HOT DRY ROCK IN THE USA: WHERE IS IT GOING?

David DUCHANE

Los Alamos National Laboratory

ABSTRACT

Since its beginning in the early 1970's, the US Hot Dry Rock (HDR) Program has carried out extensive field work at the Fenton Hill HDR pilot facility in northern NM, USA. Over a period of more than 25 years, two engineered reservoirs were created, and the practicality of producing energy from HDR was unambiguously proven. An automated surface plant was operated for a total of 11 months between 1992 and 1995. Consistent energy extraction was achieved during several flow-testing phases. When operating under steady state conditions, no declines in fluid production temperatures were observed, water consumption reached low levels and was continuing to decline, and all other measurements indicated that HDR reservoirs would have long productive lifetimes. In addition, cyclic testing showed the potential for load-following production schedules that could enhance the economic value of HDR energy production.

In late 1995, the US Department of Energy (DOE) announced its intention to restructure the US HDR program to work with "private industry and other interested parties" to address the remaining technical issues, rather than pursuing commercialization of the technology. As this paper is being written, the exact nature of these "remaining technical issues" has yet to be defined. As an initial step in the restructuring process, a group of experts from the Geothermal Energy Association met in December 1995, under the auspices of the DOE, to formulate recommendations on the future course of HDR work in the United States.

HDR field activities in the US reached a low point in 1996 with little definitive action on the restructuring process. Reservoir modeling studies at Kansas State University and some technology transfer work continued, but essentially, the only field activities involved the shutdown of the Fenton Hill test site. By the beginning of 1997, most of the geothermal wells at the Fenton Hill site had been plugged and the site assets were in the process of being diverted to non-HDR activities.

As of early 1997, proposed, but yet not implemented, DOE actions included soliciting proposals from stakeholders for projects to help advance the state-of-the-art of HDR technology, participation in International Energy Agency-sponsored tasks on HDR, the completion of a final report archiving the Fenton Hill HDR experience, and development of a 5-year plan to achieve unspecified HDR technology improvements. The DOE also indicated that it planned to commission an in-depth review of HDR and that it would transfer field management of US HDR activities to the private sector via a solicitation process, but these measures were also still awaiting action. In the meantime, budgets for federally funded HDR work in the US have continued to decline. On the positive side, several US entrepreneurial organizations are in the process of formulating HDR projects that may go forward with or without federal government participation.

INTRODUCTION

Accomplishments of the US HDR Program. The concept of extracting geothermal energy from HDR by circulating water through an engineered geothermal reservoir created by hydraulic fracturing originated in the United States more than 25 years ago. The original HDR patent (Potter et al) was issued to the Los Alamos National Laboratory in 1974. That patent has now expired. Beginning in 1974, the Los Alamos National Laboratory, working under the sponsorship of the DOE, conducted numerous experiments and extensive field testing at the Fenton Hill HDR Test Facility.

The world's first HDR reservoir was created at Fenton Hill between 1974 and 1978. Flow tests of that reservoir from 1978 to 1980 showed that it was possible to extract heat from HDR reservoirs and set the stage for worldwide interest in HDR technology (Dash et al 1981). A second, much larger HDR reservoir was developed and characterized at Fenton Hill between 1980 and 1986 by an international team comprised of scientists and engineers from Japan and Germany as well as the United States. This large, Phase II, HDR reservoir was utilized for research, developing, and testing until the autumn of 1995.

Experiments conducted with the Phase II HDR system revolutionized our understanding of the characteristics of HDR reservoirs. Originally, it had been thought that the application of hydraulic pressure caused the formation of nearly vertical, planar fractures in crystalline rock. Analysis of the development of the Phase II reservoir indicated that no new fractures are created by hydraulic stimulation, but rather that pre-existing joints are opened by the pressurized water in a pattern that is related to both the contemporary stress field and the pre-existing pattern of jointing in the rock.

The most extensive and rigidly controlled HDR flow testing to date was carried out on the Phase II reservoir at Fenton Hill. After installation of a highly-automated surface plant, the long-term sustainability of HDR energy production was demonstrated in a series of flow tests conducted from the spring of 1992 through the summer of 1995 (Duchane 1996). As shown in Table 1, production flow rates and fluid temperatures changed little over the 4-year test period, during which flow operations were sustained for a total of 11 months.

Table 1: Typical Operating Data From Flow Testing of the Fenton Hill HDR System, 1992-1995

Year:	1992	1993	1995
Primary Control Parameters			
Production Backpress., Mpa	9.7	9.7	9.7
Injection Press., Mpa	27.3	27.3	27.3
Operating Results			
Production Rate, l/s	5.68	5.86	6.57
Production Temp., °C	183	184	185

Flow testing at Fenton Hill also set new benchmarks for other aspects of HDR technology. Water loss was eliminated as a major issue in determining the fundamental viability of the HDR process, as water consumption declined to a level of 7% of the injected volume and data indicated it would continue to decline under steady-state production conditions. The dissolved solids and gases in the fluid produced from the Phase II reservoir rapidly reached equilibrium values at low concentrations, and the fluid remained uniformly geochemically benign throughout the test period. Routine operation of the automated plant showed that HDR energy systems could be run using the same economical staffing schedules that a number of unmanned commercial hydrothermal plants employ.

Finally, the testing at Fenton Hill clearly indicated the unique characteristics of HDR reservoirs that may give this technology an edge in the competitive energy market of tomorrow. A series of short flow tests showed that HDR systems are particularly applicable to load-following operation in which the system output is rapidly adjusted to meet changes in customer energy demand (Brown 1996). Figure 1 illustrates graphically the results of one short test series in which the energy production from the Phase II reservoir was increased by 60% over a baseline level for a period of 4 hours each day on several successive days, and then returned to the baseline output for the remainder of each 24-hour period.

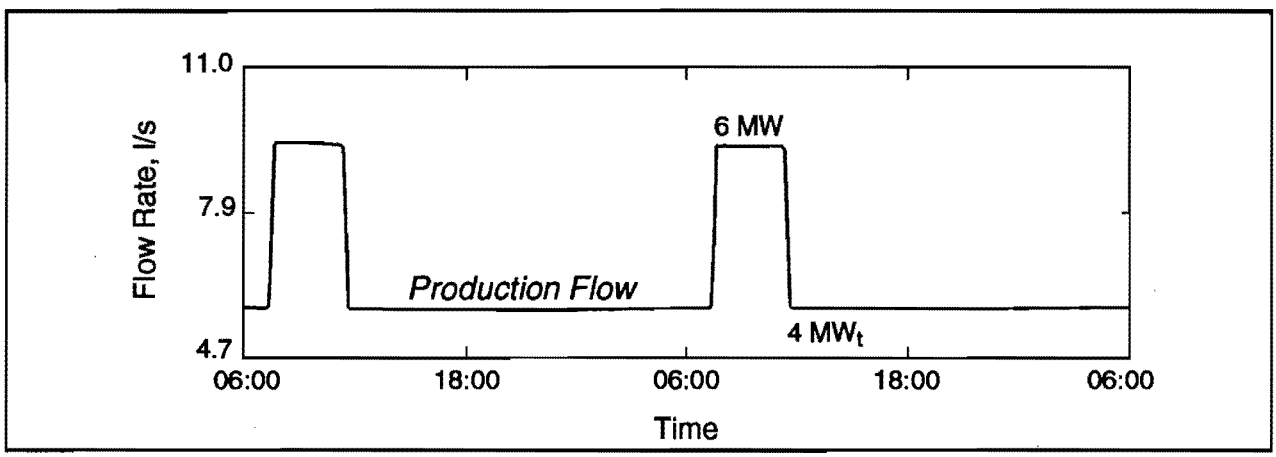

Figure 1. Cyclic testing at Fenton Hill showed that HDR systems are well suited for electricity demand load-following applications because the energy production rate can be rapidly increased substantially above a baseline production level on a daily basis, and held at that enhanced production level for an extended time period.

The variable production schedule depicted in Figure 1 was achieved with only small (<12°C) excursions in the production well temperature. After the initial parameters were established, it was automatically implemented each day via the computer control and feedback system in place at the surface plant. This short load-following experiment, in conjunction with additional cyclic operating data generated over the 4 years of flow-testing of the Phase II reservoir, unambiguously demonstrated that HDR reservoirs can be used to store energy for release only when it is most economically valuable.

DOE Actions Directed Toward Implementing HDR Power Production. In 1993, on the basis of the promising results of the Fenton Hill Phase II reservoir testing, the DOE solicited private sector interest in HDR technology. More than 40 responses were received indicating a strong industrial interest in the development of a power-producing HDR facility (Duchane 1995). In the face of this positive feedback, the DOE, in late 1994, issued a formal solicitation

seeking industrial partners to construct and operate a facility that would produce and market energy derived from an HDR resource (GRC 1995). Several proposals were submitted over the next few months. An expert panel, convened under the auspices of the DOE, met in June 1995 to evaluate the technical merit of those proposals that complied with the organizational requirements of the solicitation. After a thorough review the expert panel recommended that an award be issued and the project go forward. In October of 1995, however, the DOE changed its course on HDR, withdrew the solicitation, ordered the closure of the Fenton Hill HDR test facility, and announced that the US HDR Program would be redirected.

THE CURRENT STATUS OF HDR WORK IN THE USA

Initial Steps in Redirecting the US HDR Program. In announcing the restructuring of HDR work in the United States, the DOE stated that it intended to defer commercialization of HDR technology and instead would refocus the HDR program to "work with industry and other interested parties to resolve the key technical issues." The announcement went on to state that the Los Alamos National Laboratory was expected to play a continuing role in technology development. Shortly thereafter, the DOE asked the Geothermal Energy Association (GEA) to convene an industry panel to make recommendations on the future directions of HDR research and development in the United States.

The GEA panel met during the first week of December 1995 at the offices of Unocal Geothermal in Santa Rosa, California, USA. For the first day and one-half of the meeting, HDR experts from the US HDR Program at Los Alamos National Laboratory, the Japanese and European HDR programs, universities, and other organizations with HDR knowledge discussed all aspects of HDR technology, economics, and policy. The GEA committee then met in executive session to develop a set of "industry" recommendations on the future course of HDR in the USA. These recommendations were immediately presented in preliminary form to Allan Hoffman, then DOE Acting Deputy Assistant Secretary for the Office of Utility Technologies.

A formal report on the GEA meeting has never been issued, but a summary of the panel's recommendations appeared in an International Geothermal Association insert in the Geothermal Resources Council Bulletin in early 1996 (Wright 1996). As reported therein, the industry group affirmed the importance of HDR to the future of the geothermal industry, suggested that HDR technology should be integrated into the conventional geothermal industry, and proposed that the acronym "HDR" be replaced with a new term that would encompass all geothermal resources requiring artificial measures beyond current technology to achieve commercial heat extraction. They did not, however, offer any suggestions as to what the new term should be. The group also made the following specific recommendations:

* Unify management of all geothermal R&D programs and include HDR elements within the unified program.

* Convene a panel to formulate short- and long- term geothermal R&D goals including the long-term commercialization of HDR.

* Establish a peer-review committee to evaluate the current status of the US HDR Program, publish its findings, and implement technology transfer to move HDR technology into the geothermal mainstream.

* Mothball the Fenton Hill site.

* Coordinate US geothermal R&D efforts with HDR programs in other countries.

Decommission of the Fenton Hill HDR Site. Concurrent with its decision to redirect HDR work in the United States, and in variance with the above recommendations, the DOE ordered the full decommission and closure of the HDR field test facility at Fenton Hill, NM. Between March and December of 1996, 3 of the 4 deep geothermal wells at Fenton Hill and all but a few of the numerous shallow wells that had been used for heat flow measurements, seismic monitoring, and other supporting activities, were plugged and abandoned. The surface plant was completely dismantled and other decommission measures were implemented. Essentially all of the geothermal equipment and materials were placed in indefinite storage at Fenton Hill for possible application in future DOE projects. The Los Alamos HDR program is interested in transferring excess equipment to other organizations that may find them useful to advance HDR technology, and efforts to cooperate with the programs of other nations in this regard are currently underway.

Responsibility for the few remaining wellbores is being assumed by the Los Alamos National Laboratory. These will be used for a variety of petroleum-related tool development projects currently underway and will be available for future projects that may be undertaken by the Laboratory. Many of the assets at the Fenton Hill site will be transferred to other Los Alamos projects. The ponds at the site, for example, will be transferred to an astrophysical project that is already underway. The United States Forest Service, the owner of the property on which the Fenton Hill HDR facility was developed, has also expressed an interest in using the site for training forest fire fighters. It thus

appears that Fenton Hill will continue to be utilized for many years into the future, but unfortunately its role as the world's foremost HDR development site has come to an end.

Impending HDR Initiative by the DOE. With the closure of Fenton Hill, the potential for direct HDR field work in the United States is essentially zero. In a recent publication, the DOE stated that it plans to maintain an HDR effort by undertaking the following activities (Hooper & Duchane 1996):

* Solicit proposals from stakeholders for projects that would help advance the state-of-the-art of HDR technology.

* Participate in two or more tasks under the HDR part of the proposed International Energy Agreement on geothermal energy.

* Issue a final report archiving the Fenton Hill experience for use by interested stakeholders.

* Develop a five-year plan for technology improvements needed by the geothermal industry to increase their confidence in HDR technology.

The DOE has also indicated that it intends to commission a review of the US HDR Program that will evaluate the accomplishments to date and make suggestions for the future course of the program. Perhaps these suggestions will form the basis for the five-year plan mentioned above. As another step to increase private sector participation in US HDR work, the DOE is planning to seek a private organization to manage the reformulated HDR effort.

As this paper is being written, no definitive steps have been taken to implement any of the planned new directions in HDR work. The HDR budget in the US declined from somewhat over $3 million in Fiscal Year 1996 to less than $2 million in 1997, and the future of federally-funded HDR work is highly uncertain, especially in the face of low energy prices the US and a strong pressure to balance the national budget.

Other HDR Activities in the US. Although federal support for HDR research and development in the US is in a state of uncertainty, there are a number of opportunities to advance the state of HDR with funding from other sources. The State of California recently passed legislation that will provide very significant appropriations for research, development and demonstration work on renewable energy technologies. At the invitation of the California Energy Commission, representatives of the Los Alamos HDR program are participating in workshops and hearings that will help determine the rules under which the available funds are allocated. Because California is a state with extensive high-grade HDR resources and has a well-developed geothermal industry already in existence, there is a significant potential for the development of an advanced HDR project with a combination of state, private, and perhaps minor federal funding.

A number of private entrepreneurs have indicated an interest in taking the HDR technology proven at Fenton Hill to the next step of implementation. These projects, which generally entail applying HDR technology to unique situations, are in the early stages of development and will, no doubt, involve many proprietary activities if they move forward.

SUMMARY

In late 1995, the DOE decided to change the focus of HDR work in the United States by stepping back from a drive toward commercialization of the technology. The Fenton Hill HDR test facility has been decommissioned and guidance from the US geothermal industry has been sought to help formulate future HDR directions. Initial industry recommendations emphasized integrating HDR work into other geothermal R&D programs, assembling one or more panels to take an in-depth look at the state of HDR technology for the purpose of developing short- and long-term research and development goals, and increasing cooperation with HDR programs in other countries.

The DOE recently indicated that it intends to actively solicit proposals for HDR projects in the United States and will participate in at least two of the HDR tasks being formulated under the International Energy Agreement on geothermal energy. The DOE will also issue a final report summarizing and archiving the accomplishments at Fenton Hill. For the longer term, the DOE plans to turn the management of HDR R&D over to a private-sector contractor and to develop a five-year plan for achieving HDR technology improvements of interest to the geothermal industry.

The federal budget for HDR has been declining recently, and current trends in federal spending in the United States give no indication that these budget declines are likely to be reversed in the near future. There is some non-federal public and private industry interest in HDR development in the United States, but these efforts are still in their formative stages.

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