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IDAHO GEOTHERMAL R&D PROJECT
REPORT FOR PERIOD JULY 16, 1974, TO
SEPTEMBER 30, 1974

MASTER

Aerojet Nuclear Company

IDAHO NATIONAL ENGINEERING LABORATORY

Idaho Falls, Idaho — 83401

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The field work on the project is being conducted principally by the U.S. Geological Survey, under the director of Donald Mabey from the Denver Office of the Geological Division

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TECHNOLOGY BY THE GEOTHERMAL PROJECT

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The Idaho National Engineering Laboratory (INEL) Geothermal R&D Project was initially charted by the Division of Applied Technology in December 1973. This report covers the period July 16, 1974, to September 30, 1974. A brief summary of the work during this period is given in Section 1.0, with more detailed discussions in subsequent sections.

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1.0 SUMMARY

Site comparison charts were prepared based upon currently existing information for 12 geothermal resource areas within a radius of 350 miles from the Idaho National Engineering Laboratory (INEL) at Idaho Falls, Idaho. These charts were prepared to evaluate the selection of the Raft River Valley area as the site for a medium-temperature, low-salinity geothermal powered electric power demonstration plant.

Calcium carbonate depositions which had restricted the flow of the Crank well below requirements for corrosion and scaling tests were successfully removed. The 16-inch diameter casing had previously been reduced to 2-inch diameter by the calcite deposits built up over a number of years.

A review meeting on the Lawrence Berkeley Laboratory-Rogers Engineering isobutane binary plant design (operating from 392°F, 200°C geothermal fluid) was attended. Comparisons were then prepared of the plant cost estimates made by Rogers Engineering of that system and the dual flash steam plant design of the INEL (operating from a 302°F, 150°C geothermal fluid). The comparison confirmed the previous INEL conclusion, that existing technology and engineering design gives a significantly higher unit capital cost for binary (organic fluid systems) than for flash steam systems in the 300°F range.

Design requirements were established for the corrosion-deposition test loop to be connected between the first deep test and reinjection wells.

Two intermediate depth exploratory wells were completed in the Raft River Valley by Justice Well Drillers under USGS contract. The first was drilled to 1,101 ft., with a bottom hole temperature of about 45°C. Electric logs taken by USGS appear to confirm the resistivity predicted by the Schlumberger surface measurements. The second hole was terminated at 795 ft due to caving and sand contamination. Cores on this hole taken by USGS appear to confirm the high sound velocities observed in the active seismic work.

A hearing was held September 12 in Boise, Idaho, to review the AEC request for the temporary withdrawal of BLM land from general geothermal leasing for research and development purposes. Testimony in favor of withdrawal was presented by AEC-Idaho Operations Office, Aerojet Nuclear Company, the Sierra Club, Idaho Senator Saxvik of Cassia County, the Idaho Nuclear Energy Commission, Raft River Rural Electric Cooperative and Idaho Governor Cecil D. Andrus, as represented by Keith Higginson, Director of the Idaho Department of Water Resources. Written testimony was presented by U.S. Senator Frank Church, also favoring the temporary withdrawal for research and development purposes. Two oil companies testified against withdrawal. The AEC intent was to soon reduce its request, after completion of exploratory work, to only the acreage needed for the power plant and wells.

The second draft of the National Program Plan for non-electric utilization of geothermal energy was completed, along with a series of contacts with various industries concerning possible utilization of geothermal energy.

Drilling specifications were outlined (as a general draft) for the first deep test well in the Raft River Valley.

Laboratory testing began on the fluidized bed heat exchanger in contact with impure geothermal fluids.

A microseismic survey of a large area surrounding the likely geothermal target area was conducted by the Colorado School of Mines under contact to INEL.

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2.0 DEMONSTRATION MEDIUM TEMPERATURE GEOTHERMAL POWER PLANT PROGRAM

2.1 Background Information

The area of Southern and Eastern Idaho is one of the most promising regions in the United States for near surface, economically recoverable geothermal energy. This portion of the state is divided between two physiographic regions. The Snake River Plain is typical of the volcanic rift regions of the U.S. where approximately 8% of the hot wells, geothermal springs and geysers in the Western U.S. are located. South of this is a physiographic region called the Basin and Range Province which covers Nevada, the Western half of Utah, the Southwestern half of Arizona, as well as parts of California, New Mexico, Colorado, and Montana, in addition to parts of Southern Idaho. In this Province are located more than a third of the known hot wells, geothermal springs, and geysers in the Western U.S. This region has experienced mountain thrusting in recent years and around its borders significant, recent volcanic activity is more common than within its interior.

In and surrounding this Snake River Plain portion of Idaho there are suspected to be an enormously large number of potentially valuable geothermal fields, such as the area just West of Yellowstone National Park, the Brunneau Area and the Owyhee County region. All of these are the subject of continuing studies (particularly by the USGS and the State of Idaho) to determine their geothermal potential. However, little geological data exists in most areas within 150 miles of the Idaho National Engineering Laboratory and Idaho Falls where the U.S. Atomic Energy Commission's principal integrated contractor, Aerojet Nuclear Company, is located. Within this radius is one area in particular, bordering on the Snake River Plain and contained within the border of the Basin and Range Province. There significant amounts of geothermal data were collected in the 1970 to 1972 period. This is the Raft River Valley in Cassia County, Idaho. As a typical site, representative of Basin and Range Province regions of the Western States, the area was selected in 1973 by AEC-ID, ANC, and USGS as a prime location for continuing geological, geophysical, and geothermal research, and for the possible establishment of a medium temperature, hot water, geothermal research and development power plant project. Through silica solution tests, this area has been determined to have a probable temperature for geothermal waters in the region of 150°C (300°F). These geothermal fluids are of lower temperature than those now considered to be economical for electric power generation and have been classified by the AEC as medium temperature fluids. The huge quantities of such fluids available throughout the nation make them of enormous value for their total available energy. The area is, therefore, an appropriate location for a demonstration plant. Through the development of geothermal technology it is hoped that the economically competitive range of temperatures for electrical energy generation can be extended to lower values. The direct result being that the whole Basin and Range Province of the Western U.S. and its bordering areas would be demonstrated to be a commercially interesting geothermal field as well as resulting in a general increase in the potential value of all geothermal resource areas worldwide.

The occurrence of boiling water in the Raft River area near Malta, Idaho prompted the Raft River Rural Electric Cooperative to initiate, in 1971, preliminary geological investigations pertinent to the possibility of establishing

a geothermal plant in the area for the production of electricity. Simultaneously the Cooperative management began to secure geothermal leases on the private land owned by its members. In 1973, Aerojet Nuclear Company began a preliminary engineering and feasibility study, gathering additional geophysical information from the Raft River Valley. The USGS had initiated a basic geological study of the area beginning in 1970, and substantially increased the effort in 1973, including gathering of geophysical data.

Unlike the anomalous Geysers geothermal steam field in Northern California where the enthalpy of the hot dry steam is high, the Raft River Valley is a medium temperature hot water field of comparatively low enthalpy representative of much of the identified geothermal potential resources in the Northwest. Hot water sources of approximately 300°F have an enthalpy of approximately 270 Btu/lb which is significantly lower than obtained from producing steam fields like the Geysers and Larderello, where the exit fluid from the wells has 1100 Btu/lb. The hot water fields of Cerro Prieto, Mexico and Wairakei, New Zealand have well head fluids with about 500 Btu/lb. Hot water sources with about 270 Btu/lb are not currently attractive for commercial production of electric power. Neither the economics nor even the most economical power extraction techniques are yet unequivocally determined for these low enthalpy heat sources. However, the large amount of energy stored in these vast reservoirs make their development very valuable. The higher enthalpy fields now currently attractive represent only about 5% of the known geothermal fields.

The Raft River area appears appropriate for demonstrating the extension of power production technology to the harnessing of the power producing potential in warm, not hot, water. With only 150°C (300°F) water anticipated, conventional steam turbine systems appear only marginal for normal applications. But, the Raft River Valley's near surface aquifer is quite cold, approximately 10°C (50°F). With such a cold temperature heat sink, 150°C water becomes quite attractive, from a Carnot efficiency viewpoint. A low boiling point organic fluid is a prime candidate for the working fluid, but the economics compared to steam has not as yet been established.

The demonstration power plant will contain a steam and/or a binary (organic fluid) cycle depending upon final temperatures and mineral content of the hot water. Initial operation of the plant is anticipated to be mid-1978. More details about the geology of the area, its apparent geothermal potential can be obtained from the report ANCR-1138, entitled, "A Low Temperature Demonstration Geothermal Power Plant in the Raft River Valley," dated February 1974.

The overall goals of the project are basically as follows:

1. To demonstrate the extraction of energy from a hydrothermal field utilizing full reinjection of the waste fluid. The reinjected fluid is to contribute to the fluid recharge of the hydrothermal field, with minimum degradation of the environment and the thermal heat source.
2. To demonstrate the design and operational characteristics of a geothermal electric power plant operating from a reservoir temperature well below the enthalpy limits now considered to be economically attractive for commercial development.

3. To consider the most efficient and effective utilization of the resource available, including non-electrical applications for the heat and/or the geothermal water itself.

The activities in the previous quarter were presented in ANCR-1175, Quarterly Report (dated August 1974).

2.2 Power Cycle Studies and Power Plant Design

The basic planning and administrative functions required to implement the power plant design studies and evaluations were completed. Tasks to be completed this fiscal year were defined and a preliminary schedule was established for their completion. Principal emphasis of the design effort will be on the following:

1. Optimizing a 150°C (302°F) organic cycle design for reduced capital costs.
2. Study of the engineering economics of utilizing non-conventional turbine-condenser cooling systems for the purpose of enhancing plant output and reducing unit capital costs.
3. Use of non-conventional materials and design to reduce unit capital costs of single and dual stage steam flash plants.

Programmatic design requirements were established for a test loop to be connected between the first deep test well and a reinjection well. The design will feature several parallel branches to permit testing for corrosion and deposition while performing component tests on heat exchangers, flashers, etc. The total flow capacity of the test loop is being designed for 750 to 1000 gpm. The loop will provide the capability to test multistage flashers, conventional shell and tube heat exchanger, advanced heat exchangers such as the direct contact heat exchanger and the fluidized bed heat exchanger.

2.3 Environmental and Area Impact Considerations

The major effort during this quarter concentrated on a public relations program designed to increase public knowledge of the potential of geothermal energy and the research and development purpose of this project, and to provide contacts with local government agencies and citizens groups having an interest in the environmental aspects of geothermal power production. An introductory letter outlining the geothermal R&D effort was presented to the Federation of Western Outdoor Clubs at their annual meeting. The letter included a request for input from the Federation to the environmental analysis considerations. The Sierra Club, a member of the Federation, has publicly given their support to the project and will be one of the primary reviewers of the impact statements.

Work continued in identifying and evaluating the environmental impacts associated with the various phases of the project. The environmental analysis report for the deep drilling program is currently being drafted and should be published as a draft by December. Preliminary research for the impact statement for the power plant construction and operation is being coordinated with the plant's design phase.

In an effort to assess the economic and social impact of geothermal development in the Raft River Valley and to obtain public reaction to the research and development program, a survey of the residents of the area was taken. Eighty percent of the people questioned favored the currently outlined project. Most felt that the eventual commercial geothermal development and the resultant availability of a local power supply not dependent on fossil fuels would be of considerable significance.

2.4 Deep Drilling Program

Drilling specifications have been outlined and a general drilling specification prepared for the deep hole test well.

The matter of drilling costs and resource utilization is of major consideration in the geothermal energy program. Underground resources, with the inherent uncertainty concerning their location and extent, are customarily considered a high risk investment and a depletable resource. However, in the case of the medium and low temperature geothermal fluids (nominally less than 170°C), the resource value per unit quantity decreases with lower temperatures but its abundance becomes greater. Consequently, it would appear that engineering techniques, drilling costs, and economic analyses relating to the extraction of the resource must be considered in a context somewhat different from conventional oil well drilling or domestic water well drilling. Since the resource will be maintained in the liquid state with no or very little excess pressure, the considerations concerning drilling techniques, blow-out prevention, etc. might be viewed in somewhat different context than for high temperature steam geothermal wells.

The above considerations are receiving major attention by this project in establishing drilling specifications for commercial bid. Several resource development companies have been contacted concerning their interest. The use of "non-conventional" techniques, such as are routinely employed in the extensive geothermal program in Iceland, deserve consideration--examples being: water as the drilling fluid, use of long-life bits, and a selective casing program. Some of the matters will concern regulations established by the states and any applicable national code now existing or to be created in the future. All of these aspects would appear to cast even the drilling operations for the medium and low temperature resources into the possibly nonconventional category.

2.5 Geology and Geophysics

2.5.1 Surface Measurement Program

The principal geological and geophysics work was continued by the U.S. Geological Survey, Denver, Colorado Office.

Surface Geology - The geologic mapping and paleomagnetic studies are continuing in the Northern part of the Raft River Valley and the Cotterel Mountains.

Surface Geophysics - The resistivity survey in the Southern Raft River Valley was resumed in July and completed a month later. The active seismic survey was resumed in late August. Airborne infrared surveys in the Southern Raft River were made in July.

A detailed Bouguer gravity map of the Southern Raft River Valley was finished and is being interpreted. Interpretation of the seismic and resistivity data is in progress.

A microseismic survey net with radio linkage was set up in early summer by the Colorado School of Mines under a research contract to INEL. Monitoring has continued for a 3 month period. In general, the entire area shows little seismic activity. A few minor events averaging about three per day have been observed over the 90 day period that the area has been monitored.

2.5.2 Intermediate Depth Test Wells

On July 10, 1974, representatives of the AEC, USGS, Aerojet, and Raft River REA met in Boise to discuss the selection of sites for the intermediate depth drill holes. The site of the first hole was selected and tentative sites for additional holes were agreed upon. Justice Well Drilling Company of Boise began drilling operations the first of August and had completed the first hole and nearly completed the second test hole by the end of this reporting period.

The first well was drilled to 1101 ft, about 2 miles NE of the BLM (Schmitt) boiling well. Electrical logs and core examination confirmed both the resistivity and fault zones interpreted from surface geophysical work. Bottom hole temperature was less than 50°C. The second well about 3/4 mile SE of the Crank well (see Figure) eventually was abandoned at the 790 ft depth in loose gravel. Logging information from the well is incomplete as of this date. The drilling of the third well was to commence in mid-October about 1-mile west of the Crank well and 1 mile south of the BLM (Schmitt) well.

Fig. 1 Intermediate Depth Test Wells

3.0 ADVANCED HEAT EXCHANGER DEVELOPMENT

3.1 Background

Minerals in geothermal waters tend to foul conventional shell and tube heat exchangers by depositing on the heat transfer surfaces. The buildup of these minerals proceeds at a rate which often makes cleaning frequency impractical. Two possible methods of circumventing this problem are: 1) to use direct contact heat exchange between the geothermal fluid and the working fluid and; 2) to use the geothermal fluid to fluidize a bed through which heat exchanger tubes are passed. The direct contact heat exchanger provides high heat transfer rates due to the mixing and after heating the working fluid can be separated from the geothermal water and any mineral precipitates. The bed material in a fluidized bed heat exchanger provides much more surface area for mineral deposition than the tubes. Thus, deposition may occur on the bed particles rather than the heat exchange surface. In addition, the motion of the bed material may tend to keep the tubes from fouling.

The purpose of the heat exchanger development program is to determine if the heat exchangers described will function as indicated and become viable components for use in systems requiring heat exchange with a geothermal fluid.

3.2 Fluidized-Bed Heat Exchanger

Liquid fluidized-bed heat exchangers offer the possibility of implementing, on a practical basis, binary-cycle recovery of energy from low-temperature geothermal sources. The present study is to define the workability and the important parameters required to design a liquid fluidized-bed heat exchanger which can be used in a demonstration facility.

A small bench-scale fluidized-bed heat exchanger has been constructed from glass and copper tubing and is now being tested. The shell is made from glass and is 3-1/2 in. in diameter by 14 in. long. Two interchangeable copper coils are available; one has 0.98 square feet of surface area, and the other has 1.43 square feet of surface area. Hot simulated geothermal water passes up through the glass shell which contains a single bed of sand. Cold water is used as the secondary fluid inside of the copper coil imbedded in the sand of the single stage.

At the present time, preliminary testing of the unit is being conducted so that the characteristics of the bed and its operation can be visually determined. Several different bed support plates have been tested, as have two different sizes of sand as bed material. Throughout many of these tests, some very initial heat transfer rates have been estimated.

Two problems have been encountered so far. The capacity of the primary water pump has limited fluidizing velocities to near minimum for only the smallest sand particle sizes. A new pump has been ordered, and when available will increase the available rate of flow by a factor of four. The present heating system is not large enough. The exchanger will transfer much more heat than that available (3000 to 4000 Btu/hr). A new electric water heater is being fabricated that will provide up to 16,000 Btu/hr.

Parallel with the initial engineering development, chemical studies are being initiated with the object of identifying the sensitive parameters for detailed investigation. A series of static tests will be conducted to determine the effect of varying geothermal fluid composition, bed material, and chemical treatment on the quality of the scale deposit formed.

A survey of available* water chemistry on typical Raft River Valley hot water wells indicated that the information at hand is either incomplete or inaccurate for the purposes of heat exchanger performance analysis. A sampling and analysis program to resolve this matter is underway.

* Principal reference is "Geothermal Investigations in Idaho, Part 1, Water Information Bulletin No. 30.

4.0 NON-ELECTRIC USES OF GEOTHERMAL ENERGY

Just prior to the beginning of this reporting period, the Idaho National Engineering Laboratory was formally assigned the responsibility to coordinate a non-electric utilization program-concept definition study. This study should result in a program plan delineating the potential for the utilization of geothermal energy for non-electric uses nationwide and for assessing the research and development needs to implement such uses. The overall study will include, but not necessarily be limited to, the following factors: geographic locations and estimated sizes of resources in the United States; relationship of potential sites of energy utilization to location of resources; types of non-electric uses and applicability to the United States; economics and potential market penetration; environmental impact; need for technology development and systems studies; and recommended field projects and laboratory studies. Contributions to this program plan are expected from several other AEC laboratories as well as from University and private contacts. Collection of the data and assembling of the program plan has progressed during this period.

Reports have been received from several specialists engaged by ANC/AEC relative to exploitation of geothermal energy for non-electric uses in the fields of aquaculture, agriculture, pharmacology, refrigeration and process industries. In addition, a preliminary report has been received on the nationwide availability of geothermal resources.

INEL personnel have made personal contact with over a dozen industrial concerns to establish an indication of the types of industry which might be adaptable to the use of geothermal energy as well as to sample the industrial interest in this source of energy. In general, response of industry showed considerable interest even if additional capital investment were required to accommodate a lower temperature source (assuming of course that fuel savings would eventually amortize the capital investment addition).

A draft of the program plan was prepared during this period.

5.0 PLANS FOR SUBSEQUENT QUARTER

1. Complete preparation of Program Plan for non-electric utilization of geothermal energy and submit to AEC-DAT.
2. Prepare preliminary recommendations for the binary cycle design for the nominal 150°C Raft River source.
3. Complete the corrosion and deposition test system hardware and make necessary preparations for installation on the Crank hot well.
4. Evaluate the collection of geophysical and geological information assembled by USGS, INEL, and others. Select drilling sites for the first two or three deep exploratory wells.
5. Issue drilling specification and request bids for the first deep well.