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GEOTHERMAL R&D PROJECT REPORT FOR
PERIOD OCTOBER 1, 1975 TO DECEMBER 30, 1975

MASTER

PREPARED BY AEROJET NUCLEAR COMPANY FOR
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
IDAHO OPERATIONS OFFICE UNDER CONTRACT E(10-1) -1375

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GEOTHERMAL R&D PROJECT REPORT FOR
PERIOD OCTOBER 1, 1975 TO DECEMBER 30, 1975

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PREPARED FOR THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DIVISION OF GEOTHERMAL ENERGY AND IDAHO OPERATIONS OFFICE
UNDER CONTRACT NO. E(10-1)-1375

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ABSTRACT

The Idaho National Engineering Laboratory (INEL) Geothermal Research and Development Project is conducting two major geothermal development efforts; 1) a project aimed at medium temperature (approximately 300°F), utilization to produce electricity with supplemental direct thermal use of the energy; and 2) a low temperature (approximately 170°F) space heating project. The first effort has progressed in the field to the successful drilling of two deep geothermal wells providing flows of the desired temperature in the Raft River Valley of Southcentral Idaho. The second program involves the heating of government buildings and a university campus at Boise, Idaho. This report covers the period October 1, to December 30, 1975.

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The Northwest Public Power Association
The U.S. Bureau of Land Management, Boise and Burley Offices

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1.0 SUMMARY

1. The test loop pipeline between RRGE-1 and RRGE-2 was completed three months ahead of schedule. Completion of the line allowed the down-hole submersible pump to be tested in RRGE-1 immediately after installation.

2. Since RRGE-1 and RRGE-2 have been drilled, they have been subject to fairly extensive testing. It appears that the following can be concluded:

- a. Flows measured over the period since the wells were "completed" have not decreased, if anything there has been a slight increase. The second well has yielded natural flows without pumping of as high as 850 gallons/minute.
- b. Temperatures are at least 295°F at the bottom and throughout the major producing zones. Development of full flow for long periods should result in only approximately a 5°F temperature drop to the surface.
- c. The "reservoir" between the two wells exhibits much higher permeability than geological considerations originally anticipated, and the storage characteristics and draw-down characteristics appear to be very encouraging.

3. The design concept for a flexible test facility was further defined. Using the dual boiling isobutane cycle as the base facility, the plan outlined a variety of improvements that could be made but which cannot yet be considered state-of-art. It is the role of the planned facility to compile long term, pilot plant operating experience, the isobutane cycle, while at the same time testing the effectiveness and reliability of the proposed improvements. Among the latter are: once through cooling supplied by the near surface aquifer, phased cooling with floating turbine discharge conditions, total flow machines, improved (more effective and/or cheaper) heat exchanger and condenser devices, inexpensive means of minimizing or removing scale on pipes, etc.

4. Further examination of the practical potential for direct applications of geothermal heat (non-electric) has been made for the Raft River Valley area, currently remote from any area of industrial activity. Extensive discussions have been conducted with a number of potential industrial participants in a program to demonstrate the use of low temperature (<300°F) geothermal water in a remote area. Land and water acquisition problems appear resolvable and no insurmountable system conversion problems have been identified for the candidate industries. A definitive plan is being prepared to invite industry in general to consider the use of the hot water directly in lieu of fossil fuels. Wells of the Raft River type, when amortized for a 30% return on investment, can show a significant cost benefit over all three common fossil fuels.

5. The drilling of Boise Slim Hole 1 (BSH-1) was initiated and terminated during the reporting period. BSH-2 drilling was initiated and the sites for BSH-3 and the Demonstration Well (BHW-1) was selected. (See Figure 1 for well and hole location)

6. Field testing of piping and larger scale heat exchanger was begun on both the new deep Raft River geothermal well fluid and on fluid diverted from the 83 year old wells in Boise. Corrosion testing of assessable samples of both transmission pipe and well casing in contact with the earth is to be conducted routinely at Raft River to provide some measure of the effects on these materials that see continuous service inside the well and in the buried pipeline.

7. A site was selected for the third deep Raft River well, approximately 1-1/2 miles due south of RRGE-2, 1-1/3 miles SE of RRGE-1. About a mile from the two major identified faults, the region is believed to have a number of less prominent faults and be more representative of a reservoir situation which should be characteristic of much of the valley. After the main hole is drilled and tested, side tracking of a second channel is to be considered. A possible 50% flow increase for only a 20% increment in cost appears likely for such a double channel well, with a bottom hole separation in the production region of greater than 500 ft.

Fig. 1 Study Project Map

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 U.S. Geological Survey and the State of Idaho) to determine their geothermal potential. Initially, little geological data existed in most areas within 150 miles of the Idaho National Engineering Laboratory (INEL) and Idaho Falls were the Energy Research and Development Administration (ERDA) principal integrated contractor, Aerojet Nuclear Company (ANC), 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 INEL, and the U.S. Geological Survey (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 ERDA 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 resources 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, the Idaho National Engineering Laboratory began a preliminary engineering and feasibility study, gathering additional geophysical information from the Raft River Valley. The U.S. Geological Survey had initiated a basic geological study of the area beginning in 1970, and substantially increased the effort in 1973, including gathering of geophysical data. In early 1975, drilling began on two deep geothermal production wells. Both yielding substantial (600 to 900 gal/min) artesian flows of water at the anticipated temperature (295°F or 146°C).

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 (150°C) have an enthalpy of approximately 270 Btu/lb (150 cal/gm) which is significantly lower than obtained from producing steam fields like the Geysers and Lardarello, 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. These higher enthalpy fields now currently attractive represent only about 5% of the known geothermal fields. Hot water sources with about 270 Btu/lb are not presently attractive for commercial production of electric power. Neither the economics nor even the most technically feasible 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 promising.

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 145°-150°C (300°F) water, conventional Rankine Cycle systems appear only marginal for normal applications. But reduction in the normal heat sink temperatures would have a most noticeable effect. 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 as the working fluid varies considerably depending on the condition of the water, the productivity of the wells, the heatsink, etc.

The proposed demonstration power plant will contain a steam and/or a binary (organic fluid) cycle and will utilize the heat remaining in the water for industrial and agriculture applications. Initial operation of the plant now that two successful production wells exist, could be as early as mid-1978. More details about the geology of the area and its apparent geothermal potential can be obtained from the report ANCR-1138,

"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, operational economic characteristics of a suitable 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 beneficial thermal uses for the heat and/or the geothermal water itself.

2.2 Deep Drilling Program

2.2.1 Raft River Geothermal Exploratory Wells, RRGE-1 and RRGE-2

Basic characteristics of the two geothermal wells were given in the prior quarterly report (page 5, ANCR-1281, December 1975). Little changes have occurred in these characteristics except for the "hot" shut-in pressure of RRGE-1 has shown an increase from 165 psig (approximately 11 atm) to 180 psig. Out of the many possible explanations for this change, a definite choice cannot readily be made. A flowmeter measurement conducted down the bore of RRGE-2 by the USGS indicates a high in-flow to the well bore at about 5960 ft depth. The well logs do indeed show a minor anomaly, about 10 ft wide, which could be indicative of high porosity. The exact amount of flow is still unknown, awaiting computer analysis of the raw data.

Plans are being made to drill deeper in RRGE-2, a nominal 500 ft. In addition to the above mentioned possible source near the present bottom, the temperature gradient in the well when stagnant is virtually zero over the lower 1000 ft, all of which is quartzitic basement rock.

2.2.2 Test Loop Pipeline

The test loop pipeline between RRGE-1 and RRGE-2 was completed in November (approximately 3 months ahead of schedule). Completion of the pipeline allowed the downhole submersible pump to be tested in RRGE-1 immediately after installation. The test flow of 1,200 gpm from RRGE-1 was diverted into a holding pond at RRGE-2 for cooling prior to reinjection. Reinjection to date has been done with the mud pumps on the drill rig.

The pipeline consists of a 12 in. diameter buried concrete-asbestos pipe 4000 ft long. Considered experimental in nature, the manufacturer has provided seals which it is hoped will perform for many years at the 300°F temperatures. Tests are to be conducted during the use of the line to determine its durability in this high temperature environment. Compared to a standard steel pipeline, the concrete-asbestos represents not only a cheaper material cost but cheaper installation as well, savings being nearly 50%.

2.2.3 Drill Site Construction

The RRGE-1 site has been upgraded into a permanent site with the addition of fencing, asphalt surfacing, cooling pond with flow restrictor walls, and a transfer pipeline (12 in.) to RRGE-2. A downhole submersible pump was installed and successfully operated in RRGE-1. Limited flow testing has been accomplished through December. Preliminary results indicate that the well is capable of maintaining flows in the 900-1000 gpm range with a pump depth of 650 ft, allowing drawdown to 550 ft. This compares with a steady artesian flow of 600 gpm. Greater setting depth to allow greater drawdown is not likely to be significantly economical when the power costs of pumping are compared to the incremental flow. (Note, the pump was able to deliver 1900 gpm with a full head of water in the well.)

Construction work to complete the test loop system is now out for bids with a completion date of about the end of March. The direct contact bed (University of Utah) and fluidized bed (Allied Chemical Corp.) heat exchanger test trailers have been moved from the No. 2 site to No. 1 and installed with semi-permanent hot water and cooling water lines. More stable conditions can now be expected for their continuing experiments.

Well head connecting piping is being modified to accept two strings of corrosion/scaling tests. This will allow a full two month test prior to the component test trailer installation. The component test trailer is complete and will be pressure tested and insulated after delivery to the well site.

2.3 Electrical Power Plant

2.3.1 Thermal Loop - Pilot Plant

A thermal loop design based upon the double boiling isobutane power plant concept design was evaluated and a cost estimate prepared. The thermal loop purpose and expansion modes to a full operating pilot plant were considered in detail for both experimental usefulness and cost effectiveness. Figure 2 shows this concept, of a facility 120 MW (th) power, 15 MW(e) total, 10 MW(e) net, divided into three modules of approximately equal size. This allows easy substitution of new and advanced concepts for testing at minimum cost, yet also enables extended performance and reliability testing to be conducted. The basic isobutane cycle would comprise 2/3 of the total power level. Various improved components would be tested by substitution for existing components during the testing phase. The remaining 1/3 power capability would be reserved for components or systems that might not be compatible for direct mating with the standard isobutane cycle.

Fig. 2 Geothermal Moderate Temperature Utilization Test Facility

2.3.2 Total Flow Devices

An idealized evaluation of the use of a Hero's type turbine (lawn sprinkler) was made for comparison with the flash-steam and binary systems. This type of turbine is a pure reaction device and is characteristic of such devices. High velocities are required to produce high efficiencies. However, they have the potential of simplicity which could result in low capital cost.

The application to geothermal fluids considered its operation as a total flow device where the centrifugal action on the liquid pumped the liquid to the nozzle throat where cavitation occurred and the two phase mixture expanded to condenser conditions isentropically. Condenser pressure was assumed to be approximately 4 in. Hg abs. Homogeneous flow (with phases in thermal and dynamic equilibrium) was assumed. Since this type of unit could conceivably be used on the effluent from either a flash steam plant or a binary plant or simply as a device to produce small amounts of power from lower temperature resources, the study covered a wide range of temperatures. The results are shown in Figure 3 for a flow of 500,000 lb/hr (approximately 1000 gpm). For reference, the approximate performance of a flash steam system, binary system, and an idealized direct expansion operating with 300°F source and the same sink temperature is also shown. It is apparent that nozzle velocities (not jet velocities), V_ϕ , in the order of 800 ft/sec or greater are necessary to obtain performance equivalent to the binary cycle. These high velocities result in a liquid pressure due to centrifugal force in the order of 4000 psi or more and high velocities at the throat. In addition, the normal acceleration that would result from an 1800 rpm machine (corresponding to a 4 pole generator) is on the order of 4500 ft/sec². Such high acceleration would cause extensive separation in the nozzle with the attendant losses. Furthermore, even if the normal acceleration forces were absent, single stage expansions over the pressure ratios assumed would not be possible since the fluid would not be in both thermodynamic and dynamic equilibrium throughout the expansion.

It is concluded from this work that even at 300°F, the device as defined (Hero's type flow machine) is unsuitable even for competition with flash steam. As a bottoming device on a flash system, where it could be incorporated into the condenser and if run at low velocity it may have some merit. However, significantly lower angular velocities would require a large salient pole-type generator, with an accompanying increased cost.

2.3.3 Corrosion and Deposition Testing Field Laboratory

The construction of the piping systems for the various test loops on the Mobile Component Test Trailer were initiated and except for some added modification and the tie-in to the Fluidized Bed Heat Exchanger, the construction is essentially completed. The loop piping systems have been installed on the test trailer and are currently being instrumented to provide the desired test data once the test facility is operational. When adequate weather protection is available at the Raft River test site, the test trailer will be transported to the site and the tie-in made to RRGE-1 well. The remainder of the loop instrumentation will be

Fig. 3 "Hero's" Turbine Performance Estimate

installed and the hook-up to the data acquisition system completed after the move.

A test plan was developed for the Materials Test Loop and the Heat Exchanger Test Loop (which are located on the test trailer). This test plan describes the initial tests to be made, defines the expected operating parameters, and states those requirements that are necessary for the operation of the test loops. Test plans for the other loops and test facilities are being prepared.

A small tube heat exchanger experiment has been devised. Tests on small tubes accelerate deposition compared to that achieved with a full sized tube. The tests, should give a preliminary indication as to the severity of the scaling problem on the larger heat exchangers.

2.4 Geology and Geophysics

2.4.1 RRGE-1 and RRGE-2

The lithological sequence of RRGE-1 is depicted in Figure 4 and that of RRGE-2 in Figure 5. Figure 6 illustrates the geological sequence through both wells. There is some uncertainty as to whether or not RRGE-2 has penetrated the Bridge Fault Zone as shown in Figure 6. The deepening of RRGE-2 by approximately 500 feet should resolve this question prior to moving the drill rig to the site of RRGE-3.

2.4.2 Reservoir Testing

A series of three drawdown tests were conducted in RRGE-1 and RRGE-2 during September and October as shown in Table I. The instrument used to record the pressure changes was a highly accurate device employing a quartz crystal downhole and a frequency recorder on the surface. The INEL logging truck was used to lower and retrieve the tool from the two wells.

A coordinated effort involving INEL and the University of California Lawrence Berkeley Laboratory (Dr. Paul A. Witherspoon and Dr. T. N. Narasimhan) was accomplished during the testing. Analysis and interpretation of the data was accomplished by Witherspoon and Narasimhan.

The computation of permeability and storage coefficient result in the data of Table II for RRGE-2.

Figure 7 shows the pressure response with time, and the two discontinuities in the logarithmic slope which probably indicates the presence of two boundaries or the equivalent.

The test monitoring reservoir characteristics in RRGE-1 while RRGE-2 was flowing would more likely indicate the characteristics of the reservoir

RRGE NO. 1

Fig. 4 Raft River Geothermal Exploratory Well No. 1

Fig. 5 Raft River Geothermal Exploratory Well No. 2

Fig. 6 Lithological Sequence through RRGE-1 and RRGE-2

Table I
Drawdown Tests

Test No.	Description	Duration Hours	Production		Pressure Gage in		Maximum Pressure drop	
			Well No.	Flow Rate gpm	Well No.	Depth, feet	Well No.	Δp , psi
1	Short Term Test on RRGE #2	15	RRGE #2	210	RRGE #2	5200	RRGE #2	39
2	Long Term Test on RRGE #2	615-1/2	RRGE #2	400	RRGE #1	1000	RRGE #1	3.6
3	Short Term Test on RRGE #1	30	RRGE #1	26	RRGE #1	4700	RRGE #1	1.1

TABLE II

Characteristics of Reservoir as Deduced from Drawdown Measurements on RRGE-2
While Flowing RRGE-2

	<u>Drawdown Data</u>		<u>Recovery Data</u>
	<u>Jacob's Method (Asymptote Solution)</u>	<u>Theis Method</u>	<u>Asymptote Solution</u>
Transmissivity (gpd/ft ² at 296°F)	4,667	4,696	4,718
kH md-feet	44,134	44,442	44,623
Storage Coefficient S	1.134×10^{-2} ; $r_w = 1$ foot	1.09×10^{-2} $r_w = 1$ foot	-
ϕCH (Porosity x Compressibility x Thickness)	2.82×10^{-2} ft/psi; $r_w = 1$ foot	2.71×10^{-2} ft/psi; $r_w = 1$ foot	-

Fig. 7

DRAWDOWN DATA FROM RAFT RIVER TEST AT RRGE NO 2
(9/12/75 TO 9/13/75)

between the recording instrumentation, both at the top and bottom of the well, were able to detect linear tides in the reservoir, as seen in Figure 8.

The computation of permeability and storage coefficient result in the data for the region between RRGE-1 and RRGE-2, as shown in Table III.

The higher transmissibility than obtained in the single well test should be assumed more characteristic of the overall reservoir.

Finally, a single well test was run on RRGE-1, flowing and monitoring both in the same well.

The analysis of this showed a permeability of the reservoir fairly consistent with the two well tests. The average permeability characteristic appear to be:

$$\begin{aligned} kH &\approx 2.25 \times 10^5 \text{ md feet and a transmissibility of} \\ &\approx 23,700 \text{ gpd/ft at } 296^\circ\text{F} \end{aligned}$$

Figure 9 shows one discontinuity in the slope, implying one nearby boundary.

2.4.3 Well Logging

Well logging was conducted in both RRGE-1 and RRGE-2 by the INEL logging trucks. The logs taken by INEL exhibit good correlation with the commercial logs taken earlier. However, the most important tool (flow-meter) did not operate satisfactorily and thus no new information on production zones is available, except the preliminary information from the new USGS flow meter indicates significant production may be coming from the bottom of RRGE-2.

2.4.4 Raft River Area Subsidence Check

Elevation markers on a quarter-mile grid were established in late spring 1975, around RRGE-1 and RRGE-2. Elevation points were rechecked in December in the immediate three square mile area around the well sites. There has been no observable ground subsidence in the six month period.

2.5 Hydrology

2.5.1 Cold Ground Water

Two shallow ground water aquifer tests were run during this quarter after agricultural needs had terminated. These tests were run in the Raft River Basin to provide data on the long-term hydrogeologic parameters.

TABLE III

Results from Flowing RRGE-2 and Measuring Pressure in RRGE-1

	Preliminary Test		Long Duration Test	
	Sept. 14 to Sept. 17, 1975		Sept. 20 to Oct. 16, 1975	
	Theis Curve Matching Procedure	Asymptotic Solu. (Jacob's Method)	Theis Curve Matching Procedure	Asymptotic Solu. (Jacob's Method)
kH, md feet	2.25×10^5	2.22×10^5	2.28×10^5	2.28×10^5
ØCH, ft/psi (Porosity x Compressibility x Thickness)	5.74×10^{-4}	5.39×10^{-4}	1.19×10^{-3}	9.38×10^{-4}
Transmissi- bility gpd/ft at 296°F	2.37×10^4	2.34×10^4	2.41×10^4	2.37×10^4
Storage Coefficient S	2.31×10^{-4}	2.16×10^{-4}	4.78×10^{-4}	3.77×10^{-4}

Fig. 8

EFFECT OF LUNAR ATTRACTION ON WATER PRESSURE IN
GEOTHERMAL RESERVOIR, RAFT RIVER VALLEY, IDAHO

Fig. 9

DRAWDOWN DATA FROM RAFT RIVER TEST AT RRGE NO.1
(9/20 TO 10/12)

These tests are believed to be representative of the hydrogeological characteristics in this area.

Pump Test No. A was run using six area wells located between RRGE-2 and RRGE-3 locations. Pump test B used two wells located approximately six miles southwest near the Narrows.

These tests were terminated in mid-December and final data analysis is not available at reporting period close.

2.5.2 Geothermal

Two geothermal deep holes approximately 11 to 1200 ft were drilled in the upper Narrows by USGS to study aquifer parameters. One well flowed hot water and was located approximately 5 miles northwest of the Narrows, the other well was 9 miles west of the Narrows. Both wells were cased near the surface, pump tests have not been started at this time.

2.6 Environmental and Area Impact Considerations

The initial phase of several of the baseline environmental studies has been completed. Data obtained from this initial phase will determine where future studies should concentrate. The following is a summary of the reports that have been received on the archaeology, vegetation, aquatic, and air quality studies.

Nearly 3,000 acres of land covering a 7-mile stretch of the Raft River and the adjacent floodplain and foothills were surveyed for archaeological resources using systematic swathing techniques. A total of 7 occupancy areas and 13 use areas were located. All but two of these are within 300 meters of the river indicating that it was a major controlling factor in the development of the area. Natural occurrences resulting from activity of prior civilizations identified include chalcedony, ignimbrite, and obsidian flakes, projectile point tips, and flake scrapers. The presence of these indicates that tool manufacturing as well as hunting and hide preparation took place. Although only the surface resources were surveyed, the presence of six sites within 1.5 miles indicates a high density area where subsurface cultural resources probably exist.

The initial phase of the vegetation study concentrated on a one square mile area surrounding the two well sites. The parameters of the plant community measured include cover, frequency, and density. A species list was compiled and a total of 43 species were identified. A 500m x 500m area adjacent to the north side of RRGE-2 was more intensely sampled. The species contributing most to ground cover in this area were greasewood (22.7%), sagebrush (13.6%), and squirreltail grass (4.9%). These are the three most important species and are used to characterize the vegetation type over the entire study area. Halogeton and other annual weeds are established where the soil has been disturbed and development may cause a proliferation of these species.

Fig. 10 Raft River Geothermal Well Site Region Wells

In addition to the above study, 50 samples of the terrestrial environment were taken from an area that was to be irrigated with geothermal fluids. Another seven representative samples were taken following irrigation to be used to determine the effect of the geothermal fluids. These samples have been run through the ATR reactor at INEL for neutron activation analysis. Quantitative results will be forthcoming from the Ge(Li) spectrometer measurements.

An aquatic survey of the Raft River in the vicinity of the drill sites this fall showed low population of the commonly expected species, unusual for a river in this area. Reasons for the scarcity of findings include the flow conditions of the river at the time of sampling and the river bottom type (a very rare type similar to that of the Colorado River). A similar survey will be taken this spring following high water to determine if this condition is characteristic of the river.

Preliminary air quality studies were conducted at Malta during the summer and fall of 1975. Particulate filters collected during this period were examined with a scanning electron microscope and with energy dispersive X-ray analysis. The most predominant particles by number were sulfates, although fly ash, soil dust, and soot particles were also numerous. Although no air quality standards were exceeded, concentrations observed are higher than expected for a rural area. Although the meteorology of the valley has not been studied in enough detail as yet to confirm this, it is postulated that the substantial concentrations of sulfate particles may be due to transport from the Wasatch Front some 150 miles away, where industrial discharges abound.

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)

It is hoped to have the new equipment at Raft River by the middle of January and to recommence testing shortly thereafter on the volume boiler arrangement.

Efforts at the University is directed toward extending our previous work. Primarily this involves two items:

- a. Hydrocarbon Data - the volume boiler system used for the Refrigerant 113 tests (see the previous quarterly reports) has been moved to a special exhaust hood constructed for this work. Early in the next period, we will be determining operational information for pentane boiling in clean water. We will then contrast this data with the previously determined data to infer operational differences. We expect primary differences to be due to the fact that liquid pentane is lighter than water while liquid Refrigerant 113 is heavier than water.
- b. Salt Water Data - the surface boiler system used for the Refrigerant 113 tap water tests (see the previous quarterly reports) is being used with tap water loaded with approximately 5% by weight NaCl. Any differences from the previous data will be explored in depth.

In related work under a companion ERDA research grant, the development of a computer model for direct contact cycle analysis is moving along. Thermodynamic property subroutines have been written which cover almost all candidate fluids. Binary fluid turbine sizing considerations have been calculated for R-113, R-114 and isobutane, each operating with water vapor. This work has been done to develop the technique for later use of computer calculations. Solubility determination techniques using a gas chromatograph with an electron capture detector have been refined to give consistent data. Emphasis will soon be given to determining solubility of candidate fluids in various brines.

Documents that have been prepared during the period are listed in the Appendix.

3.2 Fluidized Bed Heat Exchanger Development Studies

(Reported by E. S. Grimmitt, C. A. Allen, K. L. Wagner - Allied Chemical Corporation, Idaho National Engineering Laboratory)

3.2.1 Bench Scale Laboratory Studies

During the second quarter of FY-1976, work on the bench scale model liquid fluidized bed heat exchanger centered on the continuation of a series

Fig. 11 Model Liquid Fluidized Bed Heat Exchanger Apparatus

TABLE III

Screen Analysis of the Sand Particles Used in the Liquid Fluidized Bed Heat Exchanger

<u>Screen Opening Size, microns</u>	<u>Percent on Screen</u>
707	0.1
500	85.9
354	12.8
250	1.1
177	< 0.1
125	< 0.1
< 125	< 0.1

Fig. 12 Model Liquid Fluidized Bed Heat Exchanger After Scale Deposition
(Note, the Scale Above and Below the Level of the Fluidized Bed)

Fig. 13 Glass Heat Exchanger Tank after Scale Deposition
(Note, the Scale Above and Below the Level of the Fluidized Sand Bed)

Fig. 14 Heat Exchanger Cooling Coil after Scale Deposition (Note, the Slight Amount of Scale Deposited Above the Level of the Fluidized Sand Bed)

of scale deposition experiments. A 17 day run was conducted in which ground calcite scale from the Crank well near Malta, Idaho was dissolved and circulated through the bench scale apparatus(Figure 11).

During previous runs, both NaCl and calcite scales were dissolved in the system, and the effects of having a fluidized sand bed present were studied after a seven day run. Experiments with and without a fluidized bed were conducted and compared.

In the experiment however, only ground calcite scale (less than 0.35 mm in diameter) was present, and the run was extended to 17 days. A fluidized bed made of sand particles less than 0.710 mm but greater than 0.500 mm in diameter was also used in this experiment. A size analysis is shown in Table III.

As in the previous runs, no visible scale formed on the cooling coil or glass heat exchanger tank where they were exposed to the scrubbing action of the fluidized sand bed. Scale did form, however, above the level of the fluidized sand and at the bottom of the tank where stainless steel balls and stainless steel shot were used as a flow distributor (Figures 12, 13, and 14). The scale was analyzed and found to consist primarily of SiO_2 . A minor amount of Ca and traces of corrosion products were also present.

A screen analysis of the bed sand after the conclusion of the run showed only a minimal amount of erosion in the bed particles.

The rest of the effort this quarter has been devoted to setting up the new geothermal test module where extended bench scale silica deposition experiments at atmospheric pressure and high pressure will be conducted during the next quarter.

After numerous modifications, the bench scale liquid fluidized bed heat exchanger has now shown that it is reliable enough to run for extended periods with minimal supervision.

3.2.2 Bench Scale Studies at Raft River

Two glass, bench scale heat exchangers 3-3/4 in. in diameter were installed in the analytical trailer at Raft River in September. Both systems contained identical 1/4 in. diameter stainless steel, helical heat exchange coils. One was operated with a fluidized bed and the other without, to compare differences in heat transfer and scaling. Hot water at 93°C was pumped from the bottom of the flash tank to the bottom of both columns. Cooling water was supplied to the coils from a 50,000 gallon reservoir which was periodically refilled from an irrigation well. Silica sand, closely screened to 16 mesh, was used as bed material. This size permitted flow velocities between 4.3 ft/min and 10.0 ft/min without elutriating the bed. Previous laboratory experiments have been limited by pump capacity to 4 ft/min.

Table IV shows the range of operating conditions used in these tests.

TABLE IV

Operating Conditions Tested in Raft River Bench Scale Fluidized-Bed
Heat Exchangers

<u>Variables</u>	<u>Operating Range</u>
Fluidizing Velocity, ft/min	0.4 to 10
Secondary Flow Rate, ml/min	1000 to 5000
Secondary Fluid Inlet Temp., °F	~50° F
Secondary Fluid Outlet Temp., °F	130 to 155
Bed Temperature, °F	180 to 195
Primary Fluid Bed Inlet-Outlet Δt , °F	15 to 20

Fig. 15 Scanning Electron Micrograph of Coil Interface. (Note, that the scratch in the coil ends in the more corroded area where a bed was not present.)

After a month of operation, the boiler surrounded by a fluidized bed was clean, with no evidence of tarnish or scale. The coil without a surrounding bed was slightly tarnished and some scale was beginning to form in isolated areas. Also, examination showed some pit corrosion. Scanning Electron Micrographs confirm initiated scale deposit and increased corrosion in the coils not surrounded by the bed. Figure 15 shows evidence of scale formation and corrosion at and above the bed interface. Improved corrosion resistance was not expected from the action of the fluidized bed, but the corrosion pits may be caused by concentration cells formed under scale deposits. Action of the bed may destroy these deposits and hence the concentration cells.

Pipes leading from the bottom of the flash tank contained a crystalline deposit approximately 1/64 in. thick identified as calcite. This is not expected in pressurized systems since CO_2 retention will prevent an equilibrium shift to $\text{CO}_2 = \text{HCO}_3^-$. Chemical analysis of the water indicated a concentration increase of 10% due to flashing.

Heat transfer coefficients between the surface of the coils and the bed were determined over a wide range of geothermal water flow rates. An additional variable was the amount of coil surface covered by the bed. Coefficients were calculated from experimental data and standard heat transfer equations.

First, the inside-tube heat transfer coefficient is calculated. The quantity of heat transferred by the coil is next determined by the cooling water flow rate and its inlet and outlet temperatures. The Δt between cooling water and bed is based on the difference between the average cooling water temperature and the average bed temperature. (Over our operating temperatures, the Δt 's are about 5% higher than those calculated by using a log mean Δt .) With this information an overall coefficient, U , can be calculated. This leads to a final calculation of the tube-to-bed coefficient, h_o . It is estimated that the values of h_o obtained by this method should be within $\pm 15\%$ of actual values.

A summary of these data are shown in Figure 16. In these experiments, heat transfer coefficients were determined at various geothermal flow rates with the exchanger tube surface not covered with a bed, one-fourth covered, one-half covered, three-fourths covered, and full covered. The near doubling of heat transfer coefficients from no bed condition to full bed conditions is dramatic. Also, a slight increase in the value of heat transfer coefficients is evident as the fluidizing velocity is increased.

3.2.3 Pressurized Six-Inch Fluidized Bed Heat Exchanger

Tests are being conducted now at Raft River in a six-inch diameter stainless steel vessel. Operating temperatures and pressures are the maximum available at present well flow conditions. A limited amount of heat transfer data have been obtained. Reduction of these data indicates coefficients somewhat higher than those obtained in the bench-scale unit. Higher heat exchange coefficients are probably due to the spiral fluted

Fig. 16

TUBE-TO-BED HEAT TRANSFER COEFFICIENTS OBTAINED IN RAFT RIVER BENCH-SCALE FLUIDIZED BED HEAT EXCHANGER

tubing used in the coil as shown in Figure 17. The spiral construction produces a more turbulent coolant flow and the flutes produce a finned tube effect. Such tubes cannot be used in most geothermal applications because of scale build-up, but the ability of a fluidized bed to scour the tube surface was demonstrated in the bench-scale experiments. The coil will be removed from the vessel and examined for scale and corrosion in mid-January following a month's continuous operation at well No. 1.

Fig. 17 Spiral Fluted Tubing Used in 6 in. Pressurized Fluidized Bed Experiments

4.0 NON-ELECTRIC USES OF GEOTHERMAL ENERGY

4.1 Introduction

In the United States, the direct (non-electric) use of geothermal energy has been limited, even over the last decade that saw such a rapid expansion of geothermal heating applications in Iceland, Hungary, and USSR. Even these non-electrical uses have centered around space heating with only minor applications to industrial processes. However, geothermal water in the moderate to low temperature range ($<150^{\circ}\text{C}$) is usable in many process applications and successful demonstrations of such uses should stimulate further development of geothermal resources.

Although the utilization of geothermal energy for non-electric applications is generally considered in terms of a single industry for a single hot water source, multiple use in the form of industrial parks or integrated industrial activities can make a major impact on our energy usage. Integrated systems take advantage of the latent heat available in the geothermal water as well as the utilization of the waste products from one system as raw materials for an adjoining system. Proper selection of activities will permit a cascading of geothermal users to allow individual processes to "tap into" the proper temperature/pressure for that process.

Current utilization of geothermal energy for non-electric uses appear to be confined to expedient means of satisfying specific needs. Until recently, no systematic technical evaluation and utilization has been undertaken to find ways to maximize its use.

Recognizing the need for a scientific evaluation of this energy resource, the Idaho National Engineering Laboratory coordinated the preparation of a national definition study entitled, "National Program Definition Study for the Non-Electrical Utilization of Geothermal Energy," (ANCR-1214). This study delineated the probable potential of geothermal energy usage throughout the nation and also points out what research and development activities might effectively implement extensive usage of the geothermal resource. The intent of this document was to provide a background base upon which the Energy Research and Development Administration could establish a program to perform the necessary research to bring extensive non-electric uses of geothermal energy to the commercial phase.

4.2 Progress During the Reporting Period

4.2.1 Industrial Process Applications for Geothermal Energy at Raft River Demonstration Site

The results of this continuing effort have been encouraging. Several potential industrial participants have shown keen interest in the utilization of low temperature ($<300^{\circ}\text{F}$) geothermal water. Land and water acquisition problems appear resolvable and no insurmountable system conversion problems have been identified. A public meeting is currently

scheduled for the month of April 1976, to provide background information, then receive public expression of interest, and finally request formal proposals for industrial participation in demonstration projects in the Raft River geothermal area.

Several outstanding questions have been identified which must be resolved satisfactorily within ERDA before arrangements with private industry or private groups can be successfully finalized.

A report has been completed for issue as ANCR-1260, "Industrial Process Applications for Geothermal Energy at Raft River Demonstration Site." This study presents an encompassing plan for the demonstration of large scale utilization of geothermal heat in an integrated industrial complex with multiplicity of participating industries. The intent of this document is to provide current information and to create awareness pertaining to an integrated, multi-use concept to obtain the maximum and most efficient use of available energy. Emphasis will be directed more to the non-electrical geothermal water utilization for process heat application, instead of (but not excluding) space heating.

4.2.2 Process Retrofit Study

A sample case industrial area has been selected to study in detail the specific problems of replacing fossil fuels with geothermal energy. The emphasis is on retrofitting existing process heat applications for food processing and related industries, generally requiring temperatures less than 350°F.

The study will consider specific existing industries and the apparent location of the geothermal resources. The area chosen is presently moderately industrialized, in one of the areas of population concentrations in the Intermountain West. Technical considerations of the retrofit requirements and the delivery of the hot water from the source to the point of use will be examined. More important considerations for study are the financial aspects of making the conversion, as these relate to a variety of institutional factors--tax laws, financing arrangements, return on investment requirements, resource utilization and leasing, etc. The integration of a variety of uses to cover the heat range span, resulting in more complete use of the available heat is an additional consideration. The geographical arrangements for such existing or planned multipurpose uses will be examined.

A single case study of this type will not necessarily provide generalized answers for all situations. But such a case study on retrofitting geothermal into an already industrialized area will help identify the most pressing problems and lead to a more reliable assessment of the ultimate impact nationally from direct heat uses of geothermal energy.

4.2.3 Geothermal Energy, An Integrated Use Plan

An article has been prepared for publication in a journal publication. The article introduces the historical use of geothermal energy, the need for

development of this viable energy resource, and the overall integrated multi-use concept being actively investigated for implementation at the Raft River Demonstration Project.

4.2.4 Butte City, Space Heating

A program has been outlined to study the feasibility for conversion of the small community of Butte City, Idaho to total geothermal energy for space heating. Butte City consists of approximately 30 home units plus several business establishments. A program for geothermal development and conversion has been outlined.

Butte City, has two production wells which were drilled for culinary water use. Both wells produced hot water. The original wells were drilled past the 450-475 ft depth, but were backfilled to that level when it was determined that the influx of hot water was adversely affecting their use for culinary purposes. From 400 to 460 ft, the temperature gradient is approximately $23^{\circ}\text{F}/100\text{ ft}$. Based on extrapolation, one might anticipate 140°F to 150°F temperatures at as shallow a depth as 700 ft. This temperature is adequate for space heating uses.

4.2.5 Geothermal Heat Utilization for Archuleta and Hinsdale Counties

Existing hot water wells are being investigated to evaluate the potential for heating public facility buildings in Joint School District No. 50, Archuleta and Hinsdale Counties, Pagosa Springs, Colorado. Technical expertise and economic evaluation is needed to develop this facility for use as a demonstration heating complex. The institutional complex consists of a high school with a floor space area of approximately $24,300\text{ ft}^2$, a middle school with $23,800\text{ ft}^2$, and a library of $1,200\text{ ft}^2$. Well head temperature at the existing wells is approximately 130°F with a head pressure of 5 to 10 psi. The last "in use" flow rate was approximately 300 gpm. The wells are presently capped and are not in use.

4.2.6 Down-Hole Heat Exchangers

A study of down-hole heat exchangers was initiated earlier by a research contract to the Oregon Institute of Technology at Klamath Falls, Oregon. The study will draw on data from the existing systems in Klamath Falls.

Surveys of some 42 different wells were conducted during the last quarter. Based on data collected, seven wells were selected for detailed corrosion analysis. Test specimens were installed in the seven wells during this reporting period. Each well has specimens installed above and just below the water line. Prior to placement of the specimens, a temperature profile was taken, a water sample extracted for dissolved gas and chemical analysis, and the location of the water level determined. All specimens were weighed and measured for future comparison at the termination of the tests.

One well was used to test the effect of stray AC and DC currents upon heat exchanger corrosion. Based on the results of that test, additional work is being conducted with the local power company to measure ground currents in the vicinity of the wells under study.

5.0 BOISE DEMONSTRATION GEOTHERMAL SPACE HEATING PROJECT

5.1 Background

A joint federal-state effort was initiated early in 1975 to convert existing heating systems in several state-owned buildings in Boise, Idaho with geothermal water. The State Capitol Building, several other state-owned buildings in the Capitol Mall, in addition to buildings on the Boise State University campus were selected for study and eventual conversion.

The selection of Boise, Idaho as the site to locate a demonstration geothermal space heating project was made on the basis of known geothermal resources, interest on the part of the Idaho governing bodies and the support of the Geology Department at Boise State University. Since 1892, up to 400 homes and businesses located along Warm Springs Avenue in Boise have been heated successfully with geothermal water from two wells and numerous other geothermal wells exist in the immediate vicinity of Boise. The increasing costs of fossil fuel and the availability of geothermal water have added impetus to the interest by the state and to the involvement by the Geology Department at Boise State University.

The project will demonstrate that low-temperature geothermal fluids ($<200^{\circ}\text{F}$), which cannot at present be employed economically for power generation, can replace or supplement fossil fuels in the production of heat for buildings with a subsequent savings of both money and fuel resources. The results of this project will be applicable to other locations in many of the Western states. As geological information continues to be developed, it appears that the availability of low grade heat in or near the major towns or cities of the Intermountain West is the rule rather than the exception.

The aggregate annual expenditure for the buildings under consideration is \$240,000 (1975 fuel cost) and many of the state buildings are located within 1/2 to 1 mile of apparent geothermal resources of moderate depths (1000 to 2000 ft). Economic feasibility is being analyzed in terms of the cost of retrofitting each of the various buildings, and of installing pipelines capable of supplying not only present needs, but expansion needs as well. Increased economic justification is expected proportionate to anticipated rising fuel costs. In addition to this direct economic benefit, the 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 planned research and development effort has the following principal objectives:

1. To determine if the proposed geothermal resource area is adequate.
2. 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.

3. To design the distribution system, the H&V systems (new and conversions) and, in particular, the geothermal waste water discharge system.
4. To determine the impact of the utilization of the geothermal water for heating the buildings on the environment. This will include effects of withdrawal of the water from the aquifer, transportation of the water through the subsurface of the city of Boise, and most importantly, the disposal of the warm waste water. Both preanalysis and post-operational monitoring would be required on environmental aspects of the program.
5. 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. This fifth phase of the program, if deemed feasible from the results of the first four phases, is expected to be undertaken by the eventual operator and user of the system; i.e., the State of Idaho.

5.2 Progress During This Reporting Period

(A joint effort by Boise State University, Idaho Bureau of Mines and Geology, and Idaho National Engineering Laboratory)

5.2.1 Hydrologic Study

A hydrologic study based on a survey of wells in the northeast section of Boise was completed during the reporting period. The preliminary information was used in the site selection of the exploration holes to be drilled in the area.

5.2.2 Remote Sensing Imagery Study

Maps have been prepared showing major linear trends as interpreted from COSA (Color Oblique Stereo Air) photos, conventional black and white airphotos, ERTS photos, U-2 Color Infrared, and CIROSA (Color Infrared Oblique Stereo Air) photos. The preliminary information from this study was used in the site selection of the exploration holes. Based primarily on results of these linears (faults), the site for the second exploratory hole (BSH-2) was selected near the intersection of two faults at the mouth of Freestone Canyon.

5.2.3 Geophysical Study

Resistivity data gathered during the summer and fall was evaluated during site selection for the exploration hole. Based primarily on this data, the site for Boise Slim Hole 1 (BSH-1) was selected in Freestone Canyon close to the junction with Cottonwood Canyon. Another location, selected in the Foothills East housing development, will be drilled in the

coming quarter. Yet another site, located farther north and east of Boise showed the lowest of all resistivity. It may be drilled at a later date for geological study, but is too far away from the capital complex to be economically useful, because of the high costs of the connecting pipelines.

5.2.4 Exploration Drilling

The drilling of Boise Slim Hole 1 (BSH-1) was initiated and terminated during the reporting period. BSH-2 drilling was initiated and the sites for BSH-3 and the Demonstration Well (BHW-1) was selected. See Figure 18 for well and hole location.

5.2.4.1 BSH-1 Drilling

BSH-1 was drilled using an Acker core-drilling rig* to a depth of 259 ft. A core barrel was lost in the hole. Basalt was encountered at this depth, and seized the coring, resulting in a fatigue failure of the drill rod. Retrieval attempts proved unsuccessful and the drill rig was moved to the site for BSH-2. Maximum fluid temperature encountered at 250 ft was 80°F. The hole will be relogged at a later date and be used for a hydrological observation well. See Figure 19 for lithology of the hole.

5.2.4.2 BSH-2 Drilling

BSH-2 was drilled to a depth of 652 ft at the end of the reporting period. Basalt was encountered at 630 ft. The basalt encountered at 630 ft appears to be acting as a cap rock as the temperature gradient has doubled over the last 50 ft of hole. The gradient above 600 ft was about 1°F/10 ft and from 600 ft to 650 ft it increased to 2°F/10 ft. The maximum recorded temperature was 132°F at 650 ft. Both BSH-1 and BSH-2 exhibit the similar temperature gradient, as shown in Figure 20.

During the early part of January, 1976, BSH-2 had to be abandoned due to a lost drill rod in the hole. The hole was being cleaned out in preparation for running casing when the tri-core bit apparently stuck in a basalt crack and the drill rod snapped leaving 135 ft of rod and bit in the hole. Retrieval attempts were unsuccessful. The fishing tool engaged the lost rod but a 15 ton shock pull was not sufficient to jar the bit loose. Perforated casing was subsequently run and set to just above the lost rod to permit the hole to be used for monitoring purposes in the future. Additional drilling will be done at BSH-2 site in January and February.

5.2.5 Area Geology

The early geologic mapping in the area and the location of warm wells indicated that the Boise Front Fault was a major structural control influencing the geothermal resource. An analysis of the limited hydrologic

* Owned jointly by the Idaho Bureau of Mines and Geology and Boise State University.

Fig. 18 Map of Linears for the Freestone-Cottonwood Canyon Area

Fig. 19 BEH-1 (preliminary) well and stratigraphic section

Temperature vs Depth

Fig. 20 Boise Geothermal Well Temperature Gradients

study, geophysical study, remote sensing imagery study and the knowledge gained from drilling BSH-1 and BSH-2, has resulted in a modification of the original concept. The Boise Front Fault apparently is not as important a structural control as are the intersecting linears (or fault zones) that occur in the immediate area of investigation. These linears generally trend NE-SW and are visible all along the foothills to the north of Boise. However, several linears cut across the general trend and appear to have a major influence in the area around both the Warm Springs Penitentiary wells and this area of investigation. The location of BSH-3 and test hole BHW-1 should confirm or refute this concept.

Drilling experience to date has also proven the difficulty of drilling through the overburden in the area, especially with a light duty core drilling rig. Also, that type of rig is very limited in its ability to drill with a tri-core bit in unconsolidated sluffing formations or basalt due to the small (2-3/16 in.) diameter of the drill rod.

APPENDIX

The following are documents that have been prepared during the reporting period.

Dart, R. H., D. T. Neill, J. F. Whitbeck, "Conceptual Design and Cost Evaluation of Organic Rankine Cycle Electric Generating Plant Powered By Medium Temperature Geothermal Water", ANCR-1226, December 1975.

Madsen, W. W., I. J. Ingvarsson, "Analysis Of The Binary Cycle For Geothermal Power Generation", ANCR-1245, December 1975.

Donovan, L. E., A. S. Richardson, "Feasibility/Conceptual Design Study for Boise Geothermal Space Heating Demonstration Project Building Modifications", ANCR-1246, October 1975.

Stoker, R. C., "Drilling Plan Boise Slim (2-3/8 in. Diameter) Holes Demonstration Space Heating Project October 1975", ANCR-1261, October 1975.

R. F. Boehm and H. R. Jacobs, "Raft River Direct Contact Heat Exchanger Project Quarterly Report, July 1 to September 30, 1975," University of Utah, UTEC ME 75-156 (October 9, 1975).

H. R. Jacobs, R. S. Deeds and R. F. Boehm, "Heat Transfer Characteristics of a Surface-Type Direct Contact Boiler," Abstract submitted for consideration for presentation at the 1976 National Heat Transfer Conference (November 26, 1975).

C. K. Blair, R. F. Boehm and H. R. Jacobs, "Heat Transfer Characteristics of a Direct Contact Volume Type Boiler," Abstract submitted for consideration for presentation at the 1976 National Heat Transfer Conference (November 26, 1975).

H. R. Jacobs, R. W. Johnson and R. F. Boehm, "Heat Transfer and Temperature Distributions in Liquid-Liquid Direct Contact Parallel Flow of Immiscible Fluids," Abstract submitted for consideration for presentation at the 1976 National Heat Transfer Conference (November 26, 1975).

R. W. Johnson, "Direct Contact Heat Transfer Between Two Immiscible Liquids in Laminar Flow between Parallel Plates," Master of Science Thesis, University of Utah, (December 1975).

R. F. Boehm and H. R. Jacobs, "Direct Contact Heat Exchanger Project Work - Short Summary," ERDA Geothermal Program Review Meeting, Washington, D.C. (December 10, 1975).

R. F. Boehm, H. R. Jacobs, C. K. Blair, R. S. Deeds, R. W. Johnson and D. Kelly, "Direct Contact Heat Exchangers for Geothermal Power Generation - Part 1 - Heat Transfer Considerations," Abstract submitted for consideration for presentation at the 1976 Intersociety Energy Conversion Engineering Conference (December 26, 1975).

R. F. Boehm, H. R. Jacobs, D. Riemer, R. Bliss, and G. Hellstrom, "Direct Contact Heat Exchangers for Geothermal Power Generation - Part 2 - Thermodynamic and Solubility Considerations," Abstract submitted for consideration for presentation at the 1976 Intersociety Energy Conversion Engineering Conference (December 26, 1975).

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