GL01216

Federal Hot Dry Rock Geothermal Program

A Brief Summary

University of California

LOS ALAMOS SCIENTIFIC LABORATORY
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The Los Alamos Scientific Laboratory (LASL)* has developed the first Hot Dry Rock (HDR) geothermal energy extraction system in the U.S. at Fenton Hill, New Mexico. The system at Fenton Hill is a field test of the LASL hot dry rock concept. In 1978, an expanded Federal Hot Dry Rock Geothermal Energy Development Program was established by the U.S. Department of Energy with LASL as Program Manager and embracing the Fenton Hill project as the first of several demonstrations.

Background on Site 1, Fenton Hill

In the LASL hot dry rock concept, a manmade reservoir is formed by connecting two deep holes in geothermally heated impermeable rock through a system of fractures produced hydraulically (by pressurizing water). Cold water flows down the deeper hole, is heated by the hot rock in the underground fracture system, and is brought to the surface in the second hole as superheated water under sufficient pressure to keep it from boiling. After the hot water flows through a heat exchanger at the surface, it is pumped back down the injection hole forming a completely contained, closed-loop recirculating heat extraction system. In a commercial operation, the heat from a system such as this could be used to heat homes, for agricultural and industrial uses, or to generate electricity.

The first deep hole of the Fenton Hill system, Geothermal Test Hole No. 2 (GT-2), was drilled in 1974 to a depth of 9620 ft, where the granite reaches a temperature of 390°F. By pumping water into a section near the bottom of the hole, sufficient hydraulic pressure was applied to split the wall of the hole, creating an artificial fracture. With continued pumping, this thin, nearly vertical crack was extended outward several hundred feet and additional fractures were created. During 1975, the second deep hole of the system, Energy Extraction Hole No. 1 (EE-1), was located approximately 250 feet north of the GT-2 wellhead and drilled to intersect the largest of the fractures. Where they intersect the fracture system, the two holes are about 40 feet apart. Hole EE-1 extends to a total depth of 10,050 feet and a rock temperature of 400°F. However, the main fracture system connecting the two holes is within the interval between 8600 and 9500 feet where the average rock temperature is about 370°F.

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* LASL, one of the largest multidisciplinary, multiprogram National Laboratories in the U.S., is managed by the University of California for the Department of Energy (DOE).

The longest continuous full-scale operation of this system was conducted between January 27 and April 12, 1978. During this 75-day test, the impedance (resistance of the fracture system to the flow of water through it) decreased by a factor of 5, to about 3 psi/gpm; and the rate of water loss by permeation into rock around the fracture decreased to less than 1-1/2 percent of the circulation rate. The maximum temperature of water reaching the surface through GT-2 was about 270^{o}F, and the rate of energy extraction increased steadily to about 5,000 kilowatts of heat (which would be sufficient to heat several hundred homes). The thermal behavior of the system was that which might be expected from one in which the fracture had a surface area of about 86,000 square feet. Toward the end of the test, there were indications that the system was growing — presumably because of pressure and cooling effects — and that new rock surfaces were being exposed.

Careful monitoring showed no evidence of induced seismic activity or of any other detectable environmental effects, aside from the release of warmed air above the site. This was the first demonstration anywhere that energy could be safely recovered at usefully high rates and temperatures from hot dry rock for a sustained period by a manmade system.

Additional testing has since been conducted and, to date, about 10 million kilowatt hours of thermal energy have been extracted.

The Federal Program

LASL's successful creation and heat extraction operation from the Fenton Hill system convinced DOE to expand the Hot Dry Rock Project to a program of national scope. While the Fenton Hill project remains the cornerstone activity, experimental operations similar to those at Fenton Hill will eventually be undertaken at selected locations elsewhere in the United States. This program - officially termed the Federal Hot Dry Rock Geothermal Energy Development Program (FHDR Program, for short) - is to be field managed jointly by LASL and DOE. Its charter is to determine the potential of HDR geothermal energy as a significant energy source and provide a basis for its timely commercial development. A major part of the FHDR program will be conducted through contracts with private industry.

In cooperation with the USGS, LASL has been conducting field studies in several states directed toward evaluation of HDR potential. In addition, three 100-square-mile areas in the United States will be chosen as prospective target areas within which future sites for the development of prototype geothermal energy extraction systems may be located. Selection of the target prospects will be made by LASL working with the National Hot Dry Rock Program Development Council. Then industrial firms, under contract to the DOE and LASL, will investigate these areas for technical feasibility, and one or more sites will be selected for a deep exploratory test well and possible subsequent development through a pilot or demonstration plant, if warranted. Drilling at still other sites may proceed after additional regional evaluations and field studies.

Under the current schedule, the three target prospect areas are to be chosen in early 1979. This selection will be followed by about a one-year effort by LASL and two subcontractors to determine the candidate locations for a new HDR experimental site (Site 2) within the three prospects. In the fall or winter of 1980 a contractor will be selected by the joint LASL-DOE FHDR Program Office to plan, initiate, and direct the implementation of a full-scale HDR R&D effort at Site 2. The objectives of this second site will be to:

(1) demonstrate the HDR reservoir-creation techniques developed at Fenton Hill in a different geologic setting;

(2) extract energy from the reservoir in an experiment of sufficient intensity and duration to establish useful reservoir life; and

(3) provide an operational pilot (probably a direct-heat application) demonstration by late 1985 to early 1986.

Advertisements and announcements to potential contractors for the second HDR experimental site effort have been placed and a solicitation of interest conducted. The response has indicated that a request for proposals will probably be issued sometime in the summer of 1979. The above schedule will depend on the priorities of, and the continued support of, the U.S. Department of Energy to the FHDR Program.

As previously noted, the FHDR program will include the current and future work at Fenton Hill, NM. The continuing reservoir development efforts at this original site will provide the basic information as well as the scientific advances and technology improvements needed to support the broader program. The LASL technical staff involved in this element of the FHDR program will provide scientific and technical advice to the program and, through the FHDR Program Manager, provide a review, planning, and evaluation function. Their expertise and experience will be available to other elements and contractors in the program as well as to other interested firms and individuals. In addition, the continued developments at the Fenton Hill Site will provide a focus for research and development in areas of drilling technology and equipment, instrumentation improvements and measurement technology, reservoir formation and testing techniques, geochemical evaluation methods, reservoir modeling and simulation, resource evaluation, and exploration methodology.

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Los Alamos Scientific Laboratory
P. O. Box 1663 MS 575
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January 1979

GEOTHERMAL CONFERENCE

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In reply refer to: Geological Applications, G-9
Mail stop: 983

January 10, 1979

Dr. P. M. Wright
Earth Science Laboratory
University of Utah Research Institute
391-A Chipeta Way
Salt Lake City, UT 84108

Dear Dr. Wright:

Enclosed is a copy of a memo from Mort Smith, G-DO (LASL) dated January 2, 1979 and one draft version of the Federal Hot Dry Rock Program.

Sincerely,

Bill

A. William Laughlin

AWL/jm

Encl. a/s

xc: ISD-5, MS 150
G-DO, MS 570
Members of Site Selection Committee
G-9 File

LOS ALAMOS SCIENTIFIC LABORATORY
UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO 87545
Telephone Ext.

OFFICE MEMORANDUM

TO : Distribution

DATE January 2, 1978

FROM : M. C. Smith *M.C.S.*

SUBJECT : HDR Site Selection

SYMBOL : G-DOT

MAIL STOP: 575

Attached is a rather elaborate memorandum on site selection which I have prepared for possible distribution to members of the Site-Selection Committee of the National HDR Program Development Council in advance of their meeting here on February 1 and 2. It is based on my memorandum of November 6, 1978, which was sent to all of you, but also includes material from memoranda by Brownlee, Heiken, and Laughlin on the same subject.

In order to be as quantitative as possible, I have been fairly arbitrary in stating such things as depths, areas, temperatures, and permeabilities. If you differ with me on any of these or any other part of the memorandum, or if you think of something that should be added, please tell me about it at once. I will either revise the memo peaceably or argue it out with you.

Unless there is strong objection, I will mail the memorandum out on or about Wednesday, Jan. 10, so that the Committee Members will have a chance to chew on it before they come to Los Alamos.

MCS:mw

Distribution:
G. Nunz
G. Heiken, MS 978
E. Kaufman
P. Franke
R. Brownlee
A. Laughlin, MS 983
J. Tester, MS 981
File

HOT DRY ROCK SITE SELECTION, FY 79-80

A. Programmatic Purpose

To arouse interest and encourage industrial investment in hot dry rock energy systems, it is necessary to demonstrate:

(1) The widespread existence of large thermal reservoirs at usefully high temperatures in crustal rock at depths which are accessible with conventional drilling equipment and techniques;
(2) Technology which is sufficiently efficient, flexible, and economical to make possible the extraction and use of energy from dry geothermal reservoirs at a profit to the investors in such systems;
(3) An institutional framework and climate of public and governmental acceptance which will permit their development in a time frame short enough to encourage investment in them.

It is the intention of the U.S. Department of Energy to demonstrate the commercial viability of hot dry rock energy systems by the mid-1980's, and thereafter, by whatever means prove to be appropriate, to encourage their large-scale development so that, by and beyond the 1990's, they will contribute significantly to the energy needs of the United States. An essential first step in accomplishing this has been a demonstration of the technical feasibility of extracting heat at usefully high temperatures from naturally heated crustal rock. This has been accomplished in the LASL experiments at Fenton Hill in northern New Mexico. It remains, however, to demonstrate that hydraulically fractured heat-extraction systems of the Fenton Hill type can be planned and created predictably and efficiently, that they will produce energy at a commercially useful intensity and rate and for a long enough time to amortize the investment in them, and that their extended, continuous operation is acceptable on the basis of water consumption and environmental effects. Accordingly, experiments at Fenton Hill ("HDR Site 1") are expected to continue for several years.

However, even a completely successful series of experiments at Fenton Hill will not demonstrate adequately the general applicability of rock systems. For that, it is necessary to develop and operate functionally similar systems in a variety of geologic environments and geographic locations. It is the purpose of the present site-selection process to examine the information that is now available concerning a number of prospect areas which appear promising for hot dry rock development, and from among them to select two areas of about 100 square miles each which appear particularly promising for that purpose. These two areas will be investigated in detail during FY-1979 and early FY-1980, after which one of them may be chosen for development and operation of an experimental heat-extraction system, probably followed by construction of a pilot plant, possibly of a demonstration plant, and hopefully by eventual commercialization. If results of this work are promising, if the need for further experiments and demonstration is felt, and if funds for it are available, this sequence of activities will be repeated at other locations scattered across the United States. To prepare for that, and to permit better evaluation of the hot dry rock geothermal resources of the Country, field reconnaissance studies will continue while the development of Site 2 is in progress.

B. Site 2 Objectives

Since it will be only the second hot dry rock geothermal reservoir ever investigated experimentally, the selection of Site 2 will involve compromises between the desirability of developing the technologies needed to create and operate a heat-extraction system in a subterranean geology quite different from that at Fenton Hill and the obvious importance of a successful and convincing development at the next site. A relatively conservative approach is therefore indicated in the present site-selection process, whose objective will be to select two limited areas, each of about 100 mi^2, at either of which:

1. A successful hot dry rock heat-extraction system can be developed and operated using techniques and equipment not greatly different from those already demonstrated successfully at Fenton Hill;
2. The geologic setting is sufficiently unlike that at Fenton Hill with regard to either heat source, reservoir rock type, etc. to demonstrate that the hot dry rock resource is not limited to that typified by Site 1 -- which is immediately adjacent to a large, young, silicic caldera;
3. Hot dry rock exploration and resource-evaluation strategies and techniques can be further developed and evaluated;
4. The entire development will be sufficiently visible to industy, government, and the public to accomplish prompt transfer of all useful new technology to industry and to arouse and maintain serious interest in similar developments elsewhere.

C. Selection Criteria

To achieve the above objectives, the following criteria (and perhaps others also) should be considered in the present site-selection process.

1. High probability that a hot dry rock heat-extraction loop can be developed successfully.

a. Convincing evidence that a usefully hot thermal reservoir exists at an economically attainable drilling depth. In this case it is considered that the depth limit for drilling is approximately 3 km (10,000 ft) and it would be helpful to know -- from previous drilling experience nearby -- that no unusual problems need be anticipated in drilling to that depth. Since most direct uses of heat will require a reservoir temperature of not less than about 80°C (176°F) and economical generation of electricity will require a minimum reservoir temperature of about 180°C (356°F), an average conductive geothermal gradient greater than 22°C/km (12°F/1000 ft) is desirable if a direct-use demonstration is contemplated and at least 55°C/km (30°F/1000 ft) if electrical generation is to be considered.

b. Existence at the expected reservoir depth of competent rock having very low permeability (of the order of 0.01 millidarcy or less) and extending upward from that depth not less than about 1000 m (3300 ft) -- to insure containment of water in the underground circulation loop; and containing no significant proportion of highly soluble minerals -- to minimize corrosion, scaling, and environmental problems.

2. Evidence (from heat-flow or other measurements) of the presence of a geothermal reservoir large enough -- say 1 km^2 (0.4 mi^2) or more in horizontal area -- to justify eventual commercial development, and (from the general geology of the area) that the area is not unique as a geothermal prospect but instead is representative of a large resource base.

3. Minimal constraints on detailed investigation of the area to begin within the next few weeks, on occupancy for several years during which holes will be drilled and an experimental system created and operated, and on eventual commercial development. Individual items to be considered in this regard include the following.

a. Land ownership: whether by federal, state, or local government or by private owners.

b. Present land use, which may be for growing annual crops, perennial crops (orchards, etc.), or timber, for grazing, for mining or quarrying, for recreation, or many other purposes. Long-term commitments of the land may be involved, including easements, rights of way, and highway planning.

c. Constraints on future land use imposed by designation as wilderness areas, game preserves, parks, monuments, or recreational areas, or by the presence of sites of historical or archeological significance or special scenic interest.

d. Leasing, permitting, or withdrawal actions required, and the time required to accomplish them.

e. Licensing and permitting laws, regulations, and procedures for all stages through commercialization, and times required to comply with and complete them.

f. Environmental issues, including regulations concerned with zoning, plant discharges, and noise, the presence of endangered species, erosion control and restoration requirements, seismic risk, and the need for and complexity of Environmental Assessments and Impact Statements.

g. Availability of water and ownership of water rights. (Some tens of acre-feet of water per year will probably be required during the experimental period, and this might increase to several hundred acre-feet per year if commercial development occurs.)

h. State, county, and local perceptions of and attitudes toward geothermal energy development.

i. Cost and convenience of operations at the site, including leasing costs and considerations of access (existing roads and public transportation systems), travel distances, topography, vegetation, climate, and availability of power, communications, drilling and other services, a work force, fuels and other supplies, and housing.

4. Proximity, nature, and interest of an appropriate local market for energy.

a. Magnitude, minimum temperature requirement, load factor, and distance to energy market.

b. Nature, adequacy, and cost of present energy supply, and projections of these into the intermediate-range future.

c. Existence of and access to transmission corridors, power grids, and distribution systems, and nature of land surface and populated areas to be crossed by any new ones.

5. Visibility to industry, the public, and Federal and State Governments, in the interests of prompt technology transfer, public education, maintenance of funding support, possible future broadening of the program, and eventual commercialization of hot dry rock energy systems.

6. Political desirability. To have the maximum impact on the public and on funding sources, future hot dry rock sites should preferably be located near major population centers and energy consumers in both the eastern and the western United States, particularly where energy shortages have occurred or are foreseen in the near future.

> Some political pressure has been felt to disperse future locations geographically and in particular, for the near future, to avoid sites in New Mexico (where Site 1 is located) and in other states (particularly California and the Gulf Coast) where a major fraction of the Federal funds for geothermal energy development is now being spent. There is considerable pressure to locate the next site somewhere along the east coast, and there would be obvious advantages with regard to leasing, permitting, and perhaps funding support if it were located at a Federal installation which has been directed to reduce its usage of oil and natural gas.

No attempt has so far been made to weight individual criteria, and some of them -- such as existence of a promising site within a wilderness area -- would, in effect, have infinite weight. However, some weighting procedures may be necessary, since it is most unlikely that any one site will satisfy all of the criteria listed.

M.C.S.
1/2/79