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**SEMIANNUAL PROGRESS REPORT
FOR THE IDAHO GEOTHERMAL PROGRAM
OCTOBER 1, 1978 TO MARCH 31, 1979**

**L. F. Burdge R. J. Schultz
R. R. Stiger**

October 1979

MASTER

EG&G Idaho, Inc.

IDAHO NATIONAL ENGINEERING LABORATORY

DEPARTMENT OF ENERGY

IDAHO OPERATIONS OFFICE UNDER CONTRACT DE-AC07-76IDO1570

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**EG&G IDAHO, INC.
Idaho Falls, Idaho 83401**

Published October 1979

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ABSTRACT

This report discusses research and development performed by the Idaho Geothermal Program between October 1, 1978 and March 31, 1979. Well drilling at the Geothermal Site is discussed. Experiments of the direct use of geothermal waters are described. The report also presents an account of the facility's first 5-megawatt power plant. The second 5-megawatt pilot plant's use of direct-contact heat exchangers is examined in the report. University of Utah work on direct-contact heat exchangers is also discussed. The report summarizes the environmental studies of injection tests, an aquatic characterization survey of the Raft River, and the ferruginous hawk. It describes the regional planning effort for accelerated commercialization. Demonstration projects in Oregon, Utah, and South Dakota are noted. A bibliographic index lists each internal and external report the Idaho Geothermal Program has published this report period.

SUMMARY

At the Raft River Site flow testing began on injection well RRG1-6 and exploration well RRGE-2. Crews began testing on production well RRGP-5 and converted RRG1-4 to a production well, RRGP-4, by deepening the well. Hydrogeologists continued to evaluate the nature of the geothermal reservoir and studies continued on analyzing the thermal system of the Raft River.

Researchers continued direct-use experiments at the test site. The aquaculture facility underwent extensive system redesign and modification during this report period. The growth rates of 600 common and mirror carp were studied. Experimenters completed the three-year irrigation experiment which examined the possibility of using cooled geothermal water to irrigate crops.

The prototype electric generator baseline tests were successfully completed. The 60-kW plant at Raft River is presently undergoing modification. For the second pilot power plant, engineers have evaluated the working-fluid recovery systems and power recovery expanders and reviewed the heat-rejection system. University of Utah personnel continued to investigate the use of direct-contact heat exchangers.

Research continued to monitor the air quality, meteorology, water quality, hydrology, and terrestrial and aquatic ecology at the Raft River Site. The ferruginous hawk study finalized plans for field observations in 1979.

Baseline data documents were issued for Colorado, Idaho, New Mexico, and Nevada. These documents describe the present status of geothermal development in these states. A draft Regional Hydrothermal Market Penetration Analysis was also issued this reporting period.

Six demonstration projects received Department of Energy funds through the Project Opportunity Notice Program. EG&G personnel supported the Department of Energy in the technical administration of the project contracts.

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SEMIANNUAL PROGRESS REPORT FOR THE IDAHO GEOTHERMAL PROGRAM OCTOBER 1, 1978 TO MARCH 31, 1979

I. THE RAFT RIVER FACILITY AND RESOURCES

The Raft River Geothermal Site is located in southern Idaho's Raft River Valley, south and west of the small town of Malta (shown in Figure 1). The Idaho Geothermal Program, sponsored by the Department of Energy (DOE), has conducted field experiments at Raft River since 1973. Engineers from the DOE's Idaho National Engineering Laboratory (INEL) have tested various applications for the valley's medium-temperature geothermal fluids. The 150°C (300°F) water has been used directly for culturing fish and irrigating crops (see Section II). Another aspect of the program involves the design, construction, and testing of pilot power plants (see Section III). The environmental considerations and regional planning activities of the program are discussed in Sections IV and V, respectively. During the report period covered by this report, from October 1, 1978 through March 31, 1979, crews conducted various testing programs on the geothermal wells as described in the following.

1. SUMMARY OF RAFT RIVER GEOTHERMAL WELLS

(D. W. Allman, D. Goldman, L. B. Nelson, W. L. Niemi)

Hydrogeologists continued to evaluate the nature of the geothermal reservoir. They conducted injection tests, additional borehole geophysics, and geochemistry studies to analyze the thermal system of the Raft River. Figure 2 shows the locations of the geothermal wells.

1.1 RRGE-2

Engineers ran a flow injection test between RRGE-2 and RRGE-6 in January 1979. The test consisted of two one-hour pulses at 52 and 47 liters per second (820 and 750 gallons per minute) that preceded 72 hours of constant flow at 44 liters per second (700 gallons per minute). After recovery from the 72-hour test, two additional tests were run at 46 and 50 liters per second (730 and 800 gallons per minute). The ratio of the pumping rate to the slope of the data on a semilogarithmic plot of wellhead pressure versus time are dependent on the flow rate. In other words, the greater the rate of withdrawal from the well, the poorer the well's ability to produce water. This dependency also indicates that significant errors in predicting drawdown can result from short duration testing; therefore, a 20-day injection test at 38 liters per second (600 gallons per minute) began in March 1979.

1.2 RRGP-4

Well RRGI-4 was converted to a production well, RRGP-4, by the insertion of an intermediate string of casing from 461 to 1954 meters (1,512 to 3,457 feet, respectively). Multiple legs were also drilled below the casing. The first leg was drilled 1654 meters (5,427 feet) deep to the northwest and experienced only limited fracturing. The second leg was drilled to the northeast to a depth of 1559 meters (5,115 feet) and also encountered limited fracturing. Drilling at well RRGP-4 was terminated due to lack of fracturing and production in Legs A and B.

In November 1978, a flow test, which was conducted at 0.93 liters per second (15 gallons per minute), was terminated after 18 hours because of a combination of low production rate, low wellhead pressure, and flashing in the discharge line. The maximum discharge temperature was 110°C (230°F) and no effects of the flow test were seen in any of the observation wells. It is estimated that pumping RRGP-4 at 6.2 liters per second (100 gallons per minute) would result in 3.6×10^3 kilopascals (520 pounds per square inch) of drawdown over one day of production.

Fig. 1 The Raft River geothermal site.

Fig. 2 Locations of geothermal wells.

1.3 RRGP-5

Well RRGP-5 began flow testing in November 1978, and included three one-hour pulses at rates of 2.5, 12, and 19 liters per second (40, 190, and 280 gallons per minute, respectively). A 72-hour test was conducted at 8.8 liters per second (140 gallons per minute), and the slope of the wellhead pressure versus the log of time was 79.3 kilopascals/log cycle (11.5 pounds per square inch/log cycle).

Some of the data suggest a recharge type boundary, but they are not conclusive due to inconsistencies. The recovery time of the well was less than 7% of the production time which indicated an ineffective and/or poorly constructed well. The well data estimated by Jacob's formula do not provide conclusive results for borehole flow conditions. Fracture-controlled ground water flow may be the reason the well does not perform well. Interference effects at RRGE-1 or RRGE-2 are questioned, since the magnitude of effect at RRGE-2 is greater than at RRGE-1, and the distance from RRGE-5 to RRGE-2 is greater than from RRGP-5 to RRGE-1. However, it is possible with fracture-controlled flow for distant wells to show greater response than nearby wells.

1.4 RRG-6

Flow testing at injection well RRG-6 began in November 1978, for two one-hour pulses at 13.2 and 22.6 liters per second (207 and 354 gallons per minute, respectively), and a 24-hour constant flow at 10.8 liters per second (170 gallons per minute). The maximum discharge temperature was 98.2°C (208.7°F) and no effects were observed at any of the monitor wells.

A flow/injection test was run between RRGE-2 and RRG-6 in January 1979. Two one-hour pulses were conducted at 52 and 47 liters per second (820 and 750 gallons per minute, respectively), prior to a constant flow rate of 44 liters per second (700 gallons per minute). There was no well plugging during the test but there were losses of about 69 kilopascals (10 pounds per square inch) when water was injected in excess of 104°C (220°F). The 72-hour test indicated a hydrologic phenomenon after 100 minutes of injection at a reduced pressure buildup: 238.5 kilopascals/log cycle (34.59 pounds per square inch/log cycle) prior to 100 minutes and 113.4 kilopascals/log cycle (16.44 pounds per square inch/log cycle) after 200 minutes. After five years of injection at 44.16 liters per second (700 gallons per minute) of 125.6°C (258°F) water, the expected wellhead pressure is 1984 kilopascals (287.7 pounds per square inch).

An in-line, 190-micron filter was used for RRG-6 testing. Chemical data suggest that pond water and direct well-to-well transfer water contain sufficient undissolved solids to cause injection loss due to formation plugging. A cyclone-type filter, which is capable of removing suspended solids to 90 microns, is scheduled to be used to prevent retardation and formation plugging. However, there is a considerable volume of solids being injected that are less than 90 microns. Existing techniques; therefore, may need to be further improved.

A 20-day flow/injection test at 38 liters per second (600 gallons per minute) began in March 1979 to investigate boundary/interference effects and to reduce error in wellhead pressure projections.

1.5 RRG-7

In November 1978, a 65-hour injection test was conducted using a Halliburton oil-field pumper truck. The pumper truck controlled injection at 25.5 liters per second (400 gallons per minute) and based on early data the wellhead pressure slope was 826.7 kilopascals/log cycle (119.9 pounds per square inch/log cycle). After five years of continuous injection at 25.5 liters per second (400 gallons per minute), the wellhead pressure is predicted to be 37.94 kilopascals/gage (550 pounds per square inch/gage).

2. SUMMARY OF ADDITIONAL BOREHOLE GEOPHYSICS

The U.S. Geological Survey Water Resource Division Borehole Geophysics section ran noncommercial logs in the Raft River wells. Open-hole acoustic televiewer logs were run in RRGP-5 and RRGP-4. The fracture data from these logs will be modeled with an EG&G Idaho construction to correct fracture orientation for hole deviation and to correlate three-dimensional in-situ fracturing. Additional types of borehole geophysical logs include directional acoustic caliper, and spectral and flowmeter logs.

II. DIRECT APPLICATIONS

1. AQUACULTURE

(J. F. Sullivan)

The development of geothermal reservoirs, either for power production or direct use applications, results in the production of vast quantities of geothermal water. Aquaculture facilities can effectively utilize waste heat from such fluids, simultaneously conserving energy and reducing the amount of heat released to the environment. An intensive aquaculture program could use temperature-controlled geothermal fluids to produce high quality protein food on a year-round basis. Therefore, the commercial feasibility of geothermal aquaculture is being evaluated in the aquaculture facility at the Raft River Geothermal Site to investigate beneficial ways to use moderate-temperature geothermal resources.

The aquaculture facility at Raft River was stocked with 1500 channel catfish and 600 common and mirror carp during early October. The facility underwent extensive system redesign and modification during the period and has operated very satisfactorily maintaining the water temperature at $26.3 \pm 0.2^{\circ}\text{C}$ ($79.3 \pm 0.4^{\circ}\text{F}$).

The objectives of the current research phase are to:

- (1) Investigate actual growth rates as compared with predicted growth rates
- (2) Determine food conversion efficiencies
- (3) Evaluate the test organisms dietary requirements in geothermal water by performing diet trials utilizing both commercial and experimental rations
- (4) Quantify bioaccumulation of heavy metals and fluorides
- (5) Determine the metabolic rate of the fish (oxygen uptake per kilograms biomass per hour)
- (6) Study hematological, serological, microbiological, and histopathological parameters.

Three diets have been evaluated to ascertain which is more conducive to fish growth in geothermal water: (a) a commercial fish chow, (b) a basal ration of known proximate analysis, and (c) a ration prepared from geothermally dried biomass material. The growth of the fish is programmed biweekly according to expected food conversion efficiencies and increase in biomass. At the end of each 14-day growth period, the fish are inventoried and their growth is compared with predicted growth rates. Additional physiological samples and tests are run on a monthly basis.

Fry catfish were stocked and had a mean weight of 0.23 grams and carp had a mean weight of 23 grams. Mean weight (grams) as of the end of March (24 weeks of culture) are as follows:

	Commercial Ration (grams)	Basal Ration (grams)	Biomass Ration (grams)
Catfish	54	66	63
Carp	550	318	482

The percentage increase in growth for *each* two-week growth cycle is as follows (mean $\pm$ standard deviation)

	Commercial Ration (%)	Basal Ration (%)	Biomass Ration (%)
Catfish	45 $\pm$ 17.0	50.0 $\pm$ 19.4	40.2 $\pm$ 6.8
Carp	31.2 $\pm$ 8.1	22.3 $\pm$ 7.0	26.2 $\pm$ 6.4

As the data suggest, the fish are growing at remarkable rates and in all cases growth exceeds that recorded at the University of Idaho control experiment. During this period only one mortality has been recorded at Raft River while an outbreak of parasites was experienced at the control facility in December.

The carp have entered their reproductive phase, and females and males averaging 788 grams and 494 grams, respectively. It is anticipated that eggs and milt will be stripped and breeding will occur in early May. Reproductive aspects of fish culture will be evaluated during FY-80 when the catfish from the current phase will be reared to reproductive maturity and spawned. Both developing embryos and young of both species will be assessed for teratogenic abnormalities and growth. Thus, both channel catfish and carp will have been evaluated through two life cycles.

2. AGRICULTURE

Experimenters completed the three-year irrigation experiment during the period. The study has examined the possibility of using cooled geothermal water to irrigate crops. The potential benefits to the arid west are obvious. A conventional power plant must consume cooling water. A geothermal facility could be a net producer of water, and the excess could be used for irrigation. The application could also reduce the cost of injecting fluids that have been used to generate power. Fluid studies terminated with the collection of postharvest crop and soil samples during late September 1978.

The suitability of geothermal water for agricultural irrigation is determined by the amount and kind of salts present, and upon the characteristics of the receiving crops and soils. The experiment was initiated with the 1976 growing season (Phase I) and continued through the 1977 (Phase II) and 1978 (Phase III) seasons. Previous reports provide detailed descriptions of the Phases I and II and comprehensive activities, results, and appendices containing plot soil descriptions and guidelines for irrigation water quality ratings. The experiments were conducted on a 13.2 hectare tract of land located near the Raft River Geothermal Test Site in south-central Idaho. The land was subdivided into three plots and several subplots depending upon the experiment phase. The experiment plot land selections were based primarily on availability and proximity to water sources. At the time of plot selection, no soil survey information was available. The plot soils are highly variable, which required random collection of crop samples from all subplots. Geothermal irrigated plot crop yield data were compared only with the area average. No yield comparisons between plots or subplots were attempted. Irrigation water for the geothermal irrigated subplots was obtained from two 1500-meter deep geothermal wells identified as RRGE-1 and -2. In selecting crops to evaluate the effects of geothermal irrigation water in the Raft River Valley, consideration was given to the nature of the local soils, climate, water characteristics, farming practices, and possible alternatives. The growing season in the Raft River Valley is short with an average frost-free growing period of only about 120 days, and many of the local soils and irrigation waters are saline. These adverse conditions limit the productivity of many crop varieties such that most of the crops currently cultured in the area are hardy and salt-tolerant.

The irrigation systems consisted of 15.2 centimeters aluminum mainlines with 7.6 centimeters lateral lines on sprinkled subplots and 15.2 centimeters gated surface pipe laterals on the surface flood sections. The lateral sprinkler line spacing was on 15.4 meters centers with sprinkler heads each 9.2 meters along the laterals. In general, plots were irrigated every ten days from mid-May through mid-September, with approximately 8 centimeters of water applied per irrigation.

Yield estimates indicated that there was essentially no difference between crops receiving geothermal and comparison water. Successful yields were also obtained in comparison to crops grown in the surrounding farm area. For example, the barley grown on a newly tilled plot during Phase II yielded 2581 kilogram per one-hectare, which was lower than the area average (3657 kilogram per one-hectare) but not uncommon for the first years production on new soil. During Phase III, barley plot yielded 5273 kilogram per one-hectare which was greater than the area historic yields from 1974 through 1977. Barley and sugar beet crops, being the most salt-tolerant of the experimental crops, exhibited the least damage. Foliar tip burn and leaf curling exhibited for these crops was minimal.

The growth and yields of barley and beets was not severely restricted by the soil and water salinity as evidenced by yield comparisons with the surrounding area farms. Agriculture irrigation offers a potential alternative means of disposal for energy expended. Raft River geothermal water which may reduce reinjection costs and provide an additional water source to this arid region. New soils receiving geothermal water may experience increased salinity and decreased permeability such that leaching irrigations must be applied to maintain a favorable soil salt balance. Cereal grain, forage and sugar beet crops produced satisfactory growth and yields with no apparent reduction in food or feed value resulting from exposure to geothermal water. Cereal grains and surface irrigated forage crops did not absorb and translocate appreciable quantities of fluoride but, geothermal sprinkled forage crops exhibited abnormally high fluoride levels.

3. WELL STIMULATION PROGRAM

During this period, data on the site resources were compiled and submitted to the program participants. The data on geology, well completion, well logging, reservoir testing, rock properties, and geochemistry are being evaluated by Republic Geothermal, Inc. Republic Geothermal will recommend what production and injection wells will receive stimulation treatments. Terratek supports the work of Republic Geothermal and will perform a stimulation treatment on a second injection well.

III. ELECTRIC APPLICATIONS

One of the Raft River projects is designed to determine whether economically competitive electricity can be generated from a medium-temperature (140° to 150°C) geothermal resource. If these medium-temperature waters can produce electricity at competitive rates, geothermal energy can supply much of the West's growing need for energy.

The conversion technology work is directed toward innovating and applying advanced conversion concepts which can lower electrical power costs of the medium-temperature hydrothermal resources. A small binary cycle plant, rated at 60 kWe, is used to investigate both analytical and experimental approaches to support this effort.

1. PROTOTYPE GENERATORS

(G. Mines, D. Rogers)

The prototype generator baseline tests were conducted during October and November 1978. These tests were conducted to assess equipment and to collect data on power output variations that are due to ambient temperature changes.

In November 1978, a continuous 50-hour test was conducted with the prototype operating with automatic controls for the first time. This test was successful in that the equipment functioned properly and the generator was stable during operation. The 50-hour test offered the first opportunity to obtain data on daily fluctuations in power output due to changes in ambient temperature. Figure 3 illustrates the potential gain in power output that could be realized by operating the prototype cooling water system at full capacity during the colder months. The average power level was 80 higher than the output at a 65°F wet bulb temperature.

Fig. 3 Potential gain in power output by prototype cooling water system operating at full capacity.

Although the magnitude of power variations for changing ambient conditions achieved with the prototype will not directly apply to other geothermal binary power plants, the test results indicate that the concept of floating power does represent an area which can improve output and enhance economic feasibility.

Since the 50-hour test, the prototype has not been operated. During this report period, the geothermal fluid has been limited and severe flooding and freezing occurred at Raft River. The plant has undergone some modifications which include the installation of a higher capacity cooling water pump for the cooling water system and upgrading the control system so the plant can be operated by automatic controls.

The 60-kW pilot plant at Raft River is undergoing modification. A contract is being negotiated for the design and purchase of a direct-contact preheater/boiler, a flash tank, and associated instrumentation and control components for the existing 60-kW prototype generator at Raft River. The requirements for a new vertical turbine isobutane feed pump have been determined and procurement is underway. The auxiliary components needed for direct contact operation of the 60 kW prototype are now being assessed.

2. FIRST 5-MEGAWATT PILOT PLANT

2.1 Turbine Generators (W. E. Waters)

A subcontract for the turbine-generator design was awarded to the Elliott Company in October 1978 and the final design details were agreed upon in November.

The award of the turbine-generator facility modification design subcontract was made by DOE to Burns and Roe Pacific, Inc. in March 1979. At the end of this reporting period, the Burns and Roe recommendations for the turbine-generators arrangement and its support structure were reviewed and approved.

2.2 Support Engineering (C. J. Bleim)

The support engineering group completed the test plan for the 5-megawatt pilot plant. This test plan forms a basis for (a) finalizing plant operating procedures, (b) establishing data acquisition software requirements and a complete control system, and (c) determining additional plant hardware requirements, such as additional instrumentation.

The primary objectives of the tests are to:

- (1) Operate plant at full capacity with minimum personnel and economic hazard
- (2) Determine the operational and performance characteristics of the system and individual components
- (3) Develop better design information for future system and component designs
- (4) Establish a data base for predicting operational and performance characteristics of the plant and its components.

The test plan comprises steady-state tests of both the system and individual components and transient tests of the control system through the normal transients of the plant.

Since publication of the test plan, additional instrumentation and instrument modifications were determined necessary for the testing program. Work is now beginning on the final system computer modeling for the purpose of pretest calculations, control system checkout, and development of information to develop detailed operating procedures.

2.2.1 Water Treatment Program: The purpose of the water treatment program is to define a total water treatment package for use of spent geothermal fluid as cooling tower makeup. The program consists of three phases: (a) pretreatment of makeup water for silica reduction, (b) treatment of recirculating water for corrosion inhibition and treatment of blowdown from the cooling tower to meet standard environmental requirements.

Jar tests were conducted to determine a chemical system that reduces silica concentration. These tests are completed and several magnesium containing systems were determined to be adequate. At present, adequate is tentatively being defined as a reduction in silica concentration to 30 parts per million or less.

A series of spinner tests are presently underway to determine corrosion rates of geothermal water pretreated for silica reduction. The spinner tests are conducted in accordance with ASTM D-2688-170 ("Corrosion of Water in the Absence of Heat Transfer"). These tests will determine the corrosion rates of carbon steel at different concentrations of a corrosion inhibitor system. Geothermal water which has been treated for silica reduction and concentrated five times is being used for these tests.

A Bench-Scale pilot plant cooling tower has been designed and is being built. The test tower will simulate the operating conditions in the pilot plant's chemical treatment system, cooling tower, and condenser. Preliminary system tests are being conducted to determine tower characteristics and to ensure the applicability of the test as a model. The results of the Jar and spinner tests will be incorporated into the test model system, and the Bench-Scale model will then be used to evaluate several pretreatment systems. The pretreatment system will include silica reduction to prevent silica scale, and the corrosion-inhibitors system will prevent corrosion in a continuous flow system.

2.2.2 Corrosion Tests. The first phase of the test which evaluates the effect of velocity on the corrosion rate is nearly complete. Carbon steel samples tested in cooled geothermal fluid from RRGE-1 stirred at a range of velocities, indicating that velocity has a definite effect on the corrosion rate. However, additional testing is needed to indicate the extent to which velocity affects the corrosion rate.

The second phase of the test is to evaluate the effect of velocity using geothermal fluid at the temperature and pressure of the heat exchanger. Another phase of the test will measure the effect of velocity on geothermal fluid open to the atmosphere but held at a constant temperature. At present, these two phases of the controlled velocity tests, the instrument probe tests, and the long-term corrosion tests have been delayed until FY-80, due to a lack of coolant or sufficient flow of geothermal fluid to the corrosion test site.

3. SECOND 5-MEGAWATT PILOT PLANT

The current objective of the Utilization Technology effort for the second Raft River 5-megawatt pilot plant is to develop the concept of an advanced binary cycle which will produce low-cost electrical energy using the Raft River geothermal resource. The use of direct-contact heat exchangers is of particular interest and is being examined because of their potential for lower component costs and possibly superior thermodynamic performance.

Work during this period can be summarized as follows: the analysis of working-fluid recovery systems, the evaluation of the power recovery expanders, and the review of the heat-rejection systems.

3.1 Working-Fluid Recovery Systems

The analysis of the mechanical and chemical working-fluid recovery system for direct-contact cycles continued during this reporting period.

A practicable mechanical system consists of: preflashing the geo-fluid to remove the dissolved noncondensable gas, compressing and cooling the condenser vent vapors to recondense most of the working fluid from the vent vapors, and postflashing the geo-fluid before reinjection to recover dissolved working-fluid. This recovery system introduced a parasitic penalty equivalent to between 2.0 and 2.7% of the net plant power for a triple-boiling, direct-contact, isobutane cycle with a shell-and-tube condenser. The corresponding loss in working fluid was estimated to equal 30×10^{-6} times the geo-fluid flow.

The chemical system approaches which were studied included: (a) bubbling condenser vent vapors through a solvent which dissolves the working fluid, and separating the working fluid from the solvent by distillation and (b) passing condenser vent vapors over a charcoal bed which absorbs the working fluid and regenerating the bed by applying heat. These chemical systems resulted in parasitic losses to the cycle which were equivalent to or higher than the simpler mechanical systems. The chemical systems were not shown to be competitive.

3.2 Power-Recovery Systems

Power-recovery expanders were evaluated for their ability to recover power from the geo-fluid as it undergoes pressure drops during several processes in a direct-contact cycle. In the basic cycle, the geo-fluid pressure drops occurred between the lower-pressure boiler/heater components. Pressure drops in the working-fluid recovery system are associated with the flashing of geo-fluid and the expansion of the flashed vapor. Hydraulic or vapor expanders would replace orifices to accomplish these pressure drops.

The expanders in the basic cycle recovered about 6 of the net plant power whereas expanders in the working-fluid recovery system recovered over 2 of net plant power.

3.3 Heat-Rejection System

A preliminary review was made of the heat-rejection systems. Wet cooling towers, dry towers, water-spray augmented towers, and evaporative condensers were compared for application to the second 5-megawatt Raft River plant. The assessment concluded that a dry cooling tower imposes large power and cost penalties as compared with a wet tower. However, evaporative condensers appear to offer a significant thermodynamic advantage over a wet or spray-augmented dry tower with a single condenser. The evaporative condenser may be superior to a wet tower with triple shell-and-tube condensing.

3.4 Binary Cycle Evaluation

Geothermal binary cycles, which included isobutane, pentane, cis-3-butene, and several mixed hydrocarbon working fluids, were evaluated using wet cooling towers with Raft River geo-fluid (290°F and 52 parts per million dissolved nitrogen). Dual and triple-boiling cycles were analyzed with both single and staged condensing. Also included in the study were both shell-and-tube and direct-contact boilers, heaters, and condensers.

The results for the direct-contact cycles are shown in Table I. These results do not include the working-fluid recovery parasitics. A summary of results for several shell-and-tube cycles is shown in Table II.

A comparison of Case 13, which represents an improved shell-and-tube isobutane cycle, with Case 12, which represents the first Raft River 5-megawatt pilot plant, indicates that an improvement of 17% in net plant power (at the same geo-fluid) can be obtained using triple boiling and condensing.

TABLE I

COMPARISONS OF GEOTHERMAL CYCLES USING
RAFT RIVER GEO-FLUID
Direct-Contact Cycles (Working-Fluid-Recovery Power Not Included)

Cycles				Power Balance, Watt hr/lb geo-fluid (Boiler/Heater Pinch Points = 10°F)						
Case	Boiler Temperature (°F)	Condenser Temperature (°F)	Working Fluid	Turbine Power	Geo-fluid Delivery Pump	Working Fluid Pump	Wet Cooling Power		Net Power	
							With Direct-Contact Condenser	With Shell & Tube Condenser	With Direct-Contact Condenser	With Shell & Tube Condenser
1	240,180	104	1C4	4.78	0.36	0.41	0.96	0.48	3.05	3.53
2	260,210,150	91,99,104	1C4	5.83	0.52	0.55	1.16	0.56	3.60	4.20*
3	230,170	104	C5	4.16	0.03	0.08	0.50	0.46	3.55	3.59
4	230,170	94.9,104	C5	4.40	0.03	0.08	0.51	0.47	3.78	3.82
5	250,210,160	104	C5	4.55	0.08	0.09	0.53	0.49	3.85	3.89
6	250,210,160	91,93,104	C5	4.83	0.08	0.10	0.54	0.52	4.11	4.13
7	240,180	104	CIS 2 Butane	4.36	0.24	0.21	0.67	0.44	3.24	3.47
8	245,180	95	.51C4/.51C5	4.36	0.16	0.19	0.70	0.49	3.31	3.52
9	245,180	95,95	.51C4/.51C5	4.40	0.16	0.19	0.70	0.49	3.35	3.56
10	245,180	84,84	.51C4/.51C5	4.83	0.16	0.20	0.66	0.52	3.81	3.95
11	270,205	84,84	.51C4/.5C6	4.07	0.07	0.12	0.59	0.51	3.29	3.37

* Cycle net power increased by 0.36 Watt hr/lb geo-fluid when boiler/heater pinch points reduced from 10°F to 5°F.

TABLE II

COMPARISONS OF GEOTHERMAL CYCLES USING
RAFT RIVER GEO-FLUID
Shell-and-Tube Cycles

Case	Cycles			Power Balance, Watt hr/lb geo-fluid (Boiler/Heater Pinch Points = 10°F)				
	Boiler Temperature (°F)	Condenser Temperature (°F)	Working Fluid	Turbine Power	Geo-fluid Delivery Pump	Working Fluid Pump	Wet Cooling Power	Net Power
12	240,180	104	1C4	5.07	0.06	0.46	0.49	4.06
13	260,210,160	93,99.8,104	1C4	5.91	0.06	0.57	0.54	4.74
14	230,170	104	C5	4.40	0.03	0.09	0.48	3.80
15	220,170.6	90.5	0.51C4/0.5C3	5.68	0.06	0.42	0.56	4.64

A proper comparison of an improved direct-contact cycle, such as Case 2, with the first 5 megawatt Raft River plant requires that working-fluid recovery parasitics be considered. The performance of a triple-boiling, triple-condensing, direct-contact isobutane cycle, having a shell-and-tube condenser, was assessed assuming direct-contact boiler/heater pinch points of 5°F and 1°F. The working-fluid recovery parasitics were evaluated for the mechanical recovery system (Section 3.1) assuming a total working-fluid loss of 30×10^{-6} times the geo-fluid flow.

The net plant power (units of watt hour per pounds of geo-fluid) is determined to be 4.78 and 4.89 for the triple-boiling cycle, and for direct-contact boiler/heater pinch points of 4°F and 1°F, respectively. When allowance is made for the higher pressure of the geo-fluid leaving the cycle of Case 12 (first Raft River pilot plant), the improved direct-contact cycle is shown to provide an increased net plant power of 16 and 19 for the 5°F and 1°F pinch points.

4. DIRECT-CONTACT HEAT EXCHANGERS

[R. F. Boehm, H. R. Jacobs (University of Utah)]

In the direct-contact heat exchanger, heat is transferred from one fluid to another when the two are intimately mixed. The use of this process eliminates an intervening heat transfer surface. This characteristic can yield higher heat transfer rates, eliminate fouling, and result in heat exchanger devices with lower capital costs than their more conventional counterparts.

Work at the University during the past period involved: additional studies of the system to aid in defining optimal plant configurations; further work in analytical tools for boiler designs; finalization of preheater studies; and completion of several condenser studies. The following offers overviews of these developments.

4.1 System Studies^a

System studies were carried out, particularly for the Raft River site, assuming 80°F condensation temperatures. This temperature was chosen as being more realistic for a yearly average rather than choosing a condenser temperature based on worst case summer conditions. The two basic cycles studied were two boiler cycles. The first cycle, termed a series cycle, is one Rankine cycle followed by another. The second cycle, termed a split cycle, allows a geothermal water flow through the high pressure boiler; the flow is split with only enough geo-fluid flowing through the high pressure preheater to maintain a 5°F pinch point. The remainder of the fluid is used in a second boiler and preheater. The working fluid in the second boiler may be the same or a different fluid. The calculations were made based on a geo-fluid flow rate of 4.55×10^5 kilograms per hour (10^6 pounds per hour). It was assumed that 0.33°C (0.6°F) was used as a preflash for N₂. The net power reported (NP) did not account for cooling tower and reinjection power losses nor fluid recovery losses. Power values based on estimates of these losses provided by EG&G are also shown in Table III. Results for the corresponding simple Rankine cycles are given in Table IV for purposes of comparison.

Additional calculations were studied to check the cases for other system configurations. Currently, some triple-boiling solutions are being studied to determine if optimum use can be made of the EG&G triple boiler.

a. D. S. Cook was the student assistant on this portion of the project.

TABLE III^a

POWER VALUES BASED ON LOSS ESTIMATES

Fluid	$\dot{m}F \times 10^{-5}$	T_{exit}	GP ^b	NP1 ^c	NP2 ^d	NP3 ^e
Pentane	2.93	64	5.23	5.16	3.96	3.76
Isobutane	3.86	58	5.90	5.43	4.23	4.03

a. All cases assume

- (1) Working fluid heat exchange occurs with 5°F pinch point
- (2) Geo-fluid flow rate = 4.55×10^5 kg/hr (10^6 lb/hr)
- (3) Well temperature = 143°C (289.4°F)
- (4) Condenser temperature = 26.7°C (80°F)
- (5) Cooling water enters at 65°F, rises 10°F, with 5°F pinch point.

b. GP = Gross power.

c. NP1 = Gross power minus cycle pump work and geo-fluid boost pump work.

d. NP2 = NP1-1.1 MW for cooling tower and 0.1MW for reinjection pumping.

e. NP3 = NP2-0.2 MW for fluid recovery.

4.2 Boiler Design Studies^a

Work continued on the homogeneous nucleation concepts discussed in the last report¹. Both experimental and numerical studies have been performed and are reported in Reference 2. An extremely pertinent result of this work is that evaporation rates predicted from analytical models that hypothesize very efficient heat transfer (evaporation without an external vapor film resistance) underpredict observed heat transfer. While more insights may be gained into this difference, the present observation underlines the effectiveness of direct-contact boiling.

From this work, a straightforward procedure was developed for analyzing surface-boiling direct contact heat exchangers. Application of this method will make it possible to directly

- (1) Compare potential systems by providing an insight in the strength of the individual variables
- (2) Design a heat exchanger for a specific application
- (3) Evaluate its performance.

The key to the method is the availability of a single algebraic equation representing the lens evaporation rate. This equation was derived using the technique of dimensional analysis; the constants were determined by applying the previously developed numerical model.

a. C. A. Kodres was the research assistant on this project.

TABLE IV^a

POWER VALUES OF RANKINE CYCLES

<u>2nd Fluid</u>	$\dot{m} \times 10^{-5}$ <u>2nd Fluid</u>	$\dot{m} \times 10^{-5}$ <u>1st Fluid</u>	<u>T_{exit}</u>	<u>GP^b</u>	<u>NP1^c</u>	<u>NP2^d</u>	<u>NP3^e</u>	
Pentane With Bottoming Cycle In Series								
	<u>kg/hr</u>	<u>kg/hr</u>	<u>°C</u>	<u>MW</u>	<u>MW</u>			
Hex	1.35	1.57	57	6.52	6.41	5.21	5.01	
F114	4.83	1.84	50	6.06	5.94	4.74	4.54	
Isop	1.63	1.84	52	6.02	5.92	4.72	4.52	
Pent	1.52	1.84	52	6.00	5.91	4.91	4.51	
Isob	1.87	1.84	51	6.03	5.90	4.70	4.50	
F12	4.87	1.84	51	6.11	5.84	4.64	4.44	
Isobutane With Bottoming Cycle In Series								
Hex	0.88	3.08	49	6.79	6.15	4.95	4.75	
F114	3.23	3.08	48	6.57	5.91	4.71	4.51	
F12	3.19	3.08	48	6.59	5.90	4.70	4.50	
Isop	1.10	3.08	49	6.54	5.90	4.70	4.50	
Pent	1.29	3.08	43	6.50	5.89	4.69	4.49	
Isob	1.22	3.33	44	6.48	5.88	4.68	4.48	
<u>2nd Fluid</u>	$\dot{m} \times 10^{-5}$ <u>2nd Fluid</u>	$\dot{m} \times 10^{-5}$ <u>1st Fluid</u>	$\dot{m} \times 10^{-5}$ <u>brine, 2nd</u>	<u>T_{exit}</u>	<u>GP^b</u>	<u>NP1^c</u>	<u>NP2^d</u>	<u>NP3^e</u>
Penetane with split cycle								
Hex	0.98	1.57	3.36	71	6.72	6.56	5.36	5.16
F114	4.68	1.57	3.36	58	6.40	6.18	4.98	4.78
Isop	1.41	1.84	3.08	58	6.30	6.14	4.94	4.74
Isob	1.67	1.84	3.08	57	6.34	6.11	4.91	4.71
Pent	1.31	1.84	3.08	59	6.27	6.11	4.91	4.71
F12	5.04	1.57	3.36	58	6.53	6.08	4.88	4.68

TABLE IV^a (continued)

2nd Fluid	$\dot{m} \times 10^{-5}$ 2nd Fluid	$\dot{m} \times 10^{-5}$ 1st Fluid	$\dot{m} \times 10^{-5}$ brine, 2nd	T_{exit}	GP ^b	NP1 ^c	NP2 ^d	NP3 ^e
Isobutane with split cycle								
Hex	0.68	2.49	2.33	76	7.10	6.16	4.96	4.76
F12	5.40	1.82	2.92	62	7.15	6.00	4.80	4.60
F114	4.25	2.19	2.58	59	6.92	5.93	4.73	4.53
Isob	1.69	2.19	2.58	60	6.92	5.90	4.70	4.50
Isop	1.23	2.49	2.33	61	6.58	5.89	4.69	4.49
Pent	1.02	2.78	2.10	57	6.80	5.86	4.66	4.46

a. All cases assume

- (1) Working fluid heat exchange occurs with 5°F pinch point
- (2) Geo-fluid flow rate = 4.55×10^5 kg/hr (10^6 lb/hr)
- (3) Well temperature = 143°C (289.4°F)
- (4) Condenser temperature = 26.7°C (80°F)
- (5) Cooling water enters at 65°F, rises 10°F, with 5°F pinch point.

b. GP = Gross power.

c. NP1 = Gross power minus cycle pump work and geo-fluid boost pump work.

d. NP2 = NP1-1 MW for cooling tower and 0.1 MW for reinjection pumping.

e. NP3 = NP2-0.2 MW for fluid recovery.

Using available Raft River and East Mesa data for comparisons the accuracy of this design procedure was estimated to be about 16. (Values ranged from 8 to 21% underprediction.)

4.3 Preheater Studies^a

Direct contact column preheater studies described in the previous semiannual report¹ have been completed. Comparisons have been made to the experimental results from a variety of other studies including Woodward³, DSS Engineers⁴, and Garwin and Smith⁵. A plot of this comparison is shown in Figure 4, where the University data are represented by the solid lines. A correlation of the University data has been developed as:

$$U_v = 2.2 = 10^5 (\phi < 0.05)$$

and

$$U_v = 9.4 = 10^5 (\phi - 0.05)e^{-0.75R} + 1.1 \times 10^4 \phi > 0.05$$

a. The student assistant for this work was S. B. Plass.

Fig. 4 Direct-contact column preheater comparisons.

where

U_v = volumetric heat transfer coefficient^a, Watt/m³ °C

ϕ = hold up

R = volumetric flow ratio, dispersed to continuous.

The predictive method for exit temperatures developed by Letan⁶ was compared to the present work. This comparison is shown in Figure 5. Letan's method is shown to predict this aspect of performance quite well. A paper on this work will appear shortly⁷.

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Fig. 5 Comparison of exit temperatures developed by Letan to present work.

4.4 Condenser Studies

Condenser studies were continued for both packed bed and collapsing bubble type condensers. Additional experiments as well as numerical calculations were performed.

Collapsing Bubble Studies. The collapsing bubble studies were primarily aimed at the influence of noncondensibles. A series of experiments dealing with different sized bubbles with noncondensibles present were performed. It was shown that the bubble collapse was predictable by a non-uniform diffusion governed model when the bubbles were initially small (retained their spherical shape) ~ 4 mm in diameter or less. For bubbles of larger initial diameter the data follow a model for uniform distribution of non-

a. Total heat transfer divided by the product of the volume of the column and log mean temperature difference.

condensibles. In general, the uniformly distributed model predicts faster collapse. Thus, an optimization based on fluid properties and amounts of noncondensable gases present is required in order to predict the best bubble size for this type of condenser.

Packed Bed Condensers. Experimental studies continued this reporting period. However, all data appear to be correlated within ± 15 by the following expression for the nondimensional heat transfer which is changed from that predicted by earlier experiments

$$St^a = 0.40 Ja C^{-0.21} H^{-0.67}$$

where

$$St^a = \frac{\bar{h} a}{\rho_v C_{p_v} U a_w}$$

$$Ja = \frac{h_{fg}}{C_{p_v} (T_{sat} - T_{avg})}$$

$$C = (mC_p)_L / (mC_p)_v$$

$$H = Z/d$$

$$Z = \text{bed height}$$

$$d = \text{packing size}$$

$$C_p = \text{specific heat}$$

$$\rho = \text{density}$$

$$a = \text{surface area per unit volume}$$

$$a_w = \text{wetted surface area per unit volume}$$

$$T = \text{temperature}$$

$$sat = \text{saturation}$$

$$U = \text{superficial vapor velocity}$$

$$\bar{h} = \text{heat transfer coefficient based on surface area}$$

$$v = \text{vapor properties}$$

$$L = \text{liquid coolant properties.}$$

-
- a. Total heat transfer divided by the product of the volume of the column and log mean temperature difference.

IV. ENVIRONMENTAL CONSIDERATIONS

(S. G. Spencer)

Researchers continued to monitor the Raft River environment during the last six months, studying air quality, meteorology, water quality, hydrology, and terrestrial and aquatic ecology. They also conducted special research studies and neared completion on the Snake River Basin environmental overview project. This section will briefly discuss the progress of these special studies, but the details are presented in the annual environmental report.

A review of the 1978 ferruginous hawk disturbance study was held in March with representatives from interested state and federal agencies, DOE, and EG&G in attendance. At that time, plans were finalized for the 1979 study. Field observations are scheduled to begin in April.

The aquatic characterization survey of the Raft River began in March and will continue for approximately one year. The species identification of the invertebrate organisms is not complete; however, mayflies, oligochaetes, and several other species were collected from the three sampling stations. Substrate types and community structure will be examined and subjected to cluster analysis to assess seasonal trends in the faunal stream populations. The substrate types were found to vary greatly in the river in the vicinity of the geothermal withdrawal; many areas are characterized by erosion habitat. The fish populations will be evaluated with respect to species diversity, habitat utilization, and population density. A mark-recapture technique will be utilized throughout the summer and fall to assess population density.

Sixteen shallow and intermediate depth wells were monitored during the 21-day injection test on RRG-6. Preliminary results from the test, which was completed on April 10, 1979, are shown in Figure 6. Monitor well, MW-4, a 305-m deep well, 820 m to the west of RRG-6, showed marked response to the injection. The water level rise in MW-4, corrected for background changes, averaged 0.4 m per week during the period of injection. No response has yet been seen in shallower wells. Monitoring of pressure response and changes in water quality will continue during the long-term injection tests this summer.

Fig. 6 Preliminary results of shallow and intermediate depth wells.

V. REGIONAL PLANNING

(J. A. Hanny)

During this period, baseline data documents were developed and draft copies were issued for Colorado, Idaho, New Mexico, and Nevada. These documents are designed to describe the present status of geothermal development in each state. They serve to provide the reader with information about who is involved in geothermal development, what is the present knowledge about the state's geothermal resources, what commercialization activities have taken place, what development plans have been made, what is the extent of government assisted activities, what is the present energy use and what is the legal and institutional climate for geothermal development. These documents, which are updated semiannually, will serve as a measuring stick to evaluate the growth of geothermal development.

A draft Regional Hydrothermal Market Penetration Analysis was issued early in this period. This report outlines the results of a survey of the potential electric and direct-heat applications of hydrothermal energy in the ten state Rocky Mountain Basin and Range (RMB&R) Region: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota, South Dakota, Utah, and Wyoming. The report provides a summary of the market analysis and will be used as a guide in the future preparation of the comprehensive DOE implementation plan to accomplish the desired accelerated commercialization of hydrothermal energy.

Regional planning includes program coordination, policy development, and state commercialization planning and outreach. The intent is to: (a) provide for program development, coordination, reporting and information dissemination, as well as for schedule, fiscal, planning, and work change control; (b) identify and resolve regulatory, legal, economic, and other institutional restraints that impede the use of geothermal energy; and (c) prepare state geothermal commercialization plans to perform outreach functions with potential users.

The market analysis survey revealed that all ten states have potential economic hydrothermal resources. Most of these resources are found in the more industrialized areas with higher population concentrations.

The current hydrothermal market potential for direct-heat applications in the region is 0.4 quads. The market potential for direct heat will be 5 to 6 quads by the year 2020. It is estimated that the hydrothermal energy market capture is 0.2 quads in 1985 and increases to 2.5 quads in the year 2000.

At present, the major direct heat markets are residential and commercial space conditioning and industrial process heat applications. The industrial market sector has the greater potential for near penetration. A major barrier to direct heat market penetrations is lack of an infrastructure.

1. BASELINE MARKET ESTIMATE AND GROWTH FORECASTS

The research considered only counties colocated with hydrothermal resources. Residential and commercial energy use was established only for space conditioning and water heating purposes. The industrial energy use was determined to be in the 40 to 60°C range for process heat.

The national industrial growth rates were applied to counties in the study. Several assumptions were made concerning the growth of these counties: (a) an annual increase of 3% per capita consumption, (b) a 5% increase of new industry spin-off by 1985, and (c) a 4% per year regional population growth (1.4 times the national average).

A major portion of the research effort was devoted to estimating the size of the current and potential future market. Figure 7 summarizes the regional energy consumption and projects the anticipated hydrothermal market capture.

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Fig. 7 Regional energy consumption of hydrothermal market.

The study revealed that most of the region's residential and industrial energy use sectors are fortunately largely colocated with hydrothermal resources. Figure 8 shows the counties in the region which have been evaluated, and indicates the resource/user match for direct-heat applications. Table V lists the forty "best match" counties of the region, wherein the user and the resource match and suitable resource temperatures are available.

High temperature hydrothermal systems are widespread in the region, but are far less numerous than the low and moderate temperature systems. These low and moderate temperature geothermal waters are most useful for direct applications and form a very sizeable resource base whose exploration has hardly begun. Table VI summarizes the availability, quality, and other considerations of this resource.

For electric generation from hydrothermal resources, the following major determinations were made.

- (1) More than 25 of the additional electrical energy required in the region by 2020 could be supplied by hydrothermal resources.
- (2) Advanced technology for utilization of 150°C for electric power generation must be available by the late 1980's to provide a substantial portion of the regional needs beyond the year 2000.
- (3) Resources suitable for electric power generation appear to be abundant in the region, but a major near-term reservoir confirmation effort is required to allow substantial commercial development by the year 2000.
- (4) Electric power grid systems are colocated with potential hydrothermal sites, but some upgrading may be required.

The methodology and assumptions used to develop these determinations are as follows for the Baseline Regional Electric Power Market Estimate:

- (1) Considered the McGraw-Hill annual electric industry survey data
- (2) Considered the McGraw-Hill (electrical world) forecast of new power-on-line through 1990
- (3) Assumed linear extrapolation, 1990 to year 2020.

V. MARKET OVERVIEW — DIRECT HEAT

COUNTIES WITH DIRECT HEAT RESOURCES CO-LOCATED WITH POTENTIAL USERS

Fig. 8 Resource/user match for direct-heat applications.

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TABLE V

40 "BEST MATCH" COUNTIES OF THE REGION

Country/State	1975 Industry Use ^a	1975 Residential/Commercial Use ^a	1975 Potential Use ^a
Maricopa, Arizona	17.12	29.90	47.02
Salt Lake, Utah	8.50	20.80	29.30
Clark, Nevada	3.75	13.95	17.70
Utah, Utah	2.13	11.00	13.13
Pima, Arizona	2.57	10.15	12.72
Weber, Utah	3.34	9.20	12.54
Bernalillo, New Mexico	1.63	10.80	12.43
Boulder, Colorado	3.48	8.60	12.08
Davis, Utah	0.68	10.90	11.58
Washoe, Nevada	1.78	9.20	10.98
Ada, Idaho	1.56	9.00	10.56
Bonneville, Idaho	3.97	2.80	6.77
Cassia, Idaho	5.30	0.60	5.90
Canyon, Idaho	5.64	2.50	5.89
Natrona, Wyoming	0.14	5.55	5.69
Twin Falls, Idaho	3.35	1.80	5.15
Pennington, South Dakota	1.04	4.10	5.14
Cache, Utah	1.94	2.90	4.84
Minidoka, Idaho	3.73	0.45	4.18
Ward, North Dakota	0.25	3.52	3.77
Bannock, Idaho	0.43	3.20	3.63
Bingham, Idaho	2.09	1.40	3.49
Missoula, Montana	0.31	3.10	3.41
Bighorn, Wyoming	0.51	2.25	2.76
Lewis & Clark, Montana	0.34	2.40	2.74
Sanpete, Utah	1.87	0.69	2.56
Fremont, Wyoming	0.09	2.25	2.34
Dona Ana, New Mexico	0.33	1.75	2.08
Carbon, Wyoming	0.05	2.00	2.05
Santa Fe, New Mexico	0.20	1.75	1.95
Power, Idaho	1.40	0.36	1.76
North Dakota	0.17	1.49	1.66
Lincoln, Wyoming	0.18	1.48	1.66
Stark, North Dakota	0.12	1.48	1.60
Jefferson, Idaho	1.30	0.18	1.48

TABLE V (continued)

<u>Country/State</u>	<u>1975 Industry Use^a</u>	<u>1975 Residential/Commercial Use^a</u>	<u>1975 Potential Use^a</u>
Conconino, Arizona	0.28	0.98	1.26
Hughes, South Dakota	0.32	0.90	1.22
Fremont, Colorado	0.12	1.00	1.12
Converse, Wyoming	0.08	0.99	1.07
Laplata, Colorado	0.08	0.88	1.04

a. (Btu/yr x 10¹²).

TABLE VI

DIRECT HEAT - RESOURCE OVERVIEW

AVAILABILITY

- Resources are available in all ten states.
- Almost all of the larger population centers in the region have some resources in their vicinity.
- As the number of resource occurrences increase, the resource temperatures decrease.
- A reservoir confirmation program is required.

QUALITY

- Often potable, but a wide range of scale/corrosion potential may be encountered.
- Temperatures are suited to many process applications and to space conditioning.

OTHER CONSIDERATIONS

- Transportation cost is a significant economic factor.
- A commercialization infrastructure needs to be established.
- Current technology is adequate for initiating commercial use.
- New technologies are needed for full market penetrations.

VI. DEMONSTRATION PROJECTS

(E. G. DiBello, F. W. Childs, J. A. Strawn)

The Commercialization Support Branch of EG&G Idaho's Geothermal Program provides technical assistance to the Department of Energy (DOE) for the Program Opportunity Notice (PON) program. The PON program was instituted to hasten the commercialization of the direct application of geothermal energy. Project costs are shared between DOE and the private companies, municipalities, or organizations that are conducting each demonstration. EG&G Idaho continued program management and technical support for the six projects in progress during this period.

1. ONTARIO, OREGON

Ontario, Oregon is located 92 kilometers (57 miles) northwest of Boise, Idaho. The Ontario Ore-Ida Foods, Inc. plant processes potatoes, corn, and onions and is currently dependent on natural gas and oil for process heat. This demonstration project will substitute geothermal energy for the potato-processing heat and space heat, and the system will supply hot potable water. Heat loads now amount to about 97 200 megawatt-hours annually (33.2×10^{10} British thermal units per year). The predicted resource is 50 liters per second (800 gallons per minute) at 160°C (320°F) from two production wells. A central group of 11 heat exchangers and one injection well is planned.

The Ore-Ida environmental report was reviewed and approved by DOE. Neither an environmental assessment nor an environmental impact statement was required. Ore-Ida completed reviews of available geological and geophysical data, and conducted active seismic measurements. Primary and secondary drilling sites were selected and drilling permits, bonds, insurance, etc., were obtained. Requests for bids for the drilling of one well, with options for three wells, are currently being advertised.

2. MONROE CITY, UTAH

Monroe City is a community of 1,500 people, 257 kilometers (160 miles) south of Salt Lake City, Utah. The local economy is based primarily on agriculture. The project will entail the drilling of one production and one injection well, and installing a district heating system. Geothermal fluid from the production well will be piped through a central heat exchanger, and then to the injection well. The expected production temperature is 75°C (165°F), with a design flow of 64 liters per second (1,000 gallons per minute). The system will initially heat the South Sevier High School, the Monroe City Hall, and the fire station, and it could later be expanded to include the major areas of Monroe. The total system will be capable of a load of 5000 kilowatts.

The Monroe City Environmental Report was reviewed and approved by DOE. Neither an environmental assessment nor an environmental impact statement was required.

Two test holes (MC.1 and MC.2), drilled by the University of Utah under the State-Coupled Program, influenced the design. The test holes changed the predicted resource characteristics from the original 121°C (250°F) determined from geochemistry, and a design flow of 32 liters per second (500 gallons per minute), to a demonstrated 75°C (165°F) with a corresponding design flow of 64 liters per second (1000 gallons per minute). The production well site was selected, the land was leased, and the 450-meter (1500 feet) production well (MC.3) was completed. An artesian flow of 11 liters per second (177 gallons per minute), at 73°C (163°F) has been demonstrated. Energy monitoring was started at a nearby spring and at the South Sevier High School.

3. PHILIP, SOUTH DAKOTA

The town of Philip is located approximately 129 kilometers (80 miles) east of Rapid City, South Dakota. Five buildings in the school complex will be retrofitted to use geothermal energy for space heating. The scope of the project involves the drilling of a well into the Madison Aquifer and the conversion of the present steam and electrical heating systems to hot-water systems. Instrumentation will be installed to monitor system performance and to provide data for other potential users. The environmental report was submitted and approved by DOE. A 1300-meter (4,266 feet) well was drilled and flow tested. The well is capable of sustaining a long-term artesian flow rate of 19 liters per second (300 gallons per minute), while maintaining sufficient wellhead pressure. The flowing temperature of the resource is 70°C (157°F). Corrosion testing has been initiated and a preliminary design review will be conducted in April 1979.

4. PIERRE, SOUTH DAKOTA

St. Mary's Hospital and Capital Lake Plaza, located in Pierre, South Dakota, are currently heated by fossil-fuel systems. This project will demonstrate the feasibility of utilizing low-temperature water from a 666-meter (2,186 feet) Madison well for space heating. The characteristics of the aquifer in this area are not well known. Therefore, the water quality and well production characteristics will be closely monitored after the well is completed. Based upon the water temperatures and quality, heating and ventilating system modifications will be designed and the hospital retrofitted to utilize the geothermal fluid. The Capitol Lake Plaza heating system will also be modified so that hot-water coils can be installed in the existing forced-air ducts. Expansion of the distribution system to other commercial businesses is considered feasible.

The environmental report was completed and approved by DOE. The well drilling phase of the project was also completed, at a cost of approximately \$250,000. As of April 15, 1979, the well is being evaluated to determine pressure, temperature, and flow rate.

5. BOX ELDER, SOUTH DAKOTA

The Douglas High School Demonstration Project, in the city of Box Elder, South Dakota, was originally proposed as a cooperative venture between the Douglas High School, City of Box Elder, and the Department of Energy. Box Elder initiated the drilling of a city water well into the Madison Aquifer in January 1978, prior to the signing of the DOE/Douglas School cooperative agreement. The City consented to heating a portion of the high school, using the 50°C (120°F) geothermal water. However, the well drilling company, under contract to the City of Box Elder, was unable to complete the well to the required depth, due to technical drilling problems. The well was subsequently completed to a shallower, cooler aquifer. DOE then requested that the Douglas School Board submit a proposal to drill a new well. The Board reconsidered their intent to continue with the geothermal demonstration project and voted to terminate the cooperative agreement. Their decision to terminate was based on the following factors: (a) the drilling of a new well was not economically justifiable, (b) the school district did not have the manpower available to effectively manage the project, and (c) the Board did not want to assume responsibility for a well drilling effort.

6. HAAKON COUNTY, SOUTH DAKOTA

Geothermal water from an artesian well that has flowed since 1959 will be used to dry grain and to heat three ranch homes, a shop, an insulated barn, and livestock shelters on the Diamond Ring Ranch in Haakon County, South Dakota. The system retrofit will consist of installing PVC pipelines to connect the wellhead to the various structures requiring heat. After flowing through the central heat exchanger, the geothermal fluid will be used as stock water and then it will be discharged into a reservoir system now used

for both geothermal-well and runoff catchment. The environmental report and the final system design were completed for this project.

During April 1979, bid documents will be prepared and distributed to interested contractors. The construction phase of the project is scheduled for completion prior to the start of the 1979-80 heating season.

7. PON DEMONSTRATION PROJECTS

Technical assistance during contract negotiations was provided to DOE for the seven demonstration projects assigned to the Idaho Operations Office under PON No. EG-78-N-03-2047. The seven projects are as follows:

- (1) Utah Roses, Inc., Sandy, Utah, for conversion of six acres of greenhouses from gas and oil heating to geothermal heating
- (2) Town of Pagosa Springs, Colorado, for a geothermal district heating system, to provide hot water to public buildings and schools, businesses, and homes
- (3) Madison County Energy Commission and Rogers Foods, Inc., Rexburg, Idaho, to use geothermal energy for municipal space heating and industrial food processing
- (4) Montana Energy and MHD Research and Development Institute, Inc., Butte, Montana, to design, construct, and operate a geothermal conversion system for space heating of the Warm Springs State Hospital, Montana
- (5) Chilton Engineering, Elko, Nevada, to demonstrate the direct use of geothermal energy for space and water heating of three commercial buildings in Elko
- (6) Utah Energy Office, Salt Lake City, Utah, to provide space and water heating from the Crystal Hot Springs geothermal resource for the Minimum Security Building at the Utah State Prison
- (7) City of Boise, Idaho, for development of a large-scale-geothermal space heating system for several commercial buildings in the downtown area and homes in the Warm Springs Water District of Boise.

Preliminary environmental report and resource assessment tasks have been initiated on these projects.

VII. REFERENCES

1. G. L. Blake (ed), *Semiannual Progress Report for the Idaho Geothermal Program, April 1 to September 30, 1978*, TREE-1295 (November 1978).
2. C. A. Kodres, H. R. Jacobs, and R. F. Boehm, "Heat Transfer to an Evaporating, Floating, N-Pentane Lens," accepted for presentation at the *ASME/AIChE National Heat Transfer Conference, San Diego, California, August 1979*.
3. T. Woodward, "Heat Transfer in a Spray Column," *Chemical Engineering Progress*, 57, (1961).
4. W. B. Suratt and G. K. Hart, *Study and Testing of Direct Contact Heat Exchangers for Geothermal Brines*, ORO-4893-1 (January 1977).
5. L. Garwin and B. D. Smith, "Liquid-Liquid Spray Tower Operation in Heat Transfer," *Chemical Engineering Progress*, 49, p 591, (1953).
6. R. Letan, "Design of a Particulate Direct Contact Heat Exchanger; Uniform, Countercurrent Flow," *ASME Paper No. 76-HT-27*, *ASME/AIChE National Heat Transfer Conference, St. Louis, Missouri (August 1976)*.
7. S. B. Plass, H. R. Jacobs, and R. F. Boehm, "Operational Characteristics of a Spray Column Type Direct Contact Preheater," accepted for presentation at the *ASME/AIChE National Heat Transfer Conference, San Diego, California (August 1979)*.

APPENDIX A
PUBLICATIONS OF THE IDAHO GEOTHERMAL PROGRAM

THE UNIVERSITY OF CHICAGO

APPENDIX A

PUBLICATIONS OF THE IDAHO GEOTHERMAL PROGRAM

The following tables list reports and brochures published by employees of the Idaho Geothermal Program. Copies of external reports are on file at the INEL Technical Library, 457 Broadway, Idaho Falls, Idaho 83401. External reports (and additional copies of this progress report) can be ordered from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161. Obtain brochures by writing R. Ihrig, EG&G Idaho, Inc., Box 1625, Idaho Falls, Idaho 83401, or by calling 208-526-9212. Internal reports are available only to employees of EG&G Idaho, Inc.

A future progress report will contain a list of journal and magazine articles, as well as a list of presentation papers, that have been written by program personnel.

TABLE A-I

EG&G IDAHO, INC.: EXTERNAL REPORT

<u>TREE Number</u>	<u>Author</u>	<u>Date</u>	<u>Title</u>
1008	J. F. Kunze, ed.	10-76	Geothermal R&D Project Report for Period April 1, 1976 to June 30, 1976
1016	J. F. Kunze	1-77	The Potential for Utilizing Geothermal Energy for Space Heating in Reconstructed Sugar City, Idaho
1023	D. T. Neil	11-76	Geothermal Shell and Tube Heat Exchanger Augmentation
1030	J. F. Kunze	12-76	Geothermal R&D Project Report for Period July 1, 1976 to September 30, 1976
1039	I. J. Ingvarsson, et al	12-76	Determination of the 5-MW Gross Nominal Design Case Binary Cycle for Power Generation at Raft River, Idaho
1048	R. C. Schmitt, et al	1-77	Beneficial Uses of Geothermal Energy Description and Preliminary Results for Phase I of the Raft River Irrigation Experiment
1085	W. C. Kettenacker	3-77	Two-Dimensional Simulation of the Raft River Geothermal Reservoir and Wells
1108	I. J. Ingvarsson, et al	4-77	Working Fluid and Cycle Selection Criteria for Binary Geothermal Power Plants with Resource Temperatures in the Range of 220°F to 400°F

TABLE A-I (continued)

<u>TREE Number</u>	<u>Author</u>	<u>Date</u>	<u>Title</u>
1114	J. F. Kunze, et al	4-77	Asbestos-Cement Pipeline Experiment at the Raft River Geothermal Project
1134	J. F. Kunze	5-77	Geothermal R&D Project Report for Period October 1, 1976 to March 31, 1977
1135	A. S. Richardson, et al	5-77	Energy Oriented Study of Fluidized Bed System
1162	L. L. Mink, et al	10-77	Geothermal Potential of the West Boise Area
1164	C. J. Shaffer	8-77	Floating Power Optimization Studies for the Cooling System of a Geothermal Power Plant
1176	R. L. Miller	10-77	Results of Short-Term Corrosion Evaluation Test at Raft River
1182	I. A. Engen	2-78	Residential Space Heating Cost: Geothermal vs Conventional Systems
1256	J. F. Kunze	3-78	Geothermal R&D Project Report for Period April 1, 1977 to September 30, 1978
1278	G. L. Blake, ed.	7-78	Semiannual Progress Report for the Idaho Geothermal Program, October 1, 1977 to March 31, 1978
1312	J. F. Whitbeck, et al	1-79	Measurement and Control Techniques in Geothermal Power Plants

TABLE A-I (continued)

<u>TREE Number</u>	<u>Author</u>	<u>Date</u>	<u>Title</u>
1362	N. E. Stanley	3-79	Effects of Irrigation with Raft River Geothermal Aquifer Three-Year Summary Report
1340	Susan G. Spencer, et al	4-79	1978 Annual Report, INEL Geothermal Environmental Program

TABLE A-II

EG&G IDAHO, INC.: INTERNAL REPORTS

<u>GP Number</u>	<u>Author</u>	<u>Date</u>	<u>Title</u>
101	D. L. Larson	7-77	Evaluation or ERDA Loan Guarantee
102	D. L. Larson, et al	8-77	Evaluation of ERDA Loan Guarantee; Applications for CUI Venture
103	S. G. Spencer	8-77	Withdrawal of Loans for Federal Geothermal Development in the Raft River Valley
104	J. F. Kunze, et al	8-77	August Monthly Report
105	S. M. Prestwich	8-77	Raft River Well Cost Summary
106	S. M. Prestwich	8-77	Drilling and Completion Report, Raft River Geothermal Injection Well Number 4
107	J. F. Kunze, et al	9-77	LPAD-I-255-459-475
108	J. F. Kunze, et. al.	9-77	LPAD 430, Reservoir Engineering
109	J. F. Kunze, et al	9-77	LPAD 322, Second Generation Heat Exchangers
110	J. F. Kunze, et al	9-77	LPAD 255 and 459, Moderate Temperature Hydrothermal
111	J. F. Kunze, et al	9-77	LPAD 571 and 461, Environmental
112	J. F. Kunze, et al	9-77	LPAD 315, Nonelectric
113	J. F. Kunze, et al	9-77	September Monthly Report
114	J. F. Kunze, et al	10-77	October Monthly Report

TABLE A-II (continued)

GP Number	Author	Date	Title
115	R. L. Miller	10-77	Materials Testing Plan and Schedules for the Raft River Geothermal Logs Facility
116	S. G. Spencer	11-77	Snake River Plain Work Statement
117	S. G. Spencer	11-77	Environmental LPAD
118	J. G. Keller	11-77	Heat Pumps Primer for use with Low-Temperature Geothermal Resources
119	J. F. Kunze, et al	11-77	November Monthly Report
120	S. G. Spencer, J. F. Sullivan	12-77	Environmental Report, Raft River Geothermal Power Plant
121	S. G. Spencer	12-77	Environmental Report, Raft River Injection Monitor Well System
122	W. D. Gertsch	12-77	Preliminary Assessment on the Development of Geothermal Energy at Hill Air Force Base
123	J. F. Kunze, et al	12-77	December Monthly Report
124	J. H. Ramsthaler, et al	1-78	Management Plan for Fluid Supply and Injection System
125	S. G. Spencer	12-77	Environmental Assessment, Raft River Geothermal Injection Well (RRGI-6) and Transfer Pipeline
126	S. G. Spencer	1-78	Environmental Assessment, Raft River Geothermal Injection Well (RRGI-7) and Transfer Pipeline

TABLE A-II (continued)

<u>GP Number</u>	<u>Author</u>	<u>Date</u>	<u>Title</u>
127	F. B. Simpson	1-78	January Monthly Report
128	S. G. Spencer	9-77	Environmental Assessment, Raft River Geothermal Production Well (RRGP-5) and Associated Development
129	G. L. Mines	2-78	INEL Interim Evaluation of RGI East Mesa Project
130	J. J. Lofthouse	2-78	Raft River Geothermal Site Safety Assessment Document
131	F. B. Simpson	2-78	February Monthly Report
132	F. B. Simpson	3-78	March Monthly Report
133	J. F. Sullivan	4-78	Monitor Well Plan
134	F. B. Simpson	4-78	April Monthly Report
135	J. F. Whitbeck	5-78	Draft Proposal for Geothermal Cycle Working Fluid Properties Research
136	S. G. Spencer, J. F. Sullivan	5-78	Environmental Assessment, Geophysical Core Hole Drilling
137	S. G. Spencer	5-78	Environmental Assessment, Sugar City, Idaho
138	G. L. Mines	5-78	INEL Initial Evaluation of the Current Status of RGI East Mesa Project
139	F. B. Simpson	5-78	May Monthly Report (Subsequent monthly reports have not been cataloged as formal reports)

TABLE A-II (continued)

<u>GP Number</u>	<u>Author</u>	<u>Date</u>	<u>Title</u>
140	C. J. Bliem	6-78	INEL Initial Evaluation of the MAPCO/RGI GLGP Application for Westmoreland Geothermal Project
141	O. J. Demuth	8-78	Preconceptual Design Study for the Second Raft River 5-MW (gross) Dual Boiling Direct Contact Pilot Plant
142	E. G. DiBello	8-78	Technical Evaluation for Honey Lake Hydroponic Loan Guaranty Application
001	S. G. Spencer, J. F. Sullivan	11-78	Environmental Assessment INEL-1 Exploratory Well, Butte County, Idaho
002	Brown, et al	12-78	Water Compatibility Test Conducted on the Geothermal Wells at the Raft River Site
004	D. W. Allman, et al	2-79	Results at RRG1-6 during January 1979 Injection from RRGE-2
005	R. E. McAtee, et al	4-79	Chemical Logging of Geothermal Wells

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