ANCR-1281

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UC-66
Geothermal Energy
TID-4500, R63

GEOTHERMAL R&D PROJECT REPORT FOR
PERIOD JULY 1, 1975, TO SEPTEMBER 30, 1975

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SUBMITTED TO THE IDAHO OPERATIONS OFFICE AND THE DIVISION OF GEOTHERMAL ENERGY
U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

AEROJET NUCLEAR COMPANY

Date Published - December 1975

MASTER

PREPARED FOR THE U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
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 July 1, to September 30, 1975.

ACKNOWLEDGEMENTS

The cooperative efforts of numerous organizations outside of INEL have been most important in the development and progress to date. In particular, the following deserve particular mention:

Reynolds Electric and Engineering Company and the Nevada Operations
Office of ERDA
The U.S. Geological Survey (Menlo Park, Denver, and Boise Office)
Lawrence Berkeley Lab (P. A. Witherspoon, T. N. Narasimhan)
The Raft River Rural Electric Coop.
The State of Idaho Department of Water Resources
The Northwest Public Power Association
The U.S. Bureau of Land Management, Boise and Burley Offices

The authors wish to express appreciation to the numerous individuals within the INEL who have made significant contributions to this program within the last three months: R. H. Dart, W. L. Godare, and others of the Engineering Division; L. E. Donovan and others in the Architect Engineering Branch, and the various field and project personnel such as: J. G. Keller, G. L. Mines, S. J. Prestwich, D. G. Swink, D. H. Suckling, C. G. Cooper, R. W. Gould, R. M. Peterson, C. A. Sandberg, and L. F. Martin.

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1.0 SUMMARY

1.1 Raft River Geothermal Project

Reservoir draw-down tests have been conducted in late September, flowing Well No. 2 (RRGE-2) at a steady controlled rate of 400 gpm, while monitoring the reservoir pressure 4,000 ft away in Well No. 1 (RRGE-1). Preliminary data indicates a highly permeable and large reservoir. Following nearly two weeks of steady flowing from RRGE-2, the pressure in RRGE-1 has dropped approximately 1-2/3 psig compared to its initial downhole pressure of 2003 psi. The interpreted results indicate high effective permeability and substantial storage coefficients.

RRGE-2 was flow tested for about five weeks during the quarter, at 400 gpm controlled flow, plus at several brief higher flow rates. It discharges 790-850 gpm just prior to reaching the flash point at the surface, starting from a subcooled condition. Once flashing begins, the back pressure generated is a result of the discharge nozzle configuration and determines the total mass flow. The water quality remained very good during the extended flow testing. The solid content is around 2,000 ppm.

Additional analysis and potential cost saving evaluations have been conducted on the power plant design and a report detailing this information has been prepared.

The component test trailer is currently under construction and will be completed by early December 1975.

The laboratory effort on the development of the liquid fluidized bed heat exchanger during the first quarter of FY-76 was directed towards the completion of a comparison scale deposition experiment using the laboratory heat exchanger apparatus without a fluidized bed.

The direct contact heat exchanger work laboratory experiments have resulted in very encouraging heat transfer information for design purposes. Testing is now being conducted at the well sites and the concept is being incorporated as an option into the power plant designs.

1.2 Geothermal Non-Electric

Extensive effort to stimulate industrial participation in the application of geothermal energy to various industrial processes was carried on throughout the quarter. A document describing the potential applications and the industrial process together with the energy, land, and water requirements was completed. It appears that an economically and sociologically realistic energy use for the industrial applications at the Raft River site is 1.6×10^7 therms/year, or \$2.0 million worth of natural gas at current prices. The technical feasibility appears definite, with economics providing energy costs as low as a third those of current natural gas prices.

1.3 Boise Demonstration Geothermal Space Heating Project

Field studies conducted at Boise, Idaho resulted in the accumulation of a large volume of geophysical data which will be utilized in geothermal test well site selections. The feasibility/conceptual design studies for the conversion

of 10 state-owned buildings in Boise, Idaho to geothermal heat was completed. In addition, distribution and discharge system conceptual design studies were essentially completed during this period. The total cost of the system now appears to be \$2.4 million plus contingency. A draft environmental assessment was prepared.

The site selection for Boise's Slim Hole No. 1 (BSH-1) was completed. Drilling commenced on the Boise Slim Hole No. 1 with the ground-breaking ceremony at the old site of the Boise Military Reservation on October 16, 1975.

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 where 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 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 wellhead fluids with about 500 Btu/lb. 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 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 Rankine Cycle 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 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, 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, 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

Two geothermal wells have been drilled in the Raft River Known Geothermal Resource Area (KGRA). (See Figure 1) The essential information concerning the wells is listed below:

	<u>RRGE-1</u>	<u>RRGE-2</u>
1. Drilling start date	1-4-75	4-27-75
2. Drilling completion date	3-31-75	6-27-75*
3. Average flow	650 gpm	800 gpm
4. Maximum bottomhole temp.	294°F (146°C)	297°F (147°C)
5. Total depth	4989 ft	5988 ft*
6. Main production zone	4350-4900 ft	4300-5000 ft
7. "Hot" shut-in pressure	~ 11 atm	~ 10 atm
8. Well location	See Fig. 2	See Fig. 3

* RRGE-2 may be deepened by 500 ft or whipstocked off to the west in attempts to even further enhance the natural artesian production of the well.

2.2.2 Reservoir Testing

RRGE-2

RRGE-2 was flow tested for about five weeks during the quarter, at controlled flows ranging from 200 to 400 gallons/min plus at several brief higher flow rates. The well discharges approximately 800 gpm just prior to reaching the flash point at the surface, starting from a subcooled condition. Once flashing begins, the back pressure generated is a result of the discharge nozzle configuration and determines the total mass flow. For instance; with 275°F outlet temperature at the top of the well casing, the maximum natural flow is about 400 gpm with the present piping and flasher-separator equipment.

The water quality remained very constant during the extended flow testing. The solid content is around 2,000 gpm. (See page 12-14 of prior quarterly report, ANCR-1222, dated June 1975)

The Amerada Bomb (downhole temperature recorder) was run in the hole several times under flow and static shutin conditions. Under static conditions the temperature was 290°F at the bottom of the casing (4230 ft) and 297°F at the bottom of the well (5988 ft). Prior information had indicated very little production from below the 4800 ft level. Such a temperature gradient represents

Fig. 1 RAFT RIVER VALLEY
DEEP TEST DRILL SITES
(Section 23)

----- FAULT

Fig. 2 Drill site and vicinity

an unusual situation for a non-producing zone. The gradient of $7^{\circ}\text{F}/1758\text{ ft}$ is much less than a normal gradient of $2^{\circ}\text{F}/100\text{ ft}$. that one would expect. This anomaly may be the result of a "hot plate" effect near the bottom of the well, with circulation above it, that is apparently not entering the well to any great extent below 4800 ft.

A pressure drawdown test of RRGE-2 was conducted in September. A downhole pressure gauge with accuracy of 0.01 psi was placed downhole at 4800 ft and the well flowed at approximately 230 gpm for 13-1/2 hours. The pressure change is depicted in Figure 3. The break in slope between line No. 1 and line No. 2 represents a possible reservoir boundary located close (approximately 135 ft) to RRGE-2. A boundary acts as an impedance to the water flow into the reservoir feeding RRGE-2 and represents a less permeable plane than the general lithology. Boundaries are to be expected and in this situation seem to be of minor importance since they represent planes of finite dimensions.

Both Wells (RRGE-1 and RRGE-2)

A reservoir test involving both wells was initiated in late September by flowing RRGE-2 and observing downhole pressure changes in RRGE-1. The latter well was observed using both a sensitive downhole pressure transducer hung at the 1000 ft level and a surface transducer, both operating as quartz crystal frequency control devices. Preliminary data indicates a highly permeable and large reservoir. See Figures 4 and 5.

Following nearly two weeks of steady flowing from well No. 2, the pressure in well No. 1 has dropped approximately 1-2/3 psig compared to its initial downhole pressure of 2003 psi. The interpreted results indicate high effective permeability and substantial storage coefficients. (INEL is being assisted in this study by Dr. Paul A. Witherspoon of the reservoir analysis geothermal group of ERDA's Lawrence Berkeley Laboratory in California.) Disposal of the produced geothermal water has been accomplished by evaporation (approximately 50%), and irrigation of local alfalfa (approximately 50%). The irrigation benefit of the hot water is being studied to the extent possible with this brief experiment. It should be noted that tidal effect pressure changes are being observed with the pressure monitoring instrumentation. This phenomenon has magnitude (peak-to-peak) of typically 0.1 psi, occasionally as large as 0.2 psi. The observed tides correspond exactly to those predicted for "land-tides" created by the sun and moon.

2.3 Electrical Power Plant and Associated Studies

The generation of electrical power from a moderate temperature heat source (about 300°F) is a very non-conventional method of producing electrical power. It is even less conventional when this source of heat is a geothermal liquid. However, a vast supply of energy is thought to exist in moderate temperature hydrothermal resources and thus an appraisal of the cost of electricity that can be produced from this resource is needed. The approach was to estimate the cost of power based upon using reasonably conventional equipment and technology, recognizing that further refinements, advances in technology and experience would result in lower cost.

Fig. 3

Fig. 4

Fig. 5

The energy conversion system used in the cost evaluation used isobutane to drive the turbine generators. Two similar but different sized plants were considered. A 10 MW(net) and a 50 MW(net) plant. The capital costs of the energy conversion systems for these plants were \$1,066/kW for the 10 MW system and \$640/kW for the 50 MW system. The cost of the energy supply and disposal system was essentially constant at \$540/kW and resulted primarily from well costs. The longer pipeline costs for the 50 MW system was offset by the economics of drilling more wells on a given contract. The above costs are in 1975 dollars without contingency and reservoir discovery and engineering costs. Significant reduction in energy supply and disposal system costs are possible with a better understanding of well performance optimization and development of enhancement techniques. Energy supply and disposal system costs in the order of \$375/kW may be possible through a combination of favorable developments. Energy conversion system costs can also be reduced as a result of the application of new technology such as the use of direct contact heat exchanger and organic mixture as a working fluid, and further optimizations such as increased heat rejection efficiency by taking advantage of daily temperature variations.

Figure 6 contains the electric power costs derived from the power plant cost estimates. For comparison are estimates of the cost of fossil and nuclear produced power. An attempt was made to place all costs on the same basis (1975 dollars), recognizing that some errors are bound to occur, to obtain a relative position for the geothermal produced power. The charts show that geothermal energy powering a 50 MW plant by rather conventional technology can produce electricity for less money than oil but somewhat higher than coal or gas. The potential improvements that can be derived through further engineering and developments promises to lower the cost of power to the point where it would be competitive with coal.

A characteristic of geothermal power production is that a large quantity of residual heat is contained in the liquid after energy is extracted for power production. This residual energy is marketable to many processes and will appear increasingly attractive as the convenient fossil fuel costs increase. Calculations made to determine the impact of selling a portion of this residual heat have shown that at costs above approximately 5 to 6¢ per therm (10^5 Btu) a reduction in power costs occur. This, in an integrated geothermal system where a portion of the energy supply and disposal system costs are charged against income from process industries, the electrical power costs are even more attractive. This would apply particularly to the smaller geothermal power plant (about 10 MW) since it may be impossible to find users for all the residual heat of a significantly larger plant.

In summary, it has been shown that the use of moderate temperature geothermal energy for electric power production by conventional means is marginal at this time compared with most fossil fuels, however, further engineering and the application of technology presently being developed offers the potential of competitive power.

Fig. 6 Power Cost Comparison (1975 Dollars)

2.4 Geology and Geophysics

2.4.1 RRGE-1 and RRGE-2

The geological sequence of RRGE-1 is depicted in Figure 7 and that of RRGE-2 in Figure 8. The Raft River and Salt Lake Formations are apparently offset as much as 500 feet between wells around the 4500 ft level. Figure 9 illustrates the lithological sequence through both wells. The Precambrian sequence (metamorphic transition zone, quartzite and quartz monzonite) does not exhibit any significant offset. The apparent offset in the younger beds above the Precambrian is due to fault influence in the vicinity of RRGE-1 and more normal basin sedimentation around RRGE-2. The lack of offset observed in the Precambrian sequence would suggest a dying out of the fault zone with depth or a steeping of the fault in the harder Precambrian sequence with very little vertical displacement.

The data acquired from RRGE-2 substantiates the occurrence of a major nonconformity between the Tertiary and Precambrian sequences. This fact not only eliminates any Mesozoic rock sequence in the area but also eliminates the Paleozoic rock sequence, at least in this immediate vicinity.

An evaluation of the available geologic data from RRGE-1 and RRGE-2 indicates that the major portion of the geothermal resource may occur directly above the Precambrian quartz monzonite (above 4,000 ft). The water migrates into the valley basin from a considerable distance away and from higher elevations than the surrounding mountains. It percolates downward until it encounters the quartz monzonite acts like a "hot plate," transmitting the heat from depth to the water. The faulting in the system encourages upward migration of the hot water wherever it occurs.

2.4.2 Surface Measurement Program (U.S. Geological Survey)

All initial field data has been collected, open-filed, and evaluated. Additional resistivity data has been gathered this summer by a U.S. Geological Survey crew, to enlarge the existing net. Also samples for dating and correlating waters in the area have been gathered and are undergoing analysis at the present time.

2.4.3 Intermediate Depth Test Wells

The intermediate depth test wells are being used as monitoring wells during the reservoir testing in RRGE-1 and RRGE-2. Results are inconclusive at this time due to limited instrument sensitivity.

2.5 Hydrology

During the entire period since the first well developed Artesian flow, the nearby shallow geothermal wells were routinely monitored for flow rate and shut-in pressure changes. These data are summarized in Figure 10. No explanation for the major trends is available. The steady increase in shut-in pressure of the test well labelled USGS No. 3 (depth of 1300 ft) may be due to a natural spring time recharge of the aquifer. Minor changes noted in the other wells can be nominally correlated either with "reinjection" (high drilling fluid pressu

RRGE NO. 1

Fig. 7 Raft River Geothermal Exploratory Well No. 1

Fig. 8 Raft River Geothermal Exploratory Well No. 2

ANC-S-5881

Fig. 9 Lithological Sequence through RRGE-1 and RRGE-2

Fig. 10 Shallow geothermal well data

during drilling operations) or with climactic changes (heavy rains). In any case, it appears that drilling and well testing activities have had effects not exceeding 10% on the nearby geothermal wells, all of which are to relatively shallow depths.

2.6 Environmental and Area Impact Considerations

Baseline studies to define the current environment are continuing. Because of increased interest in the fate of the ferruginous hawk in the valley, the U.S. Fish and Wildlife Service spent over a week mapping nesting area (two of which are within a mile of RRGE-2. Other animal species have been preliminarily inventoried.* Biologists at Idaho State University have initiated their one-year fauna study, but the major share of the surveying will not begin until next spring. UURI collected nearly two months of baseline particulate data in Malta this summer with Hi-Vol and nuclepore samplers. The filters from these samplers will be examined by scanning electron microscopy to identify quantities and species of particulates. This data will then be combined with air flow patterns in an effort to pinpoint sources of particle types.

In order to have on record independent baseline data on the quality of the shallow groundwater and surface water systems in the Raft River Valley, the Idaho Department of Water Resources conducted an inventory and sampling program on 22 wells and four sites along the Raft River. The results show a marked difference in some constituents between wells in the upper basin and those located near the drill sites.

Prior to the initiation of the long-term flow test of RRGE-2 baseline samples of soils, flora, and fauna were taken at two points where it was planned to dispose of the waste geothermal water. Duplicate samples will be taken upon completion of the flow test and will be irradiated at INEL for neutron activation analysis to determine the chemical constituent effects, if any, of irrigation with geothermal water.

Microseismic equipment was installed for the flow testing of RRGE-2, and records are currently being analyzed. The data from these records, when compared with records taken during the geophysical exploration, may give a clue or some indication of the effect of extended flow on the seismicity of the area.

* Even the common sage grouse has been observed, despite allegations from one area hunter that he has effectively eliminated (i.e., shot) the entire sage grouse population.

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)

The experimental techniques and apparatus designs have been refined to yield consistent, meaningful data. A new bench top test facility was developed and played an important role in the understanding of one type of direct contact heat exchanger.

The period witnessed the program moving into a new era. A much larger size (approximately 150 times larger than the bench top models) exchanger was designed and constructed for installation at Raft River. Preparations were made near the end of the period for installing and testing of the exchanger at the site.

Pertinent details for the various aspects of the work are outlined in several sections below.

3.1.1 Surface Boiler

Determination of the heat transfer characteristics of F-113 being sprayed onto hot laboratory brine was a primary goal during this research period. The initial test apparatus was a simple rectangular tank with a spray nozzle located several inches above the water surface. The spray nozzle was of the hollow-cone fog variety and was so installed as to provide a spray of 7 in. O.D. and 5 in. O.D. with typical spray droplet size less than 0.01 in.

Modification of the laboratory test apparatus was required due to difficulty in stabilizing the height of the water in the tank. This was accomplished by designing a stainless steel tray for insertion into the tank. The tray had a weir at one end which allowed for stable control of water height. Typical heat transfer data achieved with the final test setup are shown on Figures 11, 12, and 13. All of the data is for 14 psia chamber pressure.

Figures 11, 12, and 13 indicate the data achieved for water depths of two inches for a variety of flow rates for both Freon and water. The boiling temperature of Freon 113 under the conditions of the experiment is roughly 110°F. The data indicates a consistent increase in the heat transfer rate with increased Freon flow rate as would be expected. However, a decrease is shown for increasing water inlet temperature. This latter effect follows from the fact that further increases in water temperature for fixed flow rates serves only to superheat the Freon vapor which is a less efficient process than the vaporization process. However, it should be noted that a finite temperature above the saturation temperature was required in order to prevent a buildup of Freon in the bottom of the tray.

The requirement of a small degree of superheat prior to vaporization of droplets of Freon in direct contact with water is not a singular effect for this combination of fluids. It has been noted by other investigators that

Fig. 11

Fig. 12

Fig. 13

without impurities to disturb the local surface tension of the drops that vaporization is delayed. For instance liquid drops of pentane in distilled water had been shown to exist at 150°C superheat. The existence of small gas bubbles or impurities, however, act as a nucleation media and greatly reduce this super heat requirement. For ordinary tap water (Salt Lake variety) superheat of only 15°F was required to prevent buildup in the surface boiler. Later experiments in the volume boiler indicated the same superheat requirement. The effect of increased impurities should be to lower this requirement.

For comparison purposes, the overall heat transfer coefficients, UA, achieved with volume and surface boilers appear to be roughly the same for identical flow and temperature conditions. Based on the total surface impact area of the spray nozzle used the values of U obtained to date are up to values of 640 Btu/hr ft²°F. Based upon the surface area of the droplets prior to evaporation, values an order of magnitude higher would probably be calculated.

3.1.2 Volume Boiler Tests

Volume boiler tests experienced a change during the reporting period. The vessel which was used in the initial stages of the work (see last quarterly report) proved to be less versatile than was required. Because of this, a new facility was developed to overcome the shortcomings.

The heart of the new facility is the heat exchanger apparatus. This one is constructed from a piece of Pyrex glass tube 18 in. long by 3.563 in. I.D., by 3.75 in. O.D. standing vertically. It is capped off top and bottom by aluminum flanges that are tied-down by 24 in. threaded stock and nuts. A working fluid injection manifold is mounted about 3 in. from the bottom. The fluid is injected from the manifold through a flat perforated plate approximately 2-1/2 in. in diameter. This plate is easily removed to facilitate the testing of various perforation configurations.

Hot water is admitted through a tube penetrating the top of the vessel. The cooled water exhausts at the bottom below the Freon manifold. Liquid Freon 113 (the working fluid used throughout this phase of testing) is admitted through a tube penetration at the bottom of the vessel into the manifold and out the perforations. Vapor Freon exhausts through a tube penetration in the top of the vessel. The liquid Freon is propelled into the the exchanger from a storage tank by compressed nitrogen. After flowing from the heat exchanger the vapor flows to a water-cooled condenser and the condensed fluid then runs to a receiver tank. Hot water for the system is furnished by a combination circulating pump/constant temperature bath. On exiting the exchanger the water flows through a reservoir which can be physically raised or lowered to yield a desired operating water level in the exchanger. Instrumentation in the form of pressure gauges, thermocouples and rotameters is located at pertinent places through the system.

Considerable data has been determined using this apparatus. Typically this is defined in terms of the volumetric heat transfer coefficient, U_v (Btu/hr/F/ft³) which is defined as:

$$Q = U_v V \text{ LMTD}$$

where Q = actual heat transfer (Btu/hr)

V = volume of water above the Freon inlet manifold (ft³)

LMTD = log mean temperature difference (F)

Some of the pertinent results are shown in the accompanying figures. Figure 14 demonstrates that U_V varies much more with changes in Freon flow than with water flow. Figure 15 shows that the water inlet temperature is not a strongly influencing variable. Not shown are points at which the inlet water temperature is near, or below, the Freon temperature. At this latter operating condition, carry under occurs (see below).

Operating height does not affect the U_V product significantly as is shown in Figure 16. We have found that operating heights more than about 1 in. simply superheat the vapor which is a low efficiency heat transfer process. Figure 17 illustrates the affects of various numbers of holes through which the Freon is injected. The mass flow ratio has an impressive affect on the U_V , and a sample of this is shown in Figure 18. From this, it is obvious that it is desirable to operate at as low a value as possible--perhaps unity. Heat transfer considerations do not allow this, as liquid Freon can be swept down with the water exhaust ("carry under"). The operation at close to carry under conditions without having it occur appears to be of paramount importance. Photographic studies were made to determine visually when Freon carry under occurs. (As the liquid Freon is swept under, it still begins to form a small vapor bubble, and this can be seen in a high speed photograph.) Typical data for this study are shown in Figure 19. The solid symbols denote operating conditions where carry under occurs. A straight line seems to separate the two regions. Hence, for any heat exchanger it appears that this line should be determined, and normal operation performed as close to the line as possible.

Future work for this apparatus is anticipated to use other fluids, particularly working fluids whose liquid densities are lighter than water.

3.1.3 Preliminary Cycle Analysis

Preliminary cycle analyses for potential power cycles using direct contact heat exchangers at Raft River was added as a Work Task in June, 1975. Since a complete description of the reservoir characteristics were lacking the cycle analysis was initiated using preliminary data as to possible surface temperature and pressures obtainable. In view of incomplete chemistry data and early indication of less than 2000 ppm dissolved solids it was assumed that the water had negligible dissolved solids in computing the effects on organic working fluid solubility. This is a worst case analysis since the effects of dissolved solids is to force the organic working fluids out of solution.

Figure 20 indicates a typical cycle that could be installed utilizing Freon 113 as a working fluid in a 10 MW electrical power plant. All pressures given are in psia and temperature in °F. Such a power plant would require 32,576 lbm/minute of brine and a flow of 13,981 lbm/minute of Freon 113. The cost associated with non-recovered Freon 113 would be 1.09 mills/kW hr.*

* Editor's note: The cost calculation was based on theoretical analysis of carry-over via partial pressures and utilization of a separator unit at condensing temperatures and pressures. A carryover of 1/2 ppm into the reinjected geothermal water gives the cost figure shown.

Fig. 14 Effects of mass flow rates on the volumetric heat transfer coefficient.

Fig. 15 Effect of water inlet temperature on the volumetric heat transfer coefficient.

Fig. 16 The effects of operating column height on the heat transfer.

Fig. 17 The effect of orifice velocity on heat transfer at constant mass flows.

Fig. 13 Mass flow effects on the volumetric heat transfer coefficient using Freon 113.

Fig. 19 Operation map showing carry under conditions.

Fig. 20 Basic direct contact binary cycle using Freon 113 - Cost of Freon makeup - 1.09 mills/kW hr

However, further recovery could be accomplished by additional separation equipment or by flashing the expelled brine to pressures below the condensate pressure. This latter case would, of course, require a vacuum pump. All major pieces of equipment are indicated. The direct contact boiler is the item being developed under this contract while the liquid-liquid heater could be a simple liquid-liquid extraction column being evaluated as a piece of heat transfer equipment under other ERDA funding to us. The condenser-settler is a piece of equipment including a standard condenser and a holding tank which would allow for the recovery of the fresh water which expands through the turbine with the Freon 113 vapor. (The existence of this water causes no problem as it will not condense in the turbine.) Although it is indicated that the fresh water is dumped with the expelled brine it could be utilized for power plant purposes or domestic consumption.

3.1.4 Raft River Test Rig

A direct contact boiler was assembled for installation at the Raft River Site. The boiler test assembly was installed in an ERDA trailer together with pertinent auxiliary equipment such as pumps and condensers and working fluid holding tanks. The assembly was installed in such a manner that it only requires that geothermal test facility personnel provide piping of geothermal brine and cooling water to the trailer together with the installation of electric power and heat within the trailer. The test trailer was transported to the test site October 15, 1975.

The direct contact boiler is a two tray assembly with tray diameters of 19-1/2 in. and 18-1/2 in. nominally. The trays are assembled in such a manner that both volume and surface boiler configuration has orifice holes of 0.025 in. diameter spaced at 1.0 in. centers and is set for 1.0 in. water depths. Testing is scheduled to start on October 16, 1975. Initially, of course, system checkout will be carried out at well No. 2 prior to actual performance data gathering.

3.1.5 Future Plans

Initial testing of the direct contact boiler configurations will be carried out at near atmospheric pressure on Raft River Well No. 2 with later movement to well No. 1 for high pressure testing. Comparison of heat transfer characteristics and scaling from the laboratory set-up will be obtained. Particular attention will be paid to the required pinch-point temperature difference to insure zero holdup of working fluid in the trays and carryover in the brine out flow.

If the scaling of the test heat exchanger from the laboratory bench tests is as expected, the test vessel will be modified to include up to four trays.

The analysis of possible direct contact cycles will be extended to include a range of fluids of smaller molecular weight than Freon 113 including isobutane, pentane, and Freon 114 during the next reporting period. Incorporation of data from a related ERDA grant, particularly on solubility, will also be included. It is hoped to include plant capital cost assessments in future cycle analyses as well as maintenance and working fluid makeup costs.

Preliminary assessment of direct contact condensation processes will be made. Primarily this will be of the literature survey form. The purpose of this is to examine whether research on this phenomena would yield further economic payoff in geothermal power production.

3.2 Fluidized Bed Heat Exchanger Development Studies

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

The purpose of this study is to develop a heat exchanger which will prevent scale accumulation on the tubes in the shell-side (geothermal side) of the exchanger. The exchanger is constructed so that the geothermal fluid passes through and fluidizes a bed of particles surrounding the tubes in the shell of the heat exchanger.

Bench-scale comparison tests were made in the heat exchanger apparatus shown in Figure 21. A synthetic geothermal fluid enters the bottom of a heater tank where it is heated and contacted with ground CaCO_3 scale suspended in a cheesecloth bag. The water, saturated with CaCO_3 , is pumped into the heat exchanger where it is cooled by contact with stainless steel cooling coils. After leaving the heat exchanger the solution is recycled to the heating vessel.

Runs were made with and without a bed of sand surrounding the heat exchanger coil. At the conclusion of each run, the surfaces of the coil and vessel were examined for any deposition of scale. At the conclusion of the run made without a sand bed, deposits of CaCO_3 were found on the surfaces of the heat exchanger coil and the vessel walls. When a bed of sand surrounded the heat exchanger, no CaCO_3 deposits were found on the heat exchanger coil or the walls of the vessel exposed to the fluidized bed of sand.

Bench-scale tests are also in progress at well No. 2, at Raft River. Identical heat exchangers are being operated side-by-side. One contains a bed of sand fluidized with geothermal water, and the other without a bed. It is expected that in this run about 20 days of operating time will be available while flow tests are conducted at the well. Early data indicate that at flow velocities of 10 ft/minute, tube-side heat transfer coefficients as high as 1,000 Btu/hr ft²°F are obtained. The transfer coefficients are about twice as high with the bed present as without.

3.2.1 Water Sampling and Analysis

Chemical analysis of influent and effluent geothermal fluids in the second generation fluidized bed heat exchanger will permit collection of data pertinent to design, deposition, and reinjection. Since differences in concentration will be small, maintaining sample integrity is critical. A sampling system was designed, and is mostly constructed and tested. This system is composed of three elements.

1. Collection: Samples are collected at elevated temperature and sufficient pressure to maintain the fluid in liquid phase. Sample

Fig. 21 Present heat exchanger apparatus with thermocouple locations shown

bombs are stainless steel and equipped with a pressure gauge and thermocouple. Filtered, and unfiltered samples are collected for solid, solution and gas analysis.

2. Transportation: To prevent precipitation during sample transit, a portable oven was constructed. Samples are stored in the oven till just prior to analysis.
3. Preparation: A vessel designed for simultaneous cooling and dilution will prevent analysis errors due to precipitation. Hot geothermal fluids will be transferred from the sample bombs into the vessel (containing a measured volume of water) under pressure to prevent flashing.

Equipment and analytical procedures were tested and improved by sampling and geothermal wells at Raft River. In the last quarter, Raft River Well No. 2 was sampled three times and Table I shows a comparison of the two wells based on average values of the best samples from each.

Water composition from the two wells is similar; but, the differences are significant. For example when the temperature predictions of the reservoir are made from geothermometry calculations, RRGE-2 data predicts substantially higher temperatures as shown in Table II. The Na-K-Ca thermometer is more likely accurate, because of the probability of amorphous silica precipitation when the samples are cooled to room temperature.

3.2.2 Pilot Plant Heat Exchanger Experiment

All materials for the three vessels and the support frame have been received. Construction of the dissolver vessel has been completed, and work has begun on the heating vessel. Work will soon begin on the support frame.

The design of the heat exchanger tube bundle has been firmed up and will be finished in the very near future. Fabrication will begin as soon as the design is completed.

TABLE I *

	RRGE-1	RRGE-2
SiO_2	91 ppm	170 ppm
Cl^-	605 ppm	661 ppm
F^-	$5.4 \pm .3$ ppm	$7.6 \pm .4$ ppm
HCO_3^-	71 ppm as CaCO_3	42 ppm as CaCO_3
$\text{CO}_3^{=}$	none detected	none detected
Na^+	359 ppm	389 ppm
K^+	25 ppm	35 ppm
Ca^{2+}	51 ppm	38 ppm
Mg^{2+}	1.9 ppm	0.1 ppm
H_2	0.53 STPmℓ/ℓ	1.29 STPmℓ/ℓ
He	0.027 STPmℓ/ℓ	0.023 STPmℓ/ℓ
N_2	31.9 STPmℓ/ℓ	23.0 STPmℓ/ℓ
O_2	0.10 STPmℓ/ℓ	0.042 STPmℓ/ℓ
Ar	0.66 STPmℓ/ℓ	0.38 STPmℓ/ℓ
CO_2	5.8 STPmℓ/ℓ	0.79 STPmℓ/ℓ

* Data presented in this table are a compilation of chemical analyses to date. Differences between these data and those presented in earlier reports reflect improved sampling techniques, and in the case of RRGE-2, an increased data base.

Table II

<u>Geothermometer</u>	<u>RRGE-1</u>	<u>RRGE-2</u>
Quartz*	270°F	338°F
Na-K-Ca*	334°F	367°F

* Quartz geothermometer (Fournier and Truesdell, 1974) -

$$T(^{\circ}\text{K}) = \frac{1309}{[5.19 - \log_{10} (\text{SiO}_2 \text{ ppm})]}$$

Na-K-Ca geothermometer (Fournier and Truesdell, An empirical Na-K-Ca geothermometer for natural waters: Geochimica et Cosmochimica Acta, Vol. 37, 1973) -

$$T(^{\circ}\text{K}) = \frac{1647}{[2.24 + \log_{10} \left(\frac{\text{Na}}{\text{K}}\right) + \beta \log \left(\frac{\sqrt{\text{Ca}}}{\text{Na}}\right)]}$$

where $\beta = 1/3$ for water equilibrated above 100°C

$\beta = 4/3$ for water equilibrated below 100°C

(if $\beta = 4/3$ does not yield a temperature below 100°C, use $\beta = 1/3$ to estimate equilibration temperature)

4.0 NON-ELECTRIC USES OF GEOTHERMAL ENERGY

4.1 Introduction

Geothermal energy use has been limited for many decades. The non-electrical uses have centered around space heating with only minor applications to industrial processes. However, geothermal water in the moderate temperature range ($<150^{\circ}\text{C}$) is usable in many process applications and successful demonstration 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 investigation has been undertaken to find ways to maximize the use of this energy source.

Recognizing the need for a scientific evaluation of this potential energy source, 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

Various processes have been examined for their potential for direct non-electric application of geothermal energy.

The following outlines the proposed demonstration of the non-electrical utilization of geothermal water at Raft River to be performed in conjunction with industrial participants. The logic involved in the choice of uses, the associated land, water, and energy requirements, and the concept of cascaded energy utilization are discussed.

The Raft River Geothermal Demonstration Project will provide experience in practical application of low temperature (<300°F) geothermal water for both electric power production and direct heat utilization in industry. By developing a system of integrated use, the maximum benefit can be gained from the available heat. A significant portion of the plant costs are the well costs which can be amortized over a broader base with the non-electric heat uses. Figure 22 shows the impact on power costs of selling some of the heat directly. While not all waste heat could be effectively utilized, it quickly becomes apparent that the value of the heat can have a significant impact on power cost of an associated power plant.

Industries for potential demonstration of the utilization of geothermal energy at Raft River were selected using the following criteria:

1. The industry should be an intensive user of low to moderate temperature heat.
2. One installation should be representative of the particular industrial process at large.
3. The process is either indigenous to the Raft River area or is readily adapted to the area. Both raw materials and markets should be readily available.
4. The selection of processes should be such as to cascade the uses to energies at all levels.
5. The industry should have acceptable social and environmental impacts.

The following industries have been closely examined as potential unit types:

<u>Process</u>	<u>Desirable Size</u>
1. Potato Processing	200,000 lb/day
2. Manure Processing	300,000 lb/day (raw manure basis)
3. Cattle Feeding	10,000 head feed lot
4. Greenhousing	30 acres
5. Fish Farming	250,000 lb/yr of fish
6. Refrigeration (slaughterhouse and fish)	1,000 tons refrigeration
7. Tree Breeding	200 acres

COST REDUCTION ACHEIVABLE WITH NON-ELECTRICAL APPLICATIONS (10 MW PLANT)

Fig. 22

Fig. 23

Fig. 24

CONCEPTUAL INTEGRATED GEOTHERMAL DEMONSTRATION SYSTEM

These industrial processes are well suited to criteria outlined above, and the combination of these processes with a geothermal electric plant would form a symbiotic arrangement as shown in Figures 23 and 24. Not only is energy used efficiently but the product of many of these industries can be input to other industries in the demonstration unit.

A brief description of each of the potential demonstration units follows:

1. Potato Processing

A potato dehydration plant with an output of 100 tons/day uses approximately 25,000 therms/day of heat, requires about 1,200 gpm of fresh water and about 100 acres of land. If an acceptable method of process water disposal can be developed, as much as 80% of the land requirement could be eliminated. Water cleanup and recycle could cut water requirements materially but this will require industry incentives. The low availability of water in the Raft River area may force this kind of development in order to harness the inexpensive energy source.

Flashing should provide enthalpy of vaporization for the processes requiring steam. Sensible heat required to bring the steam up to 350°F could be provided by heat pump, solar topping, fossil fuel, or electricity whichever shows the least cost and/or greatest workability.

2. Manure Processing

The manure process has three main products:

A feed material equivalent to corn silage

A high protein (approximately 30%) feed suitable for swine, poultry, fish, and other concentrated protein users.

A soil conditioner which could also be used as a fuel (heating value approximately 7,000 Btu/lb).

A manure processing plant capable of handling the waste from 10,000 head of cattle would require approximately 5 acres. The water requirements are approximately 10 gpm. The plant heat use is approximately 2,000 therms/day.

3. Cattle Feeding

The cattle feeding should be done on a concrete pad feedlot with an area of about 7 acres. The water consumption for 10,000 head should be about 125 gpm. To insure optimum living conditions for the cattle, the lot should have a roof and closeable sides for heating in winter. Maximum heat loads during the coldest winter

weather would run about 1.8×10^6 Btu/hr and would drop to zero during the summer. The manure from the feedlot would be processed in the manure plant and the silage equivalent product could be fed back to the cattle.

4. Greenhousing

Greenhouse operations including both cut flower and vegetable culture could total about 30 acres under cultivation or about 40 acres total installation area. The fresh water irrigation requirements should be about 185 gpm. Maximum heat loads during the winter could reach 7.2×10^7 Btu/hr with an average of about 5×10^7 Btu/hr year round and a minimum of zero on warm sunny days. Water of 130-135°F would be hot enough for greenhouse heating. Soil conditioner from the manure process could be used in the greenhouse bed.

5. Fish Farming

The fish farm would raise warm water fish such as channel catfish, tilapia, and a species of fresh water shrimp. About 3/4 acre of pond surface would be required with a total area for the installation of about 5 acres. Water is recirculated at about 11,200 gpm with a 2% makeup. The resulting water demand is about 225 gpm. The water requirement is not consumptive as the water discharged could go back to the ground water system, following separation of most of the fish wastes.

The maximum heat demands will be 8.2×10^6 Btu/hr with the minimum 3.5×10^6 Btu/hr and an average use of approximately 6×10^6 Btu/hr. Geothermal water as cool as 120°F could be used and still be warm enough.

6. Refrigeration

The refrigeration system will be used for storage of products from the feedlot and the fish farm. No fresh water is required for this process. About 1 acre is required and would include adequate space for slaughtering, cutting, chilling, and deep freeze. The heat required for a 1,000 ton ammonia absorption refrigeration unit (part for the chiller for fresh slaughtered beef and part for the freezer) could be supplied by the water from one well (1,200 gpm 300°F) while dropping the outlet geothermal temperature to approximately 220°F.

7. Tree Breeding

Tree breeding would be the lowest grade use of the geothermal heat. An underground piping network is used for soil heating to extend the growing season. Trees could be grown from 5 to 9 years, uprooted, and chopped up for particle board manufacture. Geothermal water could be used in irrigation of the tree-breeding plot. Water temperatures (geothermal) would start below 120°F at the inlet of the tree breeding plot and could be useful down to approximately 90°F.

The individual and total heat use rates are shown in Table III. It should be noted that few of these processes are base loaded and therefore, Figure 25 shows projected use rate variations.

4.2.2 Down-Hole Heat Exchangers

A study of down-hole heat exchangers has been initiated by the Oregon Institute of Technology at Klamath Falls, Oregon, utilizing existing systems in that city.

Well water chemistry and corrosion data was gathered on some 42 different wells. The chemistry data was used to compare single dissolved ion concentrations to that parameter probable effect on the rate of corrosion experienced. This was done by making up separate iso-maps for total alkalinity, water hardness index, calcium, sodium, potassium, chloride, sulfate, silica and electrical conductivity. A map indicating which of the 42 wells have shown high or low corrosion rates was then overlaid on the separate maps to develop any correlation that might exist. Good correlation was not evident with these single parameters.

Of all the wells under study, selection of seven wells for detailed corrosion analysis have been selected. Test specimens have been made up to install in these wells. Each well will have specimens installed just above and below the water line. Each specimen stack will include 11 material specimens some electrically isolated from each other and some purposely coupled to better determine the corrosive effect caused by the different electrical potentials.

Table III

Raft River Non-Electrical Energy Use
Summary

POTATOES	5.8×10^6 THERMS / YR
MANURE PROCESSING	7.0×10^5 THERMS / YR
FISH FARMING	5.3×10^5 THERMS / YR
GREENHOUSING	4.4×10^6 THERMS / YR
REFRIGERATION	2.8×10^6 THERMS / YR
TREE BREEDING	1.1×10^6 THERMS / YR
FEEDLOT HEATING	8.8×10^5 THERMS / YR
<hr/>	
TOTAL	16×10^6 THERMS / YR

Current wholesale value relative to natural gas is \$2.6 million/year

Fig. 25 Yearly Energy Use Rate

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 reported thermal occurrences. Based on 1975 fuel costs and an anticipated total project installation cost of approximately \$3 million, economic feasibility based on amortization over a reasonable period is predicted. 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.
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

5.2.1 Geoscience

The initial geochemical, geological, and geophysical studies were completed during this reporting period. A composite base map (1 : 24,000) was prepared from USGS topographic sheets to map all geophysical, geochemical, and hydrological survey data. Several C.O.S.A. (Color Oblique Stereo Air) photos were taken and compared with ERTS and U-2 imagery. Linears on these photos are all being field checked and the geologic mapping of the Boise area is being extended. Preliminary geologic mapping, field alteration studies and linear interpretations support the suitability of the old Boise Military Reservation Area for geothermal development.

Geologic mapping of silicified sandstone occurrences is ongoing in conjunction with aerial photograph interpretation and field sampling. A total of 36 hand samples of silica cemented sandstones were collected in the geothermal lease area and along the Boise Front. Fifteen of these samples were thin sectioned, and were prepared for X-ray analysis. The results will be used to correlate with the thin sections in an effort to isolate the highest degree of hydrothermal silica enrichment.

Several shallow well drill sites were selected on the basis of these linears and surface alteration maps. Five test holes were drilled at various sites and are currently under analysis. The intersection of three linears at the south of Cottonwood Canyon provides the type of structural setting most favorable for geothermal system circulation.

Electrical resistivity surveys, which were initiated in May were continued throughout the summer months. Data was collected from over 200 survey stations. The majority of these stations were between Lucky Peak and Cottonwood Canyon, northeast of Boise. Data from these stations will be analyzed after remeasurement of these points with the electrical source perpendicular to its original location.

Thermal alteration studies of the Boise foothills continued and inspection of shallow well drilling chips was made using the Sieman's X-ray Diffractometer.

Three telemetering microseismic systems have been set up in the Boise foothills. These three in addition to two clock-driven systems are so located as to effectively monitor the background level of seismic activity. The array

enables the investigators to triangulate and identify the location of local microseismic events. As soon as sufficient events are detected, fault plane solutions will be possible. Minor local events are routinely being recorded and analyzed.

Active seismic surveys using the portable non-explosive seismic energy source in urban locations and dynamite in rural areas was resumed and will be completed next quarter.

Magnetometer surveys have been completed from Table Rock to the Freestone-Cottonwood Creek areas.

Monitoring of existing "hot" wells has continued wherever possible as a geophysical tool in interpreting the geothermal characteristics of the Boise Area. Monitoring of water levels and temperature logging continue to provide a better understanding of subsurface structure and interaction.

5.2.2 Environmental Considerations

A biological environmental data report was prepared by Dr. D. J. Obee, Chairman, Department of Biology, Boise State University. Included in the results of the study are:

1. A survey of published biological environmental data relevant to the physical area under consideration for this project,
2. an inventory of the principal species representing the biota of the area under consideration for this project,
3. A survey of the biological implications of geothermal waste disposal.

An extensive evaluation of all aspects of potential environmental impacts has been completed and will be incorporated into an Environmental Assessment.

The assessment covers the exploration and drilling phases of the project and will serve as the final environmental statement for those activities. In addition, it addresses some of the potential impacts of the construction and operation phases in order to outline areas of concern that need to be considered in current environmental studies. The report concludes that the most environmentally critical phases of the program will be:

1. during the drilling phase where land disturbances can have significant impacts if operational controls are not maintained,
2. during disposal of the waste geothermal fluids. Several disposal alternatives have been evaluated and the results are summarized in the assessment.

Preliminary contacts were made with the faculty of the Boise State University Biology Department concerning the development of a five-year environmental program for the project. The plan, which covers all environmental studies from the continuation of baseline surveys to the final impact evaluations, is currently being prepared.

5.2.3 Conceptual Design - Building Modifications

Based on recommendations made in Report CI-1271, Feasibility Review for Geothermal Conversion of Existing Heating and Ventilating Systems on the Boise Space Heating Project," ten state owned buildings were selected as being most easily converted for heating with geothermal water. A detailed feasibility and conceptual design study (ANCR-1246) was completed. This effort concentrated on the potential for converting to geothermal heating, the State Capitol building, three other buildings in the Capitol Mall area, the State Veteran's Home, and four of the more conversion compatible buildings that comprise the Boise State University Campus. The report is directed toward a description of building modifications required to accomplish such a conversion.

From an individual building standpoint, and with the exception of the Len B. Jordan Building*, the physical conversion to geothermal heating appears to be a relatively straight forward modification. All components used in these estimates are state-of-the-art and are used in conventional hot water heating systems.

The proposed building modifications eliminate most, but not all of the present requirements for steam. The small dependency on steam that will remain was primarily for heating potable water and kitchen use, for which purer water and higher temperatures are desired. The present steam capability will also be maintained as a backup system for peaking requirements on very cold days.

No design or construction obstacle has been found that would significantly change the project scope. Looking at each building independently, the estimated cost of conversion is in line with the estimated cost to install conventional gas-fired devices. In total, a very attractive yearly heating fuel savings can be realized. If the distribution and discharge system conceptual design estimates remain within the previously estimated range, the operational savings will result in a short overall capital investment amortization period (as short as 10 years depending on the effective interest rate).

5.2.4 Conceptual Design - Distribution and Disposal System

Based on the design assumptions used in the Building Modifications Report (ANCR-1246) a conceptual design study was made of the distribution and disposal systems required for the geothermal water needed to heat the selected buildings.

The shortest routing was determined utilizing established city streets and an overall best route chosen to minimize potential interferences with existing understreet utility services. Pipe diameters were selected based on maintaining water flow velocities at an optimum value to keep friction losses within reasonable limits yet not allowing estimated pipe material costs to become excessive.

Three different design schemes were investigated based primarily on three different piping material arrangements. These were:

* The Len B. Jordan building has limited space availability and access to its mechanical equipment room. Thus, installation and additional heat exchangers will be difficult.

1. Concrete Pipe - Temptite pipe consisting of a transite pipe and the annular space between pipes filled with insulation. Pipe would arrive on the construction site preassembled in sections and installed as assemblies similar to conventional single lengths of transite pipe.
2. Steel Pipe - Standard Schedule 40 carbon steel pipe welded in place and an incapsulating insulation (Protectalite) poured in place prior to backfilling the piping trench.
3. Snow Melting Alternate - Systems using the same conveying materials as the other two schemes but where sidewalks exist and snow/ice melting is desirable, distribution piping will be run under sidewalks in a concrete utility trench.

A materials testing program is presently underway to obtain data on materials exposed to geothermal water for the Boise area using the Warm Springs Avenue water supply system. It is anticipated that this testing will determine the best economical material choices for both the underground piping as well as the piping and equipment to be used within the buildings. This materials testing program will cover a minimum one year span. The information that will be gathered should enable selections of appropriate materials for use above ground after approximately three months of test and underground materials after approximately six months. Final anodic material selection to be used for a sacrificial metal or cathodic protection of the underground pipe should be determined after one year of testing. This should allow for a timely material selection schedule as construction designs and drawings are being prepared. Scaling rates for heat exchanger surfaces from the geothermal water will also be determined and preventive or routine maintenance procedures recommended as required to obtain reliable performance from the systems throughout their operational life.

Based on the chemical analysis of the water from the Old Penitentiary wells, a potential environmental problem under consideration in the treatment and disposal system is a high concentration of fluoride ions. Thermal considerations must also be accounted for if surface water disposal is used. At maximum flow it is estimated the disposal system will have to process 2600 gpm of geothermal water at temperatures above 100°F and approaching more nearly, 120°F.

All economical treatment and disposal concepts for the thermal consideration although seemingly complex in total configuration can be reduced to single or multiple combinations of the following six very fundamental treatment and disposal methods. These are:

1. Utilize as much residual heat as economically practical with processes or mechanisms in various arrangements, cascading if necessary and all "state-of-the-art" in technical application.
2. Construct devices (cooling towers, cooling ponds, spray ponds or fountains) to reject the residual heat efficiently to the atmosphere.
3. Make no attempt to change the water temperature or utilize any of the residual heat.
4. Utilize the water for agricultural applications either directly (irrigation) or indirectly (greenhouse heat).

5. Dispose of the geothermal water as ground water run off, ultimately to the Boise River water shed.
6. Pump the water to an underground aquifer through reinjection wells.

The method of treatment most favored initially, because of the location of buildings being served in relation to the geothermal source, the Boise River and the general area topography would be item (2) plus (5) from the list with minimal provisions to add intermediate installations, items (1) and (4), at some later date under another program, funded on its own merit or return on investment.

Regardless of the cooling method chosen, the construction of such devices would preferably be in the immediate vicinity of the Boise State Campus or the Julia Davis Park. The exposed surface area required for cooling before discharge to the river at a temperature equal to the natural river water temperature is 300,000 square feet in cooling ponds or a 10,000 square feet spary pond. The existing body of water in the park is large enough to use as a cooling pond.

For surface water disposal, a high fluoride content will present a serious design problem. It has been determined that a fluoride concentration no higher than 11.7 ppm can be tolerated discharged to the Boise River in an untreated state with the flows involved.

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