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**IDAHO GEOTHERMAL R&D PROJECT
REPORT PERIOD FOR
OCTOBER 1, 1974 TO DECEMBER 31, 1974**

Aerojet Nuclear Company

IDAHO NATIONAL ENGINEERING LABORATORY

Idaho Falls, Idaho — 83401

DATE PUBLISHED - FEBRUARY 1975

PREPARED FOR THE

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GEOTHERMAL R&D PROJECT REPORT FOR
PERIOD OCTOBER 1, 1974 TO DECEMBER 31, 1974

Prepared by Idaho Geothermal Project:

J. F. Kunze, Manager, INEL Geothermal Projects
L. G. Miller, Manager, Field Operations
J. F. Whitbeck, Manager, Power
A. S. Richardson, Manager, Non-Electric Applications
R. C. Stoker, Geological Engineer
S. G. Spencer, Environmental Engineer
J. W. Neitzel
L. F. Martin

Assisted by personnel in the Research & Engineering departments of Aerojet Nuclear Company; C. R. Nichols, Boise State University; M. W. Majors, Colorado School of Mines; L. L. Mink, Idaho Bureau of Mines & Geology, personnel of University of Utah and Allied Chemical Corp. (INEL); and with the extensive cooperation of the U.S. Geological Survey, principal investigator Donald Mabey

SUBMITTED TO THE IDAHO OPERATIONS OFFICE AND THE DIVISION OF GEOTHERMAL RESEARCH
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AEROJET NUCLEAR COMPANY

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PREPARED FOR THE U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
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Contract Technical Coordinator - J. L. Griffith

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Reynolds Electrical and Engineering Co. Drill Rig at RRGE-1 Drill Site in the Raft River Valley

ABSTRACT

The Idaho National Engineering Laboratory (INEL) Geothermal R&D Project was initially chartered by the Division of Applied Technology in December 1973. This report covers the period October 1, 1974, to December 31, 1974. A brief summary of the work during this period is given in Section 1.0, with more detailed discussions in subsequent sections.

NOTE ADDED IN PRESS (FEBRUARY 11, 1975)

Drilling on the geothermal exploratory well began on January 4, 1975, in the Raft River Valley in Section 23 of Township 15 South, Range 26 East. Water was selected as the drilling fluid so as to maximize the potential for discovery of the resource. On February 1, a depth of 4650 ft was attained, and a routine logging operation was begun. Within 12 hours spontaneous flow began to develop in the well. The well was allowed to flow freely until the completion of the logging operation, 14 hours later. At that time, bottom hole temperatures were 280°F and the estimated flow at the surface was approximately 1,400 gallons per minute. Surface temperature was saturation temperature at this altitude (206°F). At that time, the blowout preventors were closed, and the well was shut-in in preparation for casing down to the production zone. Bottom hole temperatures of as high as 291°F have been measured (February 10).

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1.0 INTRODUCTION

Drilling practice and potential problems were investigated and a drilling contractor selected; the Reynolds Electrical and Engineering Company (REECo), prime contractor for the Nevada Operations Office of the Atomic Energy Commission. A contractual arrangement was made and during December, the drill site was prepared and equipment readied for drilling. Drill site selection was made by Aerojet Nuclear Company and AEC personnel utilizing all available information, in particular data provided by the U.S. Geological Survey (see Section 2.4).

Thermodynamic calculations were performed to compare various potential operating points. A computer program was prepared to compute dissolved gas release and mineral deposition as pressure and temperature are varied.

A review of common refrigerants was performed and a study of the advantages of a dual boiling cycle was commenced for binary system applications.

Construction began on a mobile laboratory for a materials evaluation and test facility to be used at geothermal well locations.

A study was completed on condenser cooling methods relative to the sensitivity of various cooling systems (cooling towers, aquifer cooling, etc.) to variations in design temperatures.

Testing on the fluidized bed heat exchanger concept was initiated and has shown (in these preliminary tests) that the precipitation and deposition of solid materials on the heat exchanger surfaces in the bed was effectively mitigated (see Section 3.2).

Laboratory testing of direct contact heat exchanger concepts by the University of Utah was initiated (see Section 3.1).

An environmental report on the effects of deep test wells and test loop was completed, reviewed by various informed persons outside of the INEL. The report is being issued for information purposes (see Section 2.3).

Intermediate depth well drilling and testing by the U.S. Geological Survey continued in the Raft River Valley, with the third well temperature near boiling in the range of total depth (1,400 ft) (see Section 2.5.3).

The National Non-Electric Geothermal Program Definition Study was completed in draft form. Publication is pending review.

Planning and preliminary conceptual design work were initiated. The Non-Electric Project to convert the government office building complex in Boise, Idaho to geothermal heating is underway.

The activities in the previous quarter were presented in ANCR-1190, quarterly report dated October 1974.

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 Bruneau 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 Energy Research and Development Administration's principal integrated contractor, Aerojet Nuclear Company, is located. One potential site, the Raft River Valley of Cassia County, Idaho, is an exception, where significant amounts of geothermal data were collected during the 1970 to 1972 period. As a typical site, representative of Basin and Range Province regions of the Western States, this 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.

2.2 Electrical Power Plant and Associated Studies

The work primarily associated with the power plant falls in the following major areas: flash steam power plant, binary power plant, water chemistry (including gas desorption and mineral deposition materials application), test systems, and heat exchanger experiments. The progress in each of these categories is reported below.

2.2.1 Flash Steam Power Plant Studies

1. Thermodynamic Studies

A comparison with a dual flash "reference" system was made to determine the thermodynamic value of the following (with 300°F geothermal supply):

- a. The sensitivity of power output to increasing the pressure of the initial flash. This information will be useful in future tradeoff studies when the use of steam from the initial flash will be considered for air-ejector drive and also in tradeoffs with the turbine design.
- b. The advantage gained by reducing condenser pressure to 1.5 in. Hg abs as may be possible if the cold water aquifer can be used for condenser cooling.
- c. The advantage of subatmospheric flashes. Subatmospheric flashes have not been seriously considered to date because of the corrosion problem that could result due to oxygen leakage into the system.

The results of this work are summarized in Table I. The cycle power is given in terms of watt-hrs/lb of brine (equivalent to MW/million lb/hr of brine). This power is based on a combined turbine and generator efficiency of 68%. It does not include system losses.

Cases 1 through 5 indicate the sensitivity to the pressure/temperature selected for the first flash of a dual flash system when the pressure

of the second flash is held essentially constant. Case 4 is the reference case. The power output is relatively insensitive to the pressure of the first flash over the range considered. Case 6 shows the advantage (21% increase) that could be obtained by reducing the condenser pressure to 1.5 in. Hg abs as may be possible if the cold water aquifer can be used for cooling.

The advantage of a subatmospheric second flash is shown in case 7 (compare with case 5) where an 11% improvement occurred. The reduction in output (approximately 12%) caused by increasing the second flash pressure is shown by comparing cases 8 and 9 with cases 1 and 2, respectively. Some multflash (4) results are shown in cases 10 through 13. Comparing case (10) with (4) shows only a 6% improvement is obtained by the addition of two flash stages above atmospheric pressure. Subatmospheric flashes combined with low condenser pressure yield $4.93 \text{ MW}/10^6 \text{ lb/hr}$ of brine, a 50% improvement over the reference case. These results indicate that a flash steam system can be made competitive with a binary system with respect to resource utilization. Further, based on preliminary cost estimates that are currently available, it would appear that the cost to achieve this high resource utilization is not likely to exceed that of a binary cycle of the same power utilization. However, this conclusion is intended to be interpreted only qualitatively, until reliable cost estimates are made on these modified cycles.

2. System Concepts

Preliminary studies have been started which will be useful in evaluating the effectiveness of a preliminary flash to remove non-condensables and to estimate the dissolved gas release and mineral deposition in the flash stages. The computerized solution will be incorporated into flash system routines. Further discussion appears under the chemistry section.

Table I
Comparison of Various Flash Cases

Case No.	No. Flashes	Flash Press/Temp. psia/°F	No. Cond.	Cond. Pressure in. Hg	Watts/lb/hr
1	2	40/267 14/209	1	3	3.19
2	2	35/259 14/209	1	3	3.21
3	2	30/250 14/209	1	3	3.22
4	2	30/250 13/206	1	3	3.28 Ref. case 7% less than case 7
5	2	25/240 14/209	1	3	3.18
6	2	30/250 13/206	1	1.5	4.0 21% better than case 4
7	2	25/240 7/177	1	3	3.52 best thermo. at 3 in. Hg
8	2	40/267 20/227	1	3	2.85
9	2	35/259 20.257	1	3	2.85
10	4	40/267, 31/252 22/233, 13/206	1	3	3.49
11	4	46/276, 31/252 20/228, 12.5/204	2	4 1.5	3.97
12	4	40/267, 23/235 12/202, 6/170	2	4 1.5	4.29
13	4	40/267, 23/235 12/202, 6/170	1	1.5	4.93

All flashes
above atmos-
pheric
pressure

2.2.2 Binary Power Plant Studies

A review of all the common refrigerants (such as those listed in the ASHRE handbook) has been made relative to that utilization for a medium temperature geothermal system. This review has considered net brine utilization, turbine enthalpy, drop feed pump work, cooling work, thermal efficiency, turbine size, heat rejection and heat exchanger pressures. The superior fluids appear to be isobutane (R-600a) R-114 and R-12. Significant brine utilization is possible with a single boiling cycle. Currently investigations are underway to determine the advantages that can be achieved by a dual boiling cycle. Generally supercritical cycles are undesirable because the low critical temperature required for use with 300°F geothermal fluid results in a high pressure system with little system flexibility with changes in the geothermal source temperature. In the boiling systems studied, the optimum boiler temperature for maximum brine energy utilization appears to be about 200°F for R-114 and R-12 and 225°F for isobutane (R-600a). A net power production of 3.5-3.8 MW/million lb/hr of brine can be achieved (all based on a relatively optimistic 10°F pinch point). In addition to the dual boiling system studies to be conducted in the next quarter, the use of fluid mixtures will be investigated. Mixtures offer the potential of reducing heat transfer area in both the boiler and the condenser.

2.2.3 Test Systems

Two mobile test systems will be utilized at the test site, one is a mobile laboratory for evaluating materials exposed to geothermal water and will contain equipment for limited on-site chemical analysis. This system is presently being fabricated. A second test system, a mobile component test facility, is currently in the design phase. This facility will permit testing of power plant component prototypes and experimental hardware on the actual geothermal brine. The facility will also permit study of mineral deposition on heat transfer surfaces.

2.2.4 Condenser Cooling

Several methods are available for condenser cooling, among them are wet and dry cooling towers, fan cooled condensers and ponds. These various methods were evaluated relative to sensitivity of power output to decreasing the design temperature. Of interest was the reduction in the cooling system

size relative to the loss in power capability when the design temperatures (wet bulb and/or dry bulb) for the Raft River area were selected that were lower than normal. Of the systems rejecting heat to the atmosphere, the wet cooling tower was the most effective and least sensitive to changes in the design temperature. The worst systems within these considerations were cooling systems not dependent upon evaporation (dry systems). Although the typical Intermountain Valley (such as the Raft River area) is quite cool the greatest part of the year, the summer and a portion of the fall months are quite warm over an extended period. Dry cooling systems will thus incur a significant penalty on power output during this period, the very period the electric demand is highest. For these reasons, it is felt necessary to concentrate effort on cooling systems other than dry towers where such other options are available and environmentally acceptable.

2.2.5 Water Chemistry (Gas Desorption and Mineral Deposition)

In many geothermal areas, a potential source of CO_2 lies deep beneath the surface. For instance, it appears that in the Raft River area substantial beds of dolomite exist at 5000-6000 ft. Dolomite will decompose when heated strongly, for example, by the geothermal heat source, and liberate CO_2 . It is possible that the temperature is sufficient to produce a high enough partial pressure of CO_2 to reach or exceed the solubility limit of CO_2 in H_2O at the pressure and temperature found at depth. No evidence of substantial CO_2 venting at the surface has been found; however, the potential for a significant release exists when the pressure is reduced as the water rises in the well or in the flash process of a flash steam power plant.

For the expected Raft River conditions (150°C) the maximum possible CO_2 content at 6,000 ft is 47 grams per kg H_2O . This value is about double the highest value recorded at Broadlands, New Zealand (about 23 grams/kg H_2O). A more typical value is about 3.5 grams/kg H_2O encountered at Wairakei. The saturation limit of CO_2 corresponding to a pressure of 67 psia (saturation for 150°C) is about 1.4 grams/kg H_2O . From consideration of these values, it is estimated that a potential problem of substantial magnitude exists in utilizing a downhole

pump (at 200 to 500 ft depth) since the void fraction at the pump inlet could be sufficient to degrade the heat, possibly to the point that pumping is not possible. Further investigations into this problem will be conducted during the next quarter.

The use of a preliminary flash to remove non-condensables from the geothermal water (in a flash steam plant) was investigated. If significant quantities of dissolved gas exist, this method may prove feasible. However, for initial equilibrium (CO_2) with saturation pressure the steam loss is significant since the CO_2 would evolve in an approximately fixed proportion to the flashed steam (0.013 gram CO_2 evolved per gram of flashed steam). A computer program is being prepared which will estimate the solubilities of CaCO_3 , CO_2 , N_2 and O_2 in water as functions of temperature and pressure. This program will be used to estimate potential gas and mineral release in the power plant and particularly in trade-off studies concerning the removal of non-condensable gases.

2.2.6 Material Applications

No severe corrosion problems are anticipated with medium temperature geothermal power plants provided that entry of oxygen is prevented. Steel casings of existing wells have survived extended exposure to geothermal water without deterioration except where surfaces were exposed to the atmosphere. The applicability of other alloys, such as aluminum, may be limited by the influence of trace elements or by measures applied to inhibit scale formation. Concrete and asbestos-cement are potential steel substitutes in some areas of the plant, particularly with regard to cost considerations. These materials must be thoroughly tested under the range of anticipated conditions to verify their applicability.

A number of organic materials have been considered; however, they have generally appeared to be unacceptable due to either temperature limitations or cost. Investigations into alternate material applications are continuing.

2.3 Environmental and Area Impact Considerations

A preliminary draft environmental report covering the deep test wells and test loop was completed, and is being published as ANCR-1204. Interested parties may request a copy from the project office. The analysis was prepared in considerable detail in order to provide a source of information for the general public. The initial draft of the report was submitted for review to the Division of Applied Technology-AEC, BLM, Idaho Water Resources Administration, USGS, Raft River Rural Electric, and to various state legislators and universities with an interest in the project. All comments received were carefully reviewed and generally have been incorporated into the final environmental report.

Peripheral environmental activities during this period included inspections of the drill site and wells in the Raft River Valley, input to the design of the test loop to ensure compliance with the State and Federal environmental regulations, and background research into various aspects of the demonstration geothermal space heating project.

2.4 Deep Drilling Program

2.4.1 Geothermal Well Drilling Program Plan

Specific information concerning geothermal well drilling was gathered from various sources including the U.S. Bureau of Reclamation in the Imperial Valley of California, and the Los Alamos Scientific Laboratory in New Mexico. The general outline for a drilling program concerning the Raft River Geothermal Exploratory No. 1 drill hole (RRGE-1) was formulated.

Contact was made with well bit suppliers, well service contractors and commercial well drillers to acquire information relative to problems concerning well casing procurement, drilling rig availability, directional drilling techniques and rig costs.

Discussions were held with Reynolds Electrical and Engineering Company (REECo) prime contractor for the AEC's Nevada Test Site, concerning well drilling practices in general, drilling capabilities and limitations. In addition, specifics

concerning drilling techniques and actual field problems were discussed with the American Standard Company of Boise, Idaho, concerning their recent oil and gas test drilling in the Raft River Valley of Idaho.

In early November, Reynolds Electric and Engineering Company (REECO), was asked to prepare to do the exploratory drilling in the Raft River Valley. Its off-site rig was then being moved from a gas stimulation redrilling operation in Colorado, and was immediately available for use in the Raft River project.

2.4.2 Preparation for Drilling

Drilling site preparation consisted primarily of a location survey, land leveling, excavation, conductor pipe installation, domestic well drilling, electrical power connection, fuel supplies, office trailer installation, and arrangements for phone service. Considerable assistance was required of the Raft River Geothermal Development Corporation to accomplish many of these tasks.

Drilling rig mobilization and assembly was accomplished and completed by REECO by the end of the year. Drilling actually began on January 5, 1975.

A detailed drilling plan prepared jointly by REECO, and the AEC Nevada and Idaho Operations Offices was reviewed by the project office and comments were submitted for finalization of the plan. The plan was issued in mid-December. Variations to the drilling plan are still being considered, particularly concerning the type of drilling fluid to be employed (mud or water), the casing, and well completion practices to be used.

2.5 Geology and Geophysics

Except as noted in Section 2.5.2 below, the geological and geophysical work was continued by the U.S. Geological Survey, primarily through its Denver, Colorado Office of the Geological Division. Work was confined to laboratory interpretation, field work having been completed in late summer.

2.5.1 Surface Measurement Program

1. Surface Geology

Interpretation of the surface geology of the Raft River Valley and Cotterell Mountains is continuing along with possible inferences about the subsurface geology. Interpretation of paleomagnetic data is continuing.

2. Surface Geophysics

The active seismic survey and spontaneous electric potential survey were completed in November. These surveys along with the bipole-dipole, and Schlumberger deep resistivity, airborne infrared, gravity, residual magnetic, and audiomagnetotelluric surveys are being interpreted and correlated.

2.5.2 Microseismic Survey

A microseismic survey was initiated in early summer by the Colorado School of Mines under a research contract to INEL. This survey was completed in November and a report is expected shortly. In general, the entire area shows little seismic activity.

2.5.3 Intermediate Depth Test Wells

Four test hole locations were selected in July, 1974 and drilling began the first of August. The first hole was completed in the previous quarter, while the second and third were completed this quarter. The fourth hole site was finalized and drilling is expected to commence shortly after the first of the year. A fifth test hole may be drilled. See Figure 1 for test well locations.

1. First test well (1,101 ft deep) - covered in last quarterly report (July 15 - September 30, 1974).
2. Second test well (800 ft deep) - the well was abandoned due to the sloughing of loose unconsolidated gravel in the hole. Logging was completed to 683 ft and except for the unconsolidated nature of the gravel, it revealed nothing that was not expected. The temperature gradient was $205^{\circ}\text{C}/\text{km}$ and the bottom hole temperature was 55°C .

3. Third test well (1,423.5 ft deep) - the drilling encountered a poorly consolidated conglomerate member at 1,300 ft that caused extensive sloughing in the hole. Drilling was suspended at 1,423.5 ft due to this sloughing although the intended depth of the hole was 1,500 ft. Artesian geothermal water was encountered at approximately the 1,150 ft level from a highly fractured zone. Drilling had been suspended for the weekend at the 1,200 ft level and upon returning the following Monday artesian geothermal flow was encountered issuing from the hole. The bottom hole temperature was 86°C, gradient 210°C/km, and flow 60 gpm. The well has subsequently been capped with a shutoff valve.
4. Fourth test well - the site was selected and drilling commenced the first week in January.

2.5.4 RRGE-1 Exploratory Well Site Selection

A field trip to the Raft River Valley combined with an aerial photo study and aerial reconnaissance resulted in a tentative selection of a drill site by Aerojet Nuclear Company and the AEC. A meeting was conducted at Denver, Colorado to review all U.S. Geological Survey data acquired to date and to make a final selection of the drilling site. The information presented at this meeting supported the selection of the tentative site and the recommendation of two alternate sites. The final site selection was based on lease considerations and vehicle accessibility. The site selected is on Bureau of Land Management land and has good all-weather road accessibility. RRGE-1 is in the NE corner of the NE 1/4 of the SW 1/4 of Section 23, T15S, R26E. (see Figure 2).

2.6 Hydrology

2.6.1 USGS (Reported by E. G. Crostwaite)

Geologic structure, lithology, and physiographic history control the surface-drainage pattern as well as the occurrence and movement of ground water. The principal water-bearing formations (older to younger) are the

Salt Lake Formation of Pliocene age, consisting mainly of weakly consolidated sandy sediments and some layers of volcanic rock; the Raft Formation of Pleistocene age consisting of sand and gravel, lake sediments, and thin beds of silt and clay; and alluvial deposits of Holocene age that form aquifers beneath the bottom lands of the valleys.

Ground water occurs in perched water tables, normal water tables, and under confined artesian conditions with the water bearing aquifer often located less than 40 ft below the land surface. Yields of irrigation wells in the area range from a few hundred to a few thousand gpm with average depths of from 200 to 400 ft.

Several wells yield warm to hot water. The hot water plumbing system is poorly understood; however, geological and geophysical evidence suggests that the water rises from several thousand feet along fault zones and then moves laterally through permeable beds of the aquifer system. Three intermediate depth test wells have been core drilled by the USGS to investigate the nature of the hot water and character of the rocks to depths of approximately 1,000 ft (see discussion of wells under 2.5.3).

The cores and cutting were described at the well site and are awaiting lab tests, petrographic examination, etc. Most of the material cored was claystone, siltstone, and sandstone, with several beds of conglomerate. These materials exhibit extensive alteration to clay due to low temperature percolating thermal waters. Most of the water samples have been collected, but the analyses are not back from the lab at this time. Preliminary indications are that the deeper water is somewhat salty (sodium chloride) with conductivities of 7,000 to 10,000 micromhos/cm.

Geophysical borehole logs have been completed and additional logs will be run when new tools are available (for example, flow meter and televiwer).

The water level in No. 1 hole is about 150 ft below the surface; in No. 2, it is about 70 ft below the surface; and No. 3 will flow about 60 gpm.

Shut-in pressure is 15 lbs per square in. No. 3 is equipped with a shutoff valve.

The results of drilling reinforce the interpretation of the geophysical studies made by the Geologic Division last summer and were a factor in locating the deep geothermal test hole now being drilled.

2.6.2 Pump Tests and Well Interaction Studies

Pumping tests were conducted on two privately owned irrigation wells in the immediate vicinity of the deep test hole location. Both wells are approximately 200 ft deep, 18 in. in diameter with perforated casing and have a free water surface (water table) located at a depth of 30 ft. One well was pumped at 1,600 gpm and data were taken at 5 observation points. The other well was pumped at 1,200 gpm and data were taken at two observation points. Both wells exhibited a drawdown of approximately 6 ft during pumping.

The data were used in a two dimensional ground water computer code using the "Theis" equations and both transmissibility and reservoir storage capacity were calculated. A full test report is currently being prepared and will be released during the latter part of January.

Fig. 1 Intermediate Depth Test Wells

Fig. 2 Drill Site and Vicinity

3.0 ADVANCED HEAT EXCHANGER DEVELOPMENT

3.1 Direct Contact Heat Exchanger Development Studies

(Reported by R. F. Boehm and H. R. Jacobs, Department of Mechanical and Industrial Engineering, University of Utah)

Work is proceeding on two fronts: studies on bulk volume boiling and surface boiling relating to a rational end design. In the first category the working fluid in liquid form is sprayed into the brine through a submerged nozzle. Bulk boiling results from the intimate contact of the two fluids since the water is above the working fluid saturation temperature. In the second configuration, the working fluid in liquid form is sprayed onto the brine surface. This arrangement offers the benefit that the degree of mixing is decreased relative to the first configuration, which may prove beneficial for later mechanical separation of the two fluids.

Currently two models have been built for studies of the volume boiling phenomena. One is a completely glass enclosed chamber (3.5 in. in diameter by 16 in. high) filled with water which is heated on a batch basis. The desired temperature is achieved with a submersion heater. A small amount of the working fluid is forced through a submerged nozzle from a pressurized supply. Sufficient instrumentation is available that accurate heating information can be determined. To date, the apparatus is being debugged and instrumented. Qualitative studies have been performed using refrigerant 113. For a saturation temperature of 108°F, very active boiling has been demonstrated in water temperatures of 110°F.

The second volume boiler is much closer to small-scale pre-prototype. It consists of a steel chamber (approximately 8 in. in diameter by 12 in. high) which can be pressurized to 600 psia. Glass viewing ports are located on each side of the chamber. Provisions are incorporated for flowing through both the brine and the working fluid, as well as for sufficient instrumentation.

Design work on the initial test chamber for the surface boiling studies is completed and construction is about to begin. This will take the form of a

rectangular tank with two glass walls, somewhat like a low covered aquarium. Provisions are made to allow flow-through of both the working fluid and the brine. Spray nozzle design characteristics are currently being studied to allow optimum aerosol drop sizes.

Preliminary work has been initiated to determine the possibilities of mechanical entrainment. For Freon 113, even under extreme agitation, no mechanical entrainment has been found with distilled water. Work will commence on brines in January 1975.

3.2 Fluidized Bed Heat Exchanger Development Studies

(Reported by E. S. Grimmer, K. L. Smith, and D. C. Schmunk, Allied Chemical Corporation, Idaho National Engineering Laboratory)

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 purpose of the present study is to define the operating conditions and parameters required to design a liquid fluidized-bed heat exchanger which can be used in a demonstration facility.

3.2.1 Bench-Scale Test Unit

During this quarter, work on the liquid fluidized-bed heat exchanger for geothermal power generation has been devoted to developing a small fluidized-bed heat exchanger for use in preliminary laboratory scale-deposition studies. It has a diameter of 4 in., a bed depth of 11 in., and contains 0.98 ft² of copper tubing surface area. With this system, heat transfer and chemical deposition data are being obtained at atmospheric pressure and temperature up to 150°F. This information will be used to design and construct a larger model liquid fluidized-bed exchanger. This unit is being designed for testing at pressures up to 200 psi and temperatures to 350°F.

The most promising deposition experiments that have been run to date consist of two calcium carbonate scale formation runs. During these runs,

solutions of CaCO_3 were circulated from the heated reservoir where the solution was kept saturated by the presence of solid CaCO_3 , through the heat exchanger where the liquid was cooled and CaCO_3 precipitated out of solution, and then back to the reservoir (see Figure 3). The solutions were circulated 8 hours a day for 7 days on each run.

The first run was conducted without a bed present in the exchanger. After operating for 7 days, there was visible deposit on the surface of the heat exchanger coil (see Figures 4 and 5).

The second run was conducted using a bed of $<0.425, >0.300$ mm sand supported on a layer of lead shot. At the end of 7 days, there was no deposition of CaCO_3 scale on the coil where it had been exposed to the fluidized bed of sand (see Figure 6). However, deposition of CaCO_3 , as confirmed by emission spectroscopy, was visible on the coil where it was not exposed to the scrubbing action of the fluidized sand. Scale had formed on the coil inlet which was above the level of the bed, along the sides of the coil where it had been positioned against the spacers, and on the bottommost ring of the coil where it had been buried in the unfluidized lead shot (see Figures 7 and 8). CaCO_3 deposition also occurred on the lead shot distributor layer and the surrounding tank wall (see Figure 9).

During the second run, with the bed present, heat was transferred to the secondary water stream at up to 7,500 Btu/hr. The overall heat transfer coefficient was $184 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$; $980 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$ was the secondary stream inside tube coefficient and the bedside coefficient was $244 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$.

The results of these early experiments indicate that the CaCO_3 scaling problem can be controlled with a fluidized-bed heat exchanger. In addition, this type of exchanger provides high heat transfer rates from the hot geothermal fluid to the secondary fluid.

3.2.2 Single-Stage Pilot Plant

The pilot plant unit for geothermal, fluidized-bed heat exchanger studies has been sized. It will be 5 ft high with a square cross-section

7 in. on a side. Back plates with heat exchanger bundles will be interchangeable so that different stage and bundle configurations can be tested. The height of the bed is chosen so that adequate heat exchanger surfaces can be placed in the bed to get the ability to drop the temperature as much as 30°C with average driving forces of 30°C . The required equipment items (pump, temperature indicator, etc.) are being chosen and will be ordered soon as will materials of construction.

FIGURE 3

Schematic Drawing of Model Liquid Fluidized Bed Heat Exchanger Apparatus

FIGURE 4

Heat Exchanger Apparatus Without Bed Material Present

FIGURE 5

Heat Exchanger Coil After CaCO_3 Deposition-Run Without Bed Material Present

FIGURE 6

Same coils as in FIGURE 5 after a similar CaCO_3 deposition run in which the coil was surrounded by a liquid-fluidized-bed of $\langle .425 \rangle .300$ mm sand.

FIGURE 7

Heat Exchanger coil after CaCO_3 deposition with fluidized-bed present showing that scale formation was limited to areas not exposed to the scrubbing action of the sand.

FIGURE 8

Heat Exchanger coil showing CaCO_3 deposition where the coil was buried in the unfluidized lead shot distributor layer.

FIGURE 9

Heat Exchanger tank showing CaCO_3 deposition on the tank wall and pattern of deposition around the lead shot.

4.0 NON-ELECTRIC USES OF GEOTHERMAL ENERGY

4.1 National Non-Electric Utilization Program Concept Definition Study

Preparation of the draft of the National Non-Electric Utilization Program Concept Definition Study was completed. Copies were transmitted to AEC Washington and the AEC Geothermal Advisory Committee for the committee meeting which was held at ORNL on November 6, 1974. The report is in the process of internal review and will be issued during the next quarter.

4.2 Non-Electric Geothermal Program

As a result of the Advisory Committee review of the Program Concept Definition Study, the AEC initiated certain non-electric geothermal work to be performed at INEL during the remainder of FY-75. The work funded includes two basic areas of concern, namely, Non-Electric Geothermal Technical Development and a Demonstration Geothermal Space Heating Project of Government buildings.

4.2.1 Background Information

In the United States, the major research for development of geothermal energy in both the public and private sectors has been directed towards the electrical power generation aspects of the geothermal resource. But development has been slow due to a variety of geologic, economic, and political factors, not the least of which has been the rarity of the potent dry-steam type of geothermal system most suited to development for electrical generation.

Improved technology and rising energy costs will eventually allow the development of many intermediate (approximately 300°F or 150°C) and low-temperature (approximately 180°F or 82°C) geothermal systems for electrical generation. But, the majority of these low-temperature geothermal occurrences do not appear to be capable of producing either the temperatures or volumes of fluids necessary for even modest electrical generation. The logical approach would appear to be the utilization of the heat energy more directly for hot water space heating. The advantages to the nation's energy use inventory would be significant. For instance, each average American home has annual space

heating energy consumption approximately equal to the energy consumed in operating the family automobile for a year. Savings in fossil fuel could represent a one to one increase in available resources for transportation.

In general, unless the hot water was already available, geothermal heating systems have seldom received serious consideration from city or subdivision planners. It is believed that direct, deliberate efforts to employ such energy for space heating could lead to its eventual widespread use. But, several pilot demonstration programs are believed necessary before the most feasible techniques are determined and the risks are better assessed in order to give the systems general acceptance as a viable alternative in community planning considerations in the United States.

A pilot demonstration project conceptual design effort has been initiated to be installed in the city of Boise, Idaho. The project would involve a joint federal-state effort which will lead to the heating of the State Capitol and various State and other government buildings. Feasibility of converting the buildings of Boise State University, as well as city, county, and Federal buildings will be established as the first phase effort. The project will deal specifically with the identification of the resource, testing of the resource, design and construction of a distribution and discharge system, and conversion of conventional heating systems in present buildings and new State Office buildings so that these can use geothermal water. The demonstration location was based principally on apparent availability of the necessary geothermal resource and the likelihood of utilizing the resource for construction projects now beginning and for building heating system modifications now pending.

Also included in the INEL work is a general non-electric geothermal program development task responsibility. The purpose of this effort is to assist the ERDA Geothermal Branch in developing and encouraging commercial participation in use of non-electric applications of geothermal energy.

4.2.2 Purpose and Major Assumptions

1. Non-Electric Program Coordination and Technical Development
 - a. Program coordination
 - b. Develop an industry incentive plan to encourage private enterprise to take advantage of the enthalpy of readily available geothermal fluids.
 - c. Develop literature material to familiarize potential industrial or other users with sufficient data to intelligently evaluate and make decisions relative to utilization of geothermal energy in their applications.
 - d. Develop a decision modeling technique for evaluating proposals for utilization of geothermal energy.
 - e. Prepare a cost analysis and comparison of various space heating concepts to justify or defend economic feasibility.
 - f. Prepare research plans and programs for developing new and more economical techniques for harnessing low-grade geothermal energy.
 - g. Assist the Geothermal Office of ERDA in obtaining information as needed to encourage R&D toward making non-electric geothermal uses a significant contributor to the nation's energy budget.

2. Space Heating Demonstration Project

The project in Boise, Idaho will involve an investigation of the geologic, engineering, economic, and environmental factors relevant to the replacement of fossil fuel-based hot water and low-temperature steam heating systems in various State buildings. The aggregate annual expenditure for the present fossil fuel heating of the buildings is \$110,000. Based on 1973 fuel costs and an anticipated total project cost of approximately \$2-1/2 million, marginal economic feasibility based on amortization over a reasonable period is predicted. As the cost of fuel has already risen over 1973 costs and

is expected to rise significantly in the future, the economic justification will become even stronger. In addition to this direct economic benefit, the proposed replacement of fossil fuel-based heating with geothermal space heating will affect a significant long-term conservation of fossil fuel which may be practical in many other localities. The present hot water wells serving the Boise Warm Springs residential area have been pumped without any appreciable decline in productivity for 83 years.

The planned research and development effort has the following principal objectives:

- a. To determine if the proposed geothermal resource area is adequate.
- b. To determine the costs and practicality of retrofitting existing heating systems for use with low temperature (probably less than 200°F or 93°C) geothermal water.
- c. To design the distribution system, the H&V systems (new and conversions) and, in particular, the geothermal waste water discharge system.
- d. To build and test the proposed system to demonstrate the actual costs of construction and operation and to identify the technical difficulties which may arise from long term operation.

In addition to the above detailed R&D effort, studies will be conducted to determine the feasibility of converting other public structures in Boise, Idaho to geothermal heating.

The objectives of the demonstration project will be accomplished in four stages. Phase I will be a study of the feasibility of converting the State buildings and other selected public buildings to geothermal heating. Phase II, which will proceed concurrently with Phase I, will be involved with geologic, geophysical, and geochemical investigations leading to site-selection as well

as the initiation of the conceptual design and environmental analysis of the production, distribution, heating, and waste discharge systems. Phase III will be the drilling and testing of initial exploratory wells to confirm the distribution of the geothermal resource and subsequent production wells. This phase will include the completion of conceptual design of the system. Phase IV will proceed pending the successful results from the previous phases. It will represent the principal objective and expenditures centered on the construction of the distribution and discharge systems and installation of the heat exchange systems in the various heating plants. Much of this construction phase is expected to be undertaken with non-federal construction funding except for the supplemental efforts relating specifically to research and development efforts. Environmental investigations centered on the impact of geothermal exploration and development in the urban environment will begin during Phase II and continue throughout the duration of the project.

5.0 PLANS FOR SUBSEQUENT QUARTER

1. Complete the RRGE-1 (first well) drilling and initiate the testing program.
2. Evaluate the geological data acquired from RRGE-1 and perform a further interpretation and correlation of the geophysical data in relation to the RRGE-1 data.
3. Select the drilling site for a possible second hole (RRGE-2) for exploratory and/or reinjection purposes.
4. Prepare a report covering the selection of the RRGE-1 site.
5. Finalize design of the test loop between the exploratory wells.
6. Complete preflash/air-ejector studies for steam power plant.
7. Update cost estimate of flash steam system operating from 150°C fluids.
8. Select working fluid and cycle for binary power plant and initiate conceptual plant design.
9. Continue corrosion and deposition studies and provide information for materials selection.
10. Initiate geological, geophysical, and geochemical studies of the Boise, Idaho Foothills area to establish the nature and extent of the geothermal resource and determine its characteristics. This work will involve the Boise State University and the Idaho Bureau of Mines and Geology. Issue a brief environmental report relative to this work.
11. Perform studies to determine the feasibility of converting various existing heating systems in public buildings to geothermal heating.
12. Initiate conceptual design studies of geothermal water distribution and discharge systems as well as heating and ventilating system modifications for the Idaho State Capitol Building, other State office buildings and portions of the Boise State University buildings.
13. Continue non-electric program coordination and technical development activities.