Program and contains the yearly research summaries for each project.

2. "http://www.sandia.gov/eesector/gs/gtlgeotherma l.html" Geothermal Research Department, is a site for information about the Geothermal Drilling and Instrumentation research program conducted at the Sandia National Laboratory.

3. "http://ekofisk.stanford.edu/geotherm.html" Stanford Geothermal Program, is the site for geothermal research and instruction at Stanford University.

4. "http://www.oit.osshe.edu/~geoheat/" Oregon Institute of Technology, GEO-HEAT Center, is a site for information about direct use (non-electric) applications of geothermal energy.

5. "**http://www.geothermal.org/**"The Geothermal Resources Council, is the site of this international industry organization and contains a reference library for most of the published geothermal information.

6. "**http://www.eisweb.com/geo/**"Geothermal Education Office, is the site for information concerning primary and secondary school teaching materials on geothermal energy.

SUMMARY

The Geothermal Research Program of the Department of Energy has been successful in the development and deployment of new technologies because of collaboration with the geothermal industry. Joint field operations have allowed the research to expand into operational problems facing the industry, and the geothermal industry provides access to wells and power plants that are critical to many research projects. Industry review of several research programs has provided new focus to the technology development. Expanded DOE efforts in education and improved dissemination of technology developed by DOE the research program have made the results of government-funded research more available to the geothermal industry.