GL01272

SUMMARY OF TALKS
2nd Annual
HOT DRY ROCK GEOTHERMAL CONFERENCE

Sept. 17-18, 1979

Santa Fe, New Mexico

University of California

LOS ALAMOS SCIENTIFIC LABORATORY

Post Office Box 1663 Los Alamos, New Mexico 87545

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Foreword

Many participants and other interested individuals have requested a brief summary of the Second Los Alamos Scientific Laboratory Hot Dry Rock Geothermal Information Conference held in Santa Fe, New Mexico, September 17 and 18, 1979. This time we were prepared and had requested each speaker furnish an abstract of their remarks. Except for the last minute program changes, the ingredients were in hand, and we collected a set and reproduced it here.

During the Conference the signing of the Hot Dry Rock (HDR) Federal Republic of Germany and U.S. (International Energy Agency) agreement was announced, and it can be reported that a similar agreement is being discussed between Japan and the U.S. on HDR geothermal energy research and technology. This expanding international interest was reflected in the participation by the attendees from eleven nations.

At this time, the drilling of Energy Extraction hole No. 2 (EE-2) has reached a depth of about 3.9 km (13 000 ft) and the desired inclination from the vertical of 35° and azimuth of 63° East of North. Rock temperature continues to increase with depth as expected. Two successful core runs have been accomplished with the four-cone plus polycrystalline diamond compact drag cutters (furnished by Smith Tool). These recent successes are a direct reflection of the contributions of many firms and individuals that have contributed time and expertise to the HDR project.

The expansion of the HDR Program was illustrated at the Conference by the reports of the subcontractors evaluating target prospects for future potential HDR development sites. The planned feasibility study of Fenton Hill as a potential commercial HDR resource suitable for utility use announced by Plain Electric Generation and Transmission Cooperative, Inc. was also noted as significant in recognizing that the HDR geothermal should be considered for inclusion in utility long range planning. The two-year subcontract recently negotiated with Bechtel National should provide detailed clarifications of the basic HDR economic issues.

If we can answer any questions about the Conference or provide additional information on the HDR program, please contact:

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I will respond and will attempt to keep you informed of HDR program results and updates on plans.

Contents

THE HOT DRY ROCK PROGRAM
STATUS OVERVIEW AND MEETING INTRODUCTION

Gregory J. Nunz

ABSTRACT

Fiscal year 1979 saw the expansion of LASL's Fenton Hill HDR Project into a federal Program of national scope. This Program is being field-managed, with LASL as Program Manager, under the aegis of the DOE Division of Geothermal Energy. The Program embodies a group of interrelated major activities: (a) determination of nationwide resource potential; (b) site characterization; (c) establishment and demonstration of commercially exploitable reservoirs at several sites, of which Fenton Hill is the first; (e) development of downhole instrumentation and equipment which is either technologically or chronologically Program-peculiar; (f) development of HDR reservoir engineering methodology, including analytical and laboratory support, and (g) supporting environmental and institutional activities including environmental surveillance at demonstration sites and environmental documentation, economic and legal studies, and domestic and international liaison.

Hot dry rock, as an energy source, has moved from the research stage into engineering development. Present status in each of the Program's major activity areas is summarized in this presentation and discussed in detail in one or more of the subsequent presentations.

HOT DRY ROCK GEOTHERMAL CONCEPTS AND HISTORICAL PERSPECTIVES

Robert B. Duffield

ABSTRACT

The creation of a hot dry rock (HDR) heat extraction system requires the drilling of two wells, each of which is connected at depth to heat transfer surface produced in hot crystalline rock by pressurization and the resultant opening of fracture surface in the rock so that a heat transport fluid may be circulated to bring heat to the surface. Two wells (EE-1 and GT-2) were drilled and completed at Fenton Hill in the period before September 1977. These two wells have been connected by a fracture system at depth and have constituted an HDR reservoir. Heat extraction experiments have subsequently been conducted in this reservoir.

The construction of this reservoir system and its relevance to the various important issues that must be addressed by the HDR project constitute the subject matter of this presentation.

REVIEW OF FENTON HILL (SITE-1) EXPERIMENTS TO DATE

Jefferson W. Tester

ABSTRACT

Field experiments and reservoir models have focused on extending our capabilities to predict the thermal, chemical, and mechanical performance of fractured reservoirs in low permeability basement rock. Results and analysis of two major heat extraction closed-loop circulation experiments will be presented. These were conducted under low- and high-backpressure conditions in the production well of the EE-1/GT-2B system. The discussion will provide an assessment of several critical reservoir characteristics including flow impedance and distribution, fluid permeation, heat extraction area, and fluid geochemistry. In addition, the current status of workover operations in the EE-1/GT-2B system will be covered. These operations were designed to examine fracture initiation by hydraulic pressurization and rapid gas generation (Kine-Frac), as well as fracture propagation under massive hydraulic fracturing conditions in several regions of the lower section of EE-1 (9600 to 10 000 ft). Furthermore, multiple fractures under long-term heat extraction conditions are under way. These have included using CTC Pack/Perf cement packers and OTIS downhole valves.

REVIEW OF PAST FENTON HILL (SITE-1) EXPERIMENTS

Roderick W. Spence

ABSTRACT

The present situation at the Fenton Hill site will be summarized and the plans for Phase II (EE-2 and EE-3) will be presented. Estimates will be given of the initial downhole geothermal reservoir that we hope to establish and methods of subsequently enlarging the reservoir outlined. The discussion will include current plans for fracture initiation, fracture extension, and flow evaluation of the system produced.

EXPLORATION AND TARGET PROSPECTS FOR NEW HDR SITES

A. William Laughlin

ABSTRACT

During FY79, exploration activities began in earnest for additional sites for evaluating the HDR method of geothermal energy extraction. Although some work began in FY78, funding was very limited in that year and our efforts were concentrated in parts of Arizona and New Mexico where other geothermal projects had been started. With increased funding in FY79, exploration began in a number of other areas. This reconnaissance work included both in-house and subcontracted projects focused on identification of large areas characterized by high heat flow. A variety of difficult techniques including heat flow measurements, gravity surveys, MT surveys, water geochemistry and geologic mapping were employed. A particularly cost effective reconnaissance technique has been the funding of academic heat flow workers to measure gradients in available drill holes.

Reconnaissance data on a number of areas was compiled and presented to the HDR Site Selection Advisory Panel for their review and recommendations. The recommendations of the panel were considered and two areas (Snake River Plains, Idaho and Crisfield, Maryland-Wallops Island, Virginia) were recommended by LASL to DOE/DGE for detailed evaluation in the last part of FY79 and during FY80. The Division of Geothermal Energy approved the recommended areas and contracts were awarded to D'Appolonia Consulting Engineers, Inc. and Harding-Lawson Associates for the detailed examinations. Final plans for these investigations will be discussed by the next two speakers.

During FY80, in addition to the detailed target prospect examinations, reconnaissance work will continue or begin in a number of areas. We are especially interested in expanding our efforts in the Buffalo-Syracuse areas of New York and in western Nebraska, southern Colorado and Nevada.

EASTERN SITE CHARACTERIZATION

Carl E. Schubert

ABSTRACT

D'Appolonia Consulting Engineers, Inc. has commenced planning work for the detailed characterization of the eastern hot dry rock site. The site was selected on the basis of its technical merits, potential economic use considerations, and the apparent lack of abortive factors. The site is a corridor approximately five miles wide straddling the Maryland-Virginia border in the southern part of the Delmarva Peninsula. Prior investigations in the area, performed under Costain at Virginia Polytechnic Institute and State University (VPI&SU) as part of a regional evaluation, have led to the formulation of a geologic model wherein the radiogenic heat of plutons in the basement may have been sufficiently well insulated by thick (up to 7 000 feet), low thermal conductivity sediments. One deep well to basement was drilled at the western end of the site near Crisfield, Maryland, in which temperatures approximately equal to those predicted were measured. The heat flow of the eastern end, near Wallops Island is known to be higher and, with a thicker insulating blanket of sediments, may yield higher temperatures. At present, detailed field investigations are being planned to permit a detailed evaluation of the site. These will include seismic reflection, magnetics, gravity, and electrical surveys. The specific project goals are to evaluate the merit of site for further deep well drilling and to recommend, if warranted, a drill site. Additionally the program will evaluate exploration strategies and methodologies applicable to the Atlantic Coastal Plain, in that the surface and subsurface conditions and the resource model proposed for the "Cris-Wal" area are believed typical of the larger area from New Jersey to Georgia. Concurrent with this study, John Hopkins University is performing economic and resource utilization studies. Preliminary data indicate a number of potential direct utilization applications are possible, such as agriculture (e.g., heating chicken coops -- a major regional industry) and space heating.

WESTERN SITE CHARACTERIZATION

F. C. Kresse

ABSTRACT

Western site studies are still in the planning stage. The 146-square-mile site in southwestern Idaho near Mountain Home is in the north part of the Snake River Plain, and bounded on the north-northeast by the Idaho batholith. Volcanic rocks are expected to be 2000 to 3000 meters thick over granitic basement with step faults bordering the batholith.

The field program is planned to emphasize geophysical techniques, including gravity and telluric profiling, passive and active seismic surveys, and deep electrical soundings. Traditional geologic and hydrologic studies will also be conducted.

DRILLING OF HOLE EE-2
START OF THE PHASE II SYSTEM

R. E. Williams

ABSTRACT

We are learning of many of the problems and some of the solutions to drilling deviated holes in hot granitic rock. This talk will tell what we have done in hole EE-2 and in a few instances will compare methods and equipment.

Drilling has been largely with rotary equipment using conventional hard rock bits. Hole deviation has been performed using a variety of tricone bits, steering equipment, downhole motors, and shock absorbers. The variations and the uncertainties of the formations make comparison of equipment and methods risky at best and require careful analysis of results.

A casing break just below a cavity and above the granitic rock has presented considerable difficulty. Also directional drilling in some parts of the formation have been most difficult. Wear of reamers stabilizers and drill pipe collars has been extreme and will probably present increasing difficulty as the hole is deviated further from the vertical.

CEMENTING AND COMPLETION

R. A. Pettitt

ABSTRACT

In the hot dry rock (HDR) concept of extracting geothermal energy, as developed by the Los Alamos Scientific Laboratory (LASL), a manmade geothermal reservoir is created by drilling a deep hole into relatively impermeable hot rocks, creating a large surface area for heat transfer by hydraulic fracturing, then drilling a second hole to intersect the fracture to complete the closed circulation loop.

The completion of HDR geothermal wells presents cementing problems that are unique. Current well depths are from 10 000 to 14 500 ft (3 to 4.4 km) with bottom hole temperatures up to 525°F (275°C). During investigation and development of the reservoir, water injection flows may lower the temperature of the entire wellbore to 104°F (40°C). As a result, the casing string may be subjected to temperature stress cycles representing differential temperatures of up to 455°F (235°C).

Experience has shown that the conventional high-temperature completion cement formulation of Class A or B portland cement, stabilized with 40% silica sand, does not withstand these cyclic stresses, and that rapid deterioration of casing-to-cement and cement-to-formation bonds occurs, which allows significant flow in the resulting microannulus. Investigations and tests (both laboratory and downhole) are being conducted by LASL, and other national and private laboratories, to determine other portland cement formulations, thermal setting cements, and special packer completion techniques which will better withstand the temperature, pressure, and flow requirements of HDR geothermal systems.

Three items of great importance to the HDR Program (and eventually to all geothermal work) are:

(A) The performance history of casing cement for the existing EE-1 injection well, from the initial cementing in October 1977 using Class B portland cement with 40% silica flour, through the complete deterioration of the casing cement in November 1978, to the recementing of the casing using Class H portland cement with 80% silica flour.

(B) The proposed cementing plan for the EE-2 injection well presently being drilled, to include the use of a Pack/Perf cement inflatible packer "O-ring" seal at the bottom, and utilizing stage cementing collars to provide space for future use of developmental cements from the BNL/API cementing testing program.

(C) The lessons learned from the initial installation attempts of inserting a multiple-zone-isolation completion system in the open-hole section of EE-1. This system incorporated two Pack/Perf cement inflatible packers, but the cementing of the packers was unsuccessful due to wiper-plug failures. Modified systems will continue to be tested in EE-1 for expanded usage in EE-2.

INSTRUMENTATION DEVELOPMENT AND TEST FACILITIES

Bert R. Dennis

ABSTRACT

Recent developments in high-temperature materials and components have resulted in significant advancements in borehole instrumentation for geothermal environments. Several new downhole tools have been fabricated and tested to meet the Phase II (EE-2/EE-3 System) high-temperature/high-pressure requirements of 275°C and 690 bars (10 000 psi). High-temperature components have been incorporated into a multiarm independent sensing caliper sonde, a sensitive velocity tool, and combination pressure/temperature instrument. The thermal protection of mil-spec electronic components in a controlled environmental enclosure has allowed for the fabrication of multiplex switching networks to be incorporated into fracture mapping instruments, such as the geophone acoustic detection assembly. The instrumentation now includes monitoring of sonde orientation, dewar temperature, and downhole power supply voltages.

The transfer of high-temperature technology to industrial contractors has initiated cooperative development of a radioactive tracer injection and detection tool and a downhole detonator acoustic source. In addition, two industrial contracts have been awarded to develop a high-temperature acoustic transceiver system and a borehole optical survey sonde.

To facilitate testing of the instrumentation packages in a simulated geothermal environment, an Instrument Sonde Test Facility has been constructed at LASL. This facility is available to all contractors interested in testing borehole instruments at temperatures up to 275°C and pressures up to 415 bars (6000 psi).

ECONOMIC ANALYSIS OF HOT DRY ROCK ELECTRIC SYSTEMS

Glenn E. Morris

ABSTRACT

This talk describes the assumptions and results of hot dry rock (HDR) economic modeling work conducted jointly by the University of New Mexico and the Los Alamos Scientific Laboratory. The talk begins with a review of the methodology and assumptions used in the analysis of HDR/electric systems. Particular emphasis is given to the importance of optimal management in the case of this still infant technology.

A reference case set of resource, technical, and financial conditions that seem plausible for a commercial size operation given our current understanding of HDR/electric systems is presented. These conditions result in an estimated break even bus bar price of electricity of 43.2 mills/kwh ($1978).

The effect on the bus bar price of varying important analysis parameters is presented. As the geothermal temperature gradient ranges from 30° C/km to 60° C/km, the break even bus bar price ranges from 76 to 26 mills/kwh ($1978); as the real rates of return on equity and debt range from 6% and 3% respectively to 21% and 12% respectively, the break even bus bar price ranges from 28 to 72 mills/kwh ($1978). The combination of a relatively large reservoir surface area and high well flow rates result in nearly a 10 mill/kwh drop in the break even bus bar price relative to the reference case result.

The talk concludes with a discussion of the significance of new HDR drilling cost estimates made by Republic Geothermal, Inc. The new initial drilling costs rise linearly with depth and, especially for depths greater than 15 000 ft, are lower than the drilling cost estimates previously employed. New redrilling costs were also estimated and for one redrilling strategy - reservoir deepening - they were less than the previous cost estimates at depths greater than 12 000 ft. These observations suggest that optimal power plant design temperatures will be higher than previously estimated and that low gradient areas will become relatively more attractive under the new drilling cost estimates.

HOT DRY ROCK DRILLING COST ESTIMATES

Robert W. Nicholson

ABSTRACT

Major costs for hot dry rock (HDR) projects include the initial well drilling, the initial completion, and the re-completions. Projected costs for these operations are needed to analyze the economics of HDR projects and also to make decisions about operational strategies, technological research, and development directions. Costs for drilling and costs for re-completion presently used by the petroleum industry for oil or gas reservoir exploitation economics are based on past cost data from comparable projects. However, since there is no HDR cost history (except the limited experimental efforts of the Los Alamos Scientific Laboratory), projected costs must be based on the applicable drilling experiences form the geothermal and petroleum industries.

Cost estimates have been made for HDR development well drilling, completion and re-completion based on assumptions about (a) the geologic controlled drilling and well design parameters and (b) certain methods of the presently feasible technological capabilities for completion and re-completion. The basic assumption about the geologic section is that a permeable section will overlie an impermeable section. The assumptions about technology capability include (a) directional drilling, (b) penetration rates, (c) fracturing capability and (d) the well design configuration of the producer/injector pair.

The well design (depth, casing program, directional program completion scheme, etc.) significantly affects the well costs. Cost estimates were made using well designs which are considered practical by adapting the available equipment and technology, where applicable, from the geothermal and petroleum industries.

The resulting HDR well costs estimates as compared to oil and/or gas well costs as functions of depth indicate that shallow HDR wells to 12 000 feet are more costly and below 12 000 feet they are less costly than the average comparable depth petroleum industry wells. The primary reasons for this are the geologic affected drilling and completion operations. That is the hard impermeable formations penetrated at depth in HDR geologic provinces are anticipated to be less troublesome than the permeable formations encountered at depth in petroleum industry. The no tubing is required. Also, the pressures are relatively low (less than 1000 psi working pressure) as compared to the high pressures (greater than 10 000 psi in many cases) encountered in deep oil or gas drilling resulting in less costly surface and downhole hardware.

HOT DRY ROCK COMMERCIAL ECONOMICS

J. W. Hankin

ABSTRACT

Recently Bechtel was selected by the Los Alamos Scientific Laboratory to perform a major study which will assess the economic feasibility of hot dry rock (HDR) geothermal systems. The goal of this study is to project and quantitatively describe those sets of conditions under which HDR geothermal energy systems can be made to be commercially feasible during the period from the mid-1980's to the turn of the century.

The study will cover the United States and will include all aspects of energy recovery and use. Electric power generation, direct use applications, and cogeneration will be considered for use. The economics will involve calculation of capital costs and energy production costs for the various systems and will include financial, institutional, regulatory, and environmental factors.

The study is being performed by an industrial team that is headed by Bechtel and includes subcontractors and consultants. Bechtel will coordinate the effort and perform the work related to energy utilization, economics, and analytical modeling. The subcontractors are GeothermEx for geothermal geology, Intercomp for reservoir modeling, and Republic Geothermal for drilling. The consultants are Technecon for economic systems, Mr. C. M. Laffoon for utility industry considerations, and the Public Service Company of New Mexico, which will act as a utility advisor.

The approach to the study is to begin with a survey of the HDR technical status and of economic analyses methods. Ranges of important factors in HDR commercialization will then be established along with cost and financial relationships. Next, the assessment methodology will be formulated and an analytical model will be developed. Finally, the model will be used to derive commercialization recommendation for HDR systems.

This is a two-year study that began July 1979, and is scheduled to be completed June 1981.

PLANNING FOR ALTERNATIVE ENERGY RESOURCE NEEDS

S. K. Bazant

ABSTRACT

This talk discusses the considerations required for integration of the projected resource into the system load curve and the identification and evaluation of related institutional interface problems that impact the planning process. Expected project lifetime and cost criteria will also be addressed to determine viability in comparison to more traditional resources in view of consumer and regulatory concerns.

PRELIMINARY ASSESSMENT OF A GEOTHERMAL PROCESS

Loyd R. Kern

ABSTRACT

A geothermal process that uses wells containing a hydraulic fracture created in low permeability, hot rock is studied. Weighted fluid is injected into the fracture, heated by contact with the rock, produced back, and passed through a heat exchanger to power a secondary fluid electric generating plant. The behavior of the fluid-fracture system is very complex, so several approximations are developed to predict behavior.

To obtain fractures of adequate width and volume, density of the fluids under downhole conditions must be high enough so that the vertical pressure gradient (from density) in the fluid is equal to or nearly equal to the vertical gradient of horizontal stress in the rock. Such fluids are expensive, ranging from $20/bbl to $100/bbl.

Loss of fluid into the porous sytem of the hot rock is very large, even though the permeability is low, because of the large fracture area required. This is a significant cost in the process.

An approximate method to calculate the temperature history of the produced fluid over a period of many years is developed. The method may predict a more rapid decline in temperature than actually occurs because convective flow of fluid in the fracture is neglected.

With physical data determined by the Los Alamos Scientific Laboratory in their field experiments in hot rock near Los Alamos, New Mexico, an economic assessment of the process is made. The analysis indicates a price of 6-8 mil per kWh is economical.

HDR ACTIVITIES IN THE FEDERAL REPUBLIC OF GERMANY

Oskar Kappelmeyer, BGR Hannover
Ralph Hanel, NIFB Hannover
Fritz Rummel, FU-Bochum

ABSTRACT

Two projects aimed at developments of techniques for an extraction of terrestrial heat from low permeable rock sections are being executed at present.

1. Investigate on an artifically created fracture in a shallow and low-permeable environment.

The test site is located in the "Falkenberger Granit Massiv" in north-east Bavaria. Artifical circulation systems were created at 260-m and 158-m depth. Flow connection was obtained to an extraction hole at 60-m distance from injection. Field experiments on hydraulic and thermal behavior of the system are being performed. Seismic and electric methods are applied for frac location. In situ determinations of the natural stress field, the permeabilities and heat conductivities of rocks, acoustic parameters, and electric parameters in the subsurface serve for a better understanding of the phenomena of frac creation and frac extension, as well as for an application of geophysical methods for frac location. The experimental results will be integrated into models, which shall describe the behavior of artificial heat exchange systems at greater depth and at higher natural rock temperatures.

Additional field experiments with ring cavern cutters (Ringkavernen-schneider) and controlled explosions are aimed at the development of techniques for a manipulation of the impedance in multi-frac systems in respect to an improvement of the heat exchange.

This project is financed by the German Ministry for Research and Technology under the management of PLE (Project Leader for Energy Research) in Julich and the European Communities, Brussels.

2. Fracture tests in the borehole of Urach (executed by the frac-group Urach).

The object was to create a fracture system that provides a circulation loop in one hole. In a hypothetical model of ERNST (1977), the cold water is injected through the annulus space and the heated water is extracted through the pipe in the center of the borehole. The heat exchange was estimated by analytical mathematical solutions (RODEMANN, 1979) assuming penny shaped fractures. The expected well head pressure for fracture creation was 850 bars based upon laboratory measurements on core samples (RUMMEL, 1979).

Four fractures have been created: (1) fracture in the open hole at about 3325 m, the others in the cased hole section, (2) fracture at 3260 m, (3) fracture at 3275 m, and (4) fracture at 3295 m depth. Some preliminary results follow.

A. Breakdown pressure for fracture creation was 300-500 bars lower than expected; natural fissures were probably reopened in all pressurized well sections.

B. The pressure field initiated through one fracture system interacted with the stress field in such a way that the neighboring fissure systems above and below reduced their width. For a hydraulic connection between two fracture systems, the pressure difference between these systems must be small.

C. A circulation loop was created between fracture 1 (3325 m) and fracture 4 (3295 m).

D. During water injection through the hole, the circulation into the rocks occurred through the fracture width with the lowest impedance. A simultaneous water flow into all four fractures would require a device for pressure control at the different depth intervals where injection is intended.

This project is financed by the German Ministry for Research and Technology under the management of PLE (Project Leader for Energy Research) in Julich.

AN UPDATE ON EEC-SPONSORED HOT DRY ROCK ACTIVITIES

C. M. Pearson

ABSTRACT

Present hot dry rock (HDR) geothermal energy research contracts, which have received financial support from the Research, Science and Education Department of the European Economic Commission, have had the objective of carrying out work on a number of different technical problems, related to the feasibility of power generation from hot dry rocks. Research teams based at different establishments in France, W. Germany, Italy and the United Kingdom have been working on both laboratory and *in situ* field experiments.

Laboratory studies have included work in the areas of chemical leaching, three-dimensional analysis of crack propagation, and hydraulic fatigue fracturing between wells. Pressure pulse and harmonic pick-up equipment have also been designed and built, to give quantative data about fractures intercepting boreholes.

Three shallow (~300 m) *in situ* field experiments are being carried out to establish the feasibility of different methods of linking boreholes and obtaining the necessary swept heat transfer area. In W. Germany, conventional hydraulic fracturing techniques are being used; in France, another project is using a "target drilling" method to intersect a seismically mapped, hydraulic fracture, which had previously been propagated from the first well. The other field project (in England) is using small explosive charges to fracture the wells, with subsequent hydraulic extension of the explosively induced fractures.

The present contracts as outlined above are not due for completion until mid-1980. However, results obtained so far are being used in planning an HDR project at 1 1/2- to 2-km depth; work is due to start in the fall of 1980.

LEGAL, REGULATORY AND INSTITUTIONAL ISSUES OF GEOTHERMAL ENERGY DEVELOPMENT

Richard T. Meyer

ABSTRACT

The legal, regulatory and institutional issues of geothermal energy development, including hot dry rock geothermal, are as complex, challenging and costly as many of the technical research and development problems.

Major federal and state issues are as follows: (1) government regulations are too complex and costly for both large and small energy industries; (2) federal leasing acreage limitations are too small for the requirements of large industries trying to develop electrical power plants and too large for the small business sector interested in direct thermal application; (3) extensive time delays in leasing approvals and permitting procedures are the rule with certain federal agencies and are promoted by the absence of statutory time limitations; (4) land designations as KGRAs and as wilderness areas are forcing competitive bidding on unproven resources and are withdrawing hundreds of thousands of acres from resource exploration activity; (5) state public utility commissions have neither addressed the reservoir risk factor of geothermal resources nor provided for the exclusion from regulation of energy producers that provide electric and/or thermal energy for a single customer such as an industrial park; and (6) public and private awareness of the potential of geothermal energy is minimal.

At the state level specifically, outstanding issues include a diversity and/or absence of statutory and regulatory definitions of the geothermal resource, an array of assignments of the leasing and regulatory authorities among various state agencies, unresolved clarifications of water rights (appropriative, correlative, beneficial, consumptive, etc.), and lack of definition of applicability of state and local taxation to geothermal property and operations.

Key issues associated with the development of the hot dry rock geothermal resource will include the determination of the applicability of state resource definitions to the hot dry rock resource, the availability of water for the initial charge and for the makeup of the circulation system -- particularly in the western states, the requirement that larger size or value facilities qualify under state energy facility siting laws, regulation by PUCs of combined electric and thermal ouput facilities, and a general lack of knowledge by state regulators of the technical features of hot dry rock resources and applications.

Some progress is being made in solving this host of institutional problems and in providing incentives for geothermal development. At the federal level, geothermal omnibus legislation and other special legislative items are presently being considered by the U.S. Congress, the DOE San Francisco Operations Office is initiating action to streamline the Geothermal Loan Guaranty Program application procedures for small businesses, and the DOE Division of Geothermal Energy is obtaining land use priorities from the State Geothermal Commercialization Planning and Resource Assessment Teams for input to the BLM schedule of leasing and environmental assessment. Several western states have provided incentives covering the exemption of geothermal resources from water resource regulatory procedures (Arizona), exemption of geothermal facilities from property taxes (Nevada - pending Constitutional amendment), authorization to municipalities to operate hot water energy systems and to issue revenue bonds (Idaho), exclusion of small geothermal facilities (less than 25 million Btu/hr) from the state's major facilities siting act (Montana), and establishment of a cost-shared geothermal demonstration program (New Mexico).

EARTHQUAKE MONITORING

James N. Albright

ABSTRACT

Although under certain conditions microearthquakes are known to have been induced in the Fenton Hill reservoir, none of these have been of sufficient magnitude, Mb-0.5, to be detected by the existing surface seismic array. Improvements in the array to be completed for Phase II testing will result in detection sensitivity and resolution maximized within practical limits. Included will be instrumentation installed at 750 m in a well penetrating basement rock at 1500 m from the experimental site.

ENVIRONMENTAL MONITORING OF HOT DRY ROCK DEVELOPMENT

F. R. Miera, Jr.
K. Rea
G. Langhorst
C. Montoya

ABSTRACT

The development of hot dry rock (HDR) geothermal as an alternative energy technology is being evaluated simultaneously by a comprehensive environmental surveillance program. The objective of these studies is to identify areas of potential environmental impact and determine appropriate means for mitigation as the technology is developing. With Phase I completed, some of the operational stages of HDR development can now be assessed as to their potential for impact to the environment. Areas of concern or possible impact include water quality, air quality, ecology, solid waste, seismicity and natural resources (land use). Extensive baseline data have been collected in these areas for preoperational characterization and for purposes of comparison to measurements made during and at the conclusion of operations. Results of these data are discussed and their significance evaluated.

FRACTURE MAPPING - ACTIVE AND PASSIVE SEISMIC METHODS

James N. Albright

ABSTRACT

Data obtained with conventional acoustic logging tools operated in dual-well modes are used in detecting fluid-filled fractures and in determining bulk rock properties. Characteristic changes in signal propagation velocity, waveform, and attenuation are associated with pressurization and enable inferences to be made about the nature and distribution of the fracture system between wells in the reservoir.

Massive high-pressure injections of fluid into reservoir fractures under certain conditions induce microearthquake activity. The activity detected with a downhole triaxial geophone sonde positioned in the reservoir is mapped using techniques of single-station seismometry. The growth, orientation, and spatial dimensions of newly created reservoir fractures is thus obtained.

ADVANCES IN THE MAPPING OF HDR GEOTHERMAL RESERVOIRS

Robert M. Potter

ABSTRACT

The mapping of a manmade geothermal reservoir includes accurate knowledge of the wellbore geometries, the physical state of the open hole regions, location and nature of flow entry and exit regions, and finally the nature and geometric extent of the heat transfer surface(s) away from the wellbores. It also should include the changes taking place during the heat extraction period.

Improved service company gyrocompass surveys combined with acoustic and magnetic ranging techniques have been used to produce an excellent map of the two wellbores. This map is necessary for the task of modeling the fracture system using both pressure and temperature transient analysis. Conventional wellbore logging techniques such as four-arm caliper, acoustic velocity, borehole televiewer, etc. have proved useful in locating potential fracture sites. Temperature and fluid velocity (spinner) logs with flow have shown the location and properties of entry and exit regions. In addition, the use of radioactive tracers such as I^{131} and Br^{82} has given information about the nature of more complex flow paths. Residence time distribution studies (RTD) have determined the useful volume and dispersion characteristics of the fracture system. Under special conditions a measure of fracture extent has been obtained from downhole measurements of the potential field surrounding an electrified fracture. Finally, extensive information about the fracture system is obtained from both active and passive acoustic methods.

Other methods under investigation include measurement of the lateral temperature gradient existing near a planar cooled surface, measurement of the local tilt at the fracture entrance caused by inflation, *in situ* measurement of the stress ellipsoid by measurement of strain relief from overcoring measurement of the arrival times of P-waves coming from acoustic events at several separated stations, borehole radar imaging of hydraulic fractues, and measurement of borehole displacement due to pressurization.

AN ANALYSIS OF THE PRESSURE TRANSIENT TESTING OF THE FENTON HILL RESERVOIR

Henry N. Fisher

ABSTRACT

The Los Alamos Hot Dry Rock (HDR) Geothermal System which consists of fractures connecting two wellbores at Fenton Hill, New Mexico, was first established in October 1975. The fracture system, which is located in granite at a depth of approximately 2900 m, has been altered since then by two redrilling operations and subsequent hydraulic fracturing attempts. Many experiments involving the pressurization of one or both boreholes from which the fracture originates have also altered the flow characteristics of the system. These experiments have continued to give information on the permeation flow into the surrounding rocks, the properties of the reservoir rock, the geometry and extent of the main fractures, and the flow-through properties of the heat exchange paths.

As in the analysis of conventional reservoirs the data analysis is in terms of a diffusion equation that determines the flow of water and hence the pressure in the main fracture system, associated joints, and the matrix permeability. The fits of the flow data to type curve solutions of the diffusion equation for various flow geometries are presented. The following points are considered in detail: 1) The limits on the fracture geometry, aperture and diffusing areas are determined from the diffusion parameters. 2) The parameters (impedance, diffusivity) of the flow-through systems are related to those governing the inflation of the main fractures. 3) The relationship of the rock properties to the reservoir compressibility and permeability are discussed. In particular, laboratory experiments show that the properties of all sizes of cracks from large single fractures to the microstructure are pressure dependent if the fluid pressure is near the confining stress. The effects of this on the form of the type curves are discussed. 4) The competition of flow into the various types of porosity (main fractures, joints, and microstructure) and the effect on the interpretation of type curves are discussed.

HEAT AND MASS TRANSFER MODELING OF HOT DRY ROCK GEOTHERMAL RESERVOIRS

Hugh D. Murphy

ABSTRACT

To understand heat production characteristics of hot dry rock reservoirs, both theoretical and laboratory-scale models of fluid flow and heat transfer behavior in hydraulic fractures were investigated. Theoretical modeling was performed with a numerical simulator which handles two-dimensional fluid transport and heat convection equations within the hydraulic fracture which are coupled to the transient heat conduction equation for the rock surrounding the fracture. The laboratory model consists of two sheets of Plexiglas between which the simulated fracture was confirmed. The Plexiglas permits visual study of the fluid motion. Heat conduction from the rock was simulated with electrical heaters and 33 thermocouples provide temperatures as functions of position and time. The two types of models are complementary--the laboratory model is used to confirm the predictions of the numerical simulator and additionally is used to obtain results under conditions where the numerical simulator fails to provide stably convergent results.

One of these conditions occurs when the effects of buoyancy due to density difference between the injected cold water and the hot water initially present in the fracture are large. Time lapse motion pictures of the flow streamlines in the laboratory model describe these buoyancy effects vividly. The flow patterns and temperature changes that evolve were quantified in terms of the ratio of the Grashof and the Reynolds numbers, the first number representing the tendency toward natural convection while the second represents the strength of forced convection caused by injection. This ratio increases with fracture height, (fracture aperture) and the difference between the initial fracture and injection temperatures, but decreases with increasing injection rate and viscosity. At low ratios the flow streamlines aned measured fluid temperature sindicate that the fluid motion is in accord with ideal potential flow theory--the injected water flows in a fan-like pattern, directly to a near-surface outlet. With increasing ratios the injected fluid first descends, due to density difference, before resuming its flow towards the outlet. At high ratios the buoyancy effect becomes greatly exaggerated. The downward flow takes on the form of a jet and as the local rock temperature is lowered by heat transfer to the jet, the jet sinks lower until eventually the only obstacle to continuous descent is the physical bottom of the fracture. These results have significant implications for theories of water penetration of the earth's crust as well as for geothermal energy exploitation. For example, injection through wells drilled through fractures could result in large rates of heat production, particularly so if the fractures extend to great depths and their apertures provide sufficient permeability.

HOT DRY ROCK GEOCHEMISTRY

Charles O. Grigsby

ABSTRACT

Analyses of fluids circulated through the prototype hot dry rock geothermal system at Fenton Hill indicate the importance of the combined effects of "pore" fluid displacement and rock dissolution in the total system chemistry. Changes in the fluid composition can be described by a simple mixing/dissolution model which accounts for addition of fresh fluid to replace permeation fluid losses in the reservoir. Changes in reservoir temperature, pressure and rates of water loss have an effect on the observed fluid composition.

Concentration variations of SiO_2, HCO_3, and Cl^- depict three patterns for geochemical behavior in the reservoir, and these species and others are used as internal tracers in the system. The SiO_2 and Na-K-Ca geothermometers are also used to study reservoir behavior.

Comparison between field circulation experiments and laboratory rock-water experiments are made to predict the compositions of geothermal fluids for the Phase II 20- to 50-MW(t) system at higher reservoir temperatures.

PREVIEW OF FENTON HILL TOUR

R. H. Hendron

ABSTRACT

Some points of interest between Santa Fe and the Fenton Hill Site were mentioned in a general location description for the Los Alamos Scientific Laboratory's Fenton Hill Hot Dry Rock Project. Views of the site and several features of the site were shown and described as a preview of the site tour.

SECOND ANNUAL
HOT DRY ROCK GEOTHERMAL ENERGY
INFORMATION CONFERENCE

September 17-18, Santa Fe, New Mexico

Monday, 17 September

Session I - E. F. Hammel, LASL, Presiding

8:45 AM	CALL TO ORDER
8:50 - 9:00	GREETING AND WELCOME - Bruce King, Governor of New Mexico
9:00 - 9:15	CONFERENCE KEYNOTE, Franke DiLuzio, LASL
9:15 - 9:45	THE FEDERAL GEOTHERMAL ENERGY DEVELOPMENT PROGRAM - Bennie DiBona, Director, DOE Division of Geothermal Energy
9:45 - 10:15	THE HOT DRY ROCK PROGRAM: STATUS OVERVIEW AND MEETING INTRODUCTION - Greg Nunz, LASL, Prog. Mgr: HDR Program

* * * COFFEE BREAK * * *

Session II - W. Porter Grace, DOE/ALOO-SPD, Assoc. Prog. Mgr: HDR Program, Presiding

10:35 - 10:55 AM	HDR GEOTHERMAL CONCEPTS AND HISTORICAL PROSPECTIVES - R. B. Duffield, LASL Consultant, HDR Program
10:55 - 11:40	REVIEW OF FENTON HILL (SITE 1) EXPERIMENTS TO DATE - J. W. Tester, LASL, Mgr: Reservoir Engrg., HDR Program
11:40 - 12:00	PRESENT AND FUTURE FENTON HILL ACTIVITIES - R. W. Spence, LASL, Project Mgr: Fenton Hill Project, HDR Program

* * * LUNCH * * *

Session III - S. Prestwich, DOE/IDOO, Presiding

1:30 - 1:55 PM HDR RESOURCE EVALUATION AND SITE SELECTION - A. W. Laughlin, LASL, Mgr: Resource Eval. & Site Explor., HDR Program

1:55 - 2:05 EASTERN SITE CHARACTERIZATION - C. Schubert, D'Appolonia Consulting Engineers Inc.

2:05 - 2:15 WESTERN SITE CHARACTERIZATION - F. Kresse, Harding-Lawson Associates

2:15 - 2:45 DRILLING WELL EE-2: START OF THE PHASE 2 SYSTEM - R. E. Williams, LASL, Mgr: FH Drilling & Completions, HDR Program

2:45 - 3:00 CEMENTING AND COMPLETION - R. A. Pettitt, LASL, FH Drilling and Completions Staff, HDR Program

3:00 - 3:15 INSTRUMENTATION DEVELOPMENT AND TEST FACILITIES - B. R. Dennis, LASL, Mgr: Mtls., Instrumentation & Equipt. Devt., HDR Program

* * * COFFEE BREAK * * *

Session IV - E. Wellbaum, Republic Geothermal Inc., Presiding

3:35 - 3:55 PM ECONOMIC ANALYSIS OF HDR/ELECTRIC SYSTEMS - G. E. Morris, LASL, Institutional & Industrialization Activities Staff, HDR Program

3:55 - 4:10 HDR DRILLING COST ESTIMATES - R. Nicholson, Terra Services Inc.

4:10 - 4:25 HDR COMMERCIAL ECONOMICS - J. Hankin, Bechtel Corp.

4:25 - 4:40 PLANNING NEEDS FOR ALTERNATE ENERGY RESOURCES - S. K. Bazant, Plains Electric Generation & Transmission Cooperative Inc.

4:40 - 5:00 PERFORMANCE AND ECONOMIC ANALYSIS OF AN HDR "HUFF-&-PUFF" PROCESS - L. Kern, Atlantic Richfield Corp.

* * * END FIRST DAY TECHNICAL SESSIONS * * *

EVENING

5:30 - 7:00 PM No Host Reception, Inn at Loretto

7:00 - 9:00 Banquet, Inn at Loretto
Speaker: Bob Greider, Intercontinental Energy Inc.

Tuesday, 18 September

Session V - P. R. Franke, LASL, Mgr: Planning and Administration, HDR Program, Presiding

8:30 - 8:50 AM GEOTHERMAL DEVELOPMENTS IN THE FEDERAL REPUBLIC OF GERMANY - R. Hanel, O. Kappelmeyer, J. Wohlenberg, F.R.G. Geological Survey

8:50 - 9:10 AN UPDATE ON EEC-SPONSORED HDR ACTIVITIES - C. M. Pearson, Gambourne School of Mines, UK

9:10 - 9:30 LEGAL ISSUES - R. Meyer, Western Energy Planners

9:30 - 9:45 SEISMIC MONITORING - J. N. Albright, LASL, Reservoir Engineering Staff, HDR Program

9:45 - 10:05 ENVIRONMENTAL MONITORING OF HDR DEVELOPMENT - F. R. Miera Jr., LASL, Mgr: FH Environmental Surveillance, HDR Program

* * * COFFEE BREAK * * *

Session VI - P. M. Wright, UURI/Earth Science Laboratory, Presiding

10:25 - 10:40 AM FRACTURE MAPPING BY SEISMIC & ACOUSTIC TECHNIQUES - J. N. Albright, LASL, Reservoir Engineering Staff, HDR Program

10:40 - 10:55 ADVANCED RESERVOIR MAPPING CONCEPTS - R. M. Potter LASL, Reservoir Engineering Staff, HDR Program

10:55 - 11:10 ANALYSIS OF PRESSURE TRANSIENT TESTING - H. N. Fisher, LASL, Reservoir Engineering Staff, HDR Program

11:10 - 11:25 HEAT EXTRACTION AND FLUID FLOW MODELING - H. D. Murphy, LASL, Reservoir Engineering Staff, HDR Program

11:25 - 11:40 HDR GEOCHEMISTRY - C. O. Grigsby, LASL, Analytical & Experimental Support Staff, HDR Program

11:40 - 12:00 PREVIEW OF FENTON HILL TOUR - R. H. Hendron, LASL, Fenton Hill Test Site Manager, HDR Program

* * * END TECHNICAL SESSIONS * * *

12:30 PM Fenton Hill Tour Bus No. 1 - Departs Hilton
1:30 PM Fenton Hill Tour Bus No. 2 - Departs Hilton

Conference To Focus On HDR

Los Alamos Scientific Laboratory's hot, dry rock project will be the subject of a two-day conference that starts Monday in Santa Fe.

The conference will focus on techniques developed by LASL during the unique energy experiment now under way in the Jemez Mountains.

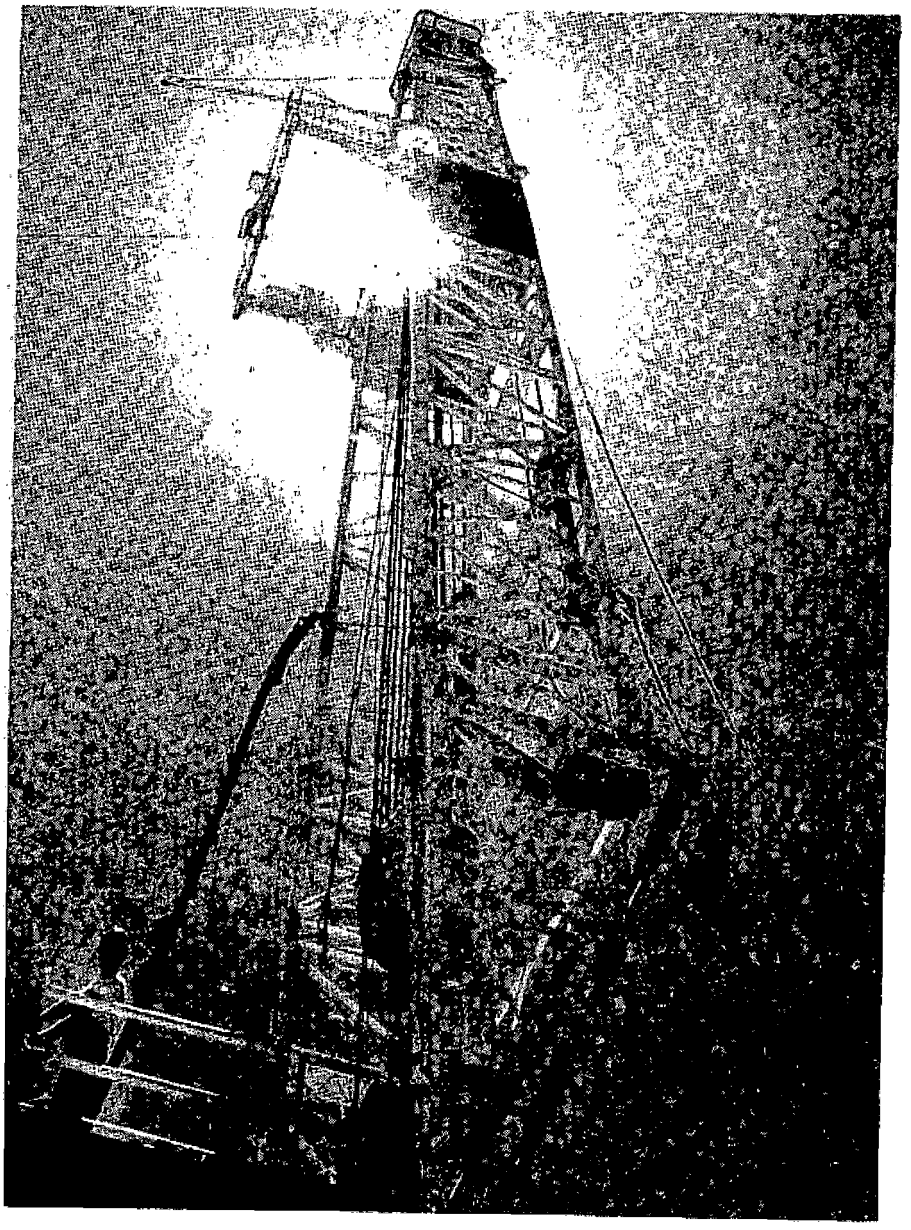
Some 200 participants, including many from energy and drilling companies, are expected to attend to learn some of the methods used to extract energy from naturally hot, dry rock locked underground.

"We have shown that hot, dry rock geothermal energy production is technically feasible," LASL Director Donald Kerr said. "We now are interested in a successful interface with industry where the benefits of this new technology can be enjoyed by the public."

LASL officials believe their succesful hot, dry rock project — which differs from traditional geothermal projects — has the potential to produce electricity, heat buildings and serve in an industrial capacity.

A tour and briefing at the LASL experimental heat extraction site at Fenton Hill will take place Tuesday morning.

Sessions devoted to exploration for potential geothermal sites and sessions dealing with the cost of developing the hot, dry rock geothermal energy concept are also scheduled.



Fenton Hill HDR project site (LASL photo)

Reprinted from The Los Alamos Monitor, September 16, 1979

Firm may acquire LASL project

FRONT PAGE

Plains Electric Generation and Transmission Cooperative, Inc., of Albuquerque, is interested in acquiring the Los Alamos Scientific Laboratory's Fenton Hill hot, dry rock geothermal project to produce commercial power, a Department of Energy spokesman said Monday.

Bennie DiBona, director of the DOE's Geothermal Energy Division, said about $120,000 could be given to Plains, possibly as soon as October, to study possibilities of acquisition of the LASL project.

According to DiBona, there are several problems that would have to be overcome before any acquisition...

The company would be given money to study possible environmental problems and problems dealing with private acquisition of federal land.

The Plains proposal "indicated an interest in putting a 10 megawatt power plant at Fenton Hill," DiBona said.

If such a plant were built, it would be the first such plant in the world. The Fenton Hill project, being conducted by LASL, is the first of its kind in the world.

The Fenton Hill project takes a new track in getting energy from geothermal power.

The Fenton Hill project is concerned only with hot, dry rock geothermal energy. This differs from hydrothermal power in that only the heat of the earth, not the hot water from the earth, is used.

Other, fresh water is provided to hot rock. The water is heated and recycled through a heat exchanger to produce electrical energy.

The environmental problems with hydrothermal energy production, such as noxious odors and a lowering of the hot water springs, are not associated with hot, dry rock geothermal energy production.

Most authorities say that hot, dry rock energy is not as environmentally damaging as is hydrothermal.

DiBona said if Plains can take over the operation at Fenton Hill and produce commercial power "it would be a shot in the arm" for hot, dry rock power.

Reprinted from The New Mexican, September 18, 1979

W. Germany to join hot rock study

West Germany has agreed to contribute $2.5 million to the Los Alamos Scientific Laboratory's hot, dry rock (HDR) geothermal program.

An announcement of the agreement, expected to be signed in Paris next week, was made Tuesday during a HDR conference at the Santa Fe Hilton Inn.

Jurgen Wohlenberg, of the West German Geological Survey, said the agreement would contribute up to 25 percent of the LASL HDR program budget or $2.5 million, which ever is less.

Wohlenberg said it was "pretty solid" that the agreement would be signed.

There was also an indication that the Japanese government is working on a similar agreement which would also contribute about $2.5 million.

Word of negotiations between the Japanese and United States governments was announced Monday at the HDR conference by Bennie DiBona, a Department of Energy official.

The agreement with the West German government would also include sending three Germans to Los Alamos to work with the LASL HDR program.

The West German government is very interested in the program for several reasons, Wohlenberg said, because there are few, if any, hydrothermal energy sources in West Germany, Wohlenberg said.

A hydrothermal energy source takes naturally occurring hot water and uses it to turn an electric turbine, whereas HDR uses the natural heat of hot, dry rock to convert water into steam.

Wohlenberg said HDR energy development is possible in West Germany.

The agreement is being made, from the West German point of view, to show "we do not sleep," Wohlenberg said.

He said the West German government thinks it is important to show anti-nuclear groups in West Germany that the government is looking at alternative energy sources.

The agreement has been in the talking stage for more than two years and the Paris signing will finally make international cooperation in the HDR field a reality.

The agreement will be for two years and West German personnel at the LASL site will be changed every year.

Wohlenberg, who also addressed the conference on West Germany's own HDR work, said the cost of energy would have to go up before HDR produced electricity would be economically feasible.

He said at the present time drilling costs were too high to produce a cost effective return.

Reprinted from The New Mexican, September 19, 1979

Drawing energy from rock

One of the most interesting, if relatively unpublicized quests for new energy sources is the Hot, Dry Rock (HDR) Program now in full swing at New Mexico's Los Alamos Scientific Laboratory.

As several recent articles in the facility's journal, The Atom, attest, the concept of extracting energy from hot, dry rock in the earth's crust is being recognized as a viable, and maybe necessary alternative to fossil fuel use for certain applications. By drilling deep into the earth and circulating water through the freshly bored hole, researchers have been successful in drawing substantial amounts of heat to the earth's surface. The task now, and one that LASL workers are eager to tackle, is to prove to industry that enough heat can be extracted for enough time to justify large-scale investments.

In their first experiment with this unique form of geothermal energy extraction in 1977, LASL Geoscience Division workers drilled into 200°C granite at a depth of about 3000 meters. Heat was extracted from the rock by forcing pressurized water down one hole, through a fractured rock reservoir, and back to the surface through another hole. The closed loop system operated for more than 2800 hours between 1977 and 1978.

More recently, LASL has contracted with Brinkerhoff-Signal, a Denver drilling company, to bore into Fenton Hill, in New Mexico's Jemez Mountains, near the original drilling site. This time, depths of more than 3900 meters are expected to be achieved, and temperatures to reach 250°C. Digging is currently proceeding at about 30 meters a day, at daily costs of between $7000 and $8000. The first of the two boreholes may take as much as six months to complete.

The researchers at LASL hope the Fenton Hill project will eventually be capable of supporting a five- to ten-megawatt generating plant, though plans for such a plant are not currently in the works. They estimated a facility that size could supply electricity to between five and ten thousand people. For a commercial plant, they said, a 50-megawatt facility would be more practical.

Besides being useful for the generation of electricity, researchers say the HDR concept could be applied to even lower temperature rock for space heating, food processing and manufacturing purposes. The resource is nearly inexhaustible, they say, and the technology needed is well within reach. All that remains now is to convince industry that drilling for heat has its financial rewards as well. □

Reprinted from Optical Spectra, Pittsfield, MA
September 1979

Geothermal delays expected

Dick Behnke
The New Mexican Staff

LOS ALAMOS—The second annual Hot, Dry Rock Geothermal Conference has ended, but its implications may linger for years.

The implications are that no new energy source, despite claims of "clean energy," will be easily established in the market place.

While the Santa Fe conference dealt mainly with hot, dry rock geothermal energy, there was also discussion about the other kind of geothermal energy, hydrothermal, and the environment's concerns.

Hydrothermal-geothermal power uses hot, briney water from the earth to power steam turbines to produce electrical power.

It is the water which is a subject for criticism of hydrothermal projects because in addition to containing salts of various kinds, the odor associated with it smells like rotten eggs.

These problems plagued a California project known as the Guysers, where hydrothermal power is turned into electricity.

Many government and industry represenatives were ready to challenge those concerns with facts about new abatment methods.

However, few government or industry represenatives were ready to deal with Indian claims that the Jemez Mountains area, where hydrothermal power generations projects are scheduled, have religious significance to many pueblos.

A Department of Energy official said the DOE had no idea of the scope of the opposition to a partially DOE-funded project to build a geothermal power plant in the mountains "until we had a man on the scene."

The DOE is trying to determine if the Indians believe the whole area is sacred to Indians or only specific sites.

Once the opposition was expressed, the DOE included an option in its Environmental Impact Statement (EIS) to not build a power plant in the Jemez Mountains.

However, that option would have to be accepted by two assistant secretaries in the DOE and the chances for that appear to be slim.

At the same time the inclusion of that option, which was not previously included in the draft EIS, could be seen as a take-it-or-leave-it option.

Either accept the fact that the power plant might be built or it will not be built.

Since the DOE is already involved in a multi-million dollar contract with Union Oil Co. and Public Service Co., to build the Jemez power plant, exercising that option would be a long shot.

But the whole point of including the option seems to be a challenge to environmentalists who claim the project would damage the water tables, cause odor problems and change the Indians' culture.

Damaging a culture is a particularly repugnant option to the government and if the subject is fought in court, as some Pueblos have said it would be, the government may decide to exercise the option.

The whole subject of environmental concerns seems to many government and industry people to be a roadblock to the job of finding alternative power sources for the country.

"Even if everyone had wood stoves, the environmentalists would complain about the wood smoke pollution," one delegate to this week's conference said.

"We are almost out of options which environmentalists find acceptable," said another delegate.

That is the problem which may continue to resound for years; environmental concerns versus power needs.

Hearing a person from industry or government say "we ought to just quit and let them freeze to death" is not unusual.

Just as environmentalists are fed up with plans which will continue to degrade the environment, there are many energy people who are fed up with what they feel are "minor problems" that are blown out of porportion by environmentalists.

It may be one of the hardest problems in the whole energy picture to solve.

The reason it is so difficult to solve is that every energy option available, with the exception of passive solar energy for personal home heating, has an environmental problem associated with it.

Solar arrays, or power towers, require a lot of space and as with any electric power source they will need transmission lines.

Geothermal power, while thought to be relatively clean, will have the same transmission line problems, not to mention noxious odors.

Any other power form such as nuclear, coal and oil take up so much land and have so many pollution problems associated with it that they are already prime targets for environmental concerns.

While no one is ready to quit working on the problems, most energy people agree that there is no such thing as a "no environmental risk" power option.

It appears that while environmental concerns must be continued to be considered, environmentalists are going to have to back off a hard line if they expect anyone to get anything accomplished.

A mutual agreement of risk versus benefit must be arrived at or the United States energy crisis will come to the same point as the Jemez Mountain geothermal project.

In the Jemez, the government is saying, some things can be done. The air may be protected, the water may be alright, specific religious sites may be protected, but we can not do everything the environmentalists want.

And since we can not be perfect, we just will not do it at all.

Reprinted from The New Mexican, September 23, 1979

Can you squeeze energy from a rock?

Scientists from the Los Alamos Scientific Laboratory have been doing just that under a grant from the Department of Energy. Working in the Santa Fe National Forest, they drilled two holes into low-permeability, high-temperature (150 F) rock to create a flow passage. Then they injected water under pressure into one hole and extracted it, heated, from the second hole. Energy extraction rates have reached 5 MW of power.

Reporting on the project at the ASME Piping and Pressure Vessel Conference last June, the scientists said they plan to expand the project to a 20- to 50-MW power system.

Reprinted from Welding Design & Fabrication, Cleveland, Ohio Monthly, 40,000, September 1979

DON SAYS

Five to ten years hence, 1979 may look like the year when America smartened up. Actions by OPEC which seem like highway robbery now are forcing us to dust off energy options we should have begun long ago.

For example, the Los Alamos Scientific Laboratory is using a Dept. of Energy grant to drill twin holes into high temperature, Precambrian rock in the Santa Fe National Forest. Cold water poured down one hole comes up the other hot enough to generate power. Other DOE investigations include a variety of means for converting high-sulfur coals into low-sulfur fuel, gaseous fuels, or refinable syncrude. Also in the works is the nation's first solar electric generating facility designed for connection to a utility grid. Located in the Mojave Desert, the $120 million project should be operating by 1981.

Meanwhile, all manner of make-do's are being tried, such as a suggestion by Manufacturers' Agents National Association that its members cut business driving to four days a week. Our guess, however, is that by the time this is read gasoline will be headed toward $1.50 a gallon, and will be plentiful.

Reprinted from Automatic Machining, Rochester, NY August 1979

GEOTHERMAL POWER REALLY TAKES OFF

By Robert C. Cowen

Geothermal power — electricity made from subterranean heat — is becoming more than a gleam in an energy planner's eye.

The world's installed geothermal electric generating capacity still is only about 1,400 or 1,500 megawatts, equivalent to a single large central power station. But it is growing at a 16 percent annual rate. That's more than double the 7 percent rate that prevailed up to 1975.

"Something dramatic has happened over the past few years, both in the United States and in the rest of the world," says L.J.P. Muffler of the U.S. Geological Survey. It encourages him to have confidence in the projection made by his group that geothermal power can meet something like 10 to 15 percent of US energy needs within two or three decades.

The energy reserve on which geothermal power plants can draw is immense. In a recently published study, Muffler's team estimates there are 32 million quads (quadrillion Btus) of heat energy in the upper 10 kilometers of Earth's crust under the United States. Perhaps as much as 6,400 quads could be put to practical use. That's an impressive resource, compared with the 80 quads of energy from all sources now consumed annually in the U.S. It also is equivalent to 1,200 billion barrels of oil.

Muffler's team considered two types of geothermal energy sources. One — called a hydrothermal convection system — powers natural geysers. This is the kind of resource already being exploited, for example, by the 660 megawatts' worth of plant at "The Geysers" in California. The USGS study estimates recoverable reserves of this kind of energy at 2,300 quads. That's 20 percent less than a 1975 estimate, due to better data and estimating techniques.

The other kind of geothermal resource (not yet exploited) is called "geopressured." This is hot water, rich in natural gas, held under pressure in deep formations. The Gulf Coast region has abundant geopressured resources. Exploiting them means developing techniques to drill to depths of several kilometers. Expressing confidence that this can be done, Muffler says this resource represents anywhere from 400 to 4,200 quads of recoverable energy in the form of hot water and methane (natural gas).

These two types of geothermal energy rely on naturally provided water. If engineers could develop practical ways to extract energy from hot dry rocks by injecting water or other fluids, this could increase geothermal resources. A research team at the Los Alamos Scientific Laboratory estimates that exploitable HDR (hot dry rock) resources could equal U. S. coal reserves in energy value.

Muffler says that HDR power is still too speculative to be included in his geothermal projections. Even without it, the estimated resources amply justify his expectation that geothermal power will become "a significant, although not a dominant, energy source." The possibility of developing HDR power only strengthens that expectation.

Reprinted from Water Equipment News, Urbana, ILL September 1979