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Semiannual Progress Report for the Idaho Geothermal Program April 1 to September 30, 1979

R. R. Ihrig, Ed.

March 1980

Prepared for the
U.S. Department of Energy
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SEMIANNUAL PROGRESS REPORT FOR THE IDAHO GEOTHERMAL PROGRAM APRIL 1 TO SEPTEMBER 30, 1979

R. R. Ihrig, Ed.

Published March 1980

**EG&G Idaho, Inc.
Idaho Falls, Idaho 83415**

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ABSTRACT

This report discusses progress made by the Idaho Geothermal Program between March 31 and September 30, 1979. It summarizes geothermal well tests at the Raft River geothermal site, reports on facility construction, and describes the first hydraulic fracture treatment of a geothermal well. The results of direct applications experiments are described briefly, including experiments in aquaculture, agriculture, fluidized bed space heating, fluidized bed food drying, essential oil extraction, and geothermal assisted conversion of biomass to ethanol. The report discusses improvements to the binary cycle prototype power plant at Raft River, construction progress on the 5-MW pilot plant, and experimental work on direct contact heat exchangers. Also outlined is

progress on environmental studies at Raft River, including a brief discussion of socioeconomic impacts of geothermal development on Cassia County, Idaho. Results are presented of a 48-industry survey conducted to determine industry's views of the technology barriers to accelerating hydrothermal energy commercialization. A projection summarizes the capital and manpower needed through 1987 to place 6800 MW of direct applications development on-line. Progress reports are also included on DOE's Program Opportunity Notice (PON) Program demonstration projects and DOE's Program Research and Development Announcement (PRDA) Program study projects.

CONTENTS

ABSTRACT	ii
SUMMARY	vi
RAFT RIVER FACILITY AND RESOURCES	1
Summary of Raft River Geothermal Wells	1
RRGE-2 to RRGI-6 Test	1
RRGP-5 to RRGI-6 Test	1
RRGE-2 to RRGI-7 Test	1
Summary of Additional Borehole Geophysics	4
Well Stimulation Program	4
RAFT RIVER CASE STUDY	5
DIRECT APPLICATIONS	6
Aquaculture	6
Agriculture	8
Components and System Development	9
Fluidized Bed Space Heater Experiment	9
Fluidized Bed Dryer Experiment	10
Essential Oil Experiment	14
Geothermal Assisted Biomass Conversion	15
ELECTRIC APPLICATIONS	17
Prototype Power Plant	17
Five-Megawatt Pilot Plant	17
Support Engineering	18
Water Treatment Program	19
DIRECT CONTACT HEAT EXCHANGERS	21
System Studies	21
Direct Contactors	21
Direct Contact Condenser Studies	21
Heat Transfer Augmentation Comparisons	22
Contribution to Geothermal Sourcebook	22
ENVIRONMENTAL CONSIDERATIONS	23

Aquatics	23
Raptors	23
Mammals and Songbirds	25
Flora and Soils	25
Socioeconomics	25
Monitor Wells	26
Continuing Environmental Monitoring Programs	26
ENERGY TECHNOLOGY REQUIREMENTS TO ACCELERATE HYDROTHERMAL ENERGY COMMERCIALIZATION	27
NATIONAL GEOTHERMAL DIRECT HEAT APPLICATIONS MANPOWER AND EXPENDITURE REQUIREMENTS THROUGH FY 1987	35
PON AND PRDA PROJECTS	37
PON Projects	37
Ore-Ida Foods, Inc., Ontario, Oregon	37
Monroe City, Utah	37
Haakon School District, Philip, South Dakota	37
St. Mary's Hospital, Pierre, South Dakota	38
Diamond Ring Ranch, Haakon County, South Dakota	38
Elko, Nevada	38
Warm Springs State Mental Hospital, Montana	38
Pagosa Springs, Colorado	38
Utah Roses, Sandy, Utah	39
Utah State Prison, Draper, Utah	39
Madison County, Idaho	39
Boise, Idaho	39
PRDA Projects	40
APPENDIX A—PUBLICATIONS OF THE IDAHO GEOTHERMAL PROGRAM	43

FIGURES

1. Location of Raft River geothermal site	2
2. Location of Raft River wells	3
3. Effect of various diets on growth rate of carp cultured in Raft River geothermal water	7
4. Effect of various diets on growth rate of channel catfish cultured in Raft River geothermal water	8
5. Fluidized bed space heater	9

6.	Fluidized bed space heater output at various geothermal water and air flow rates, and at different bed particle sizes	11
7.	Fluidized bed space heater overall heat transfer coefficients at various geothermal water and air flow rates, with and without fluidized bed, and at different bed particle sizes	12
8.	Fluidized bed experimental dryer	13
9.	Small-scale geothermal assisted biomass-to-ethanol pilot plant schemetic	15
10.	Raft River 5-MW(e) pilot power plant generator output under summer conditions and design heat exchanger fouling conditions	19
11.	Random-order list of technology requirements to accelerate hydrothermal energy commercialization, as presented to industry for prioritization	28
12.	Top five technology requirements to accelerate hydrothermal energy commercialization, as viewed by five different industries	30
13.	Top ten technology requirements to accelerate hydrothermal energy commercialization, as viewed by five different industries	31
14.	Top five technology requirements to accelerate hydrothermal energy commercialization, as viewed by electric and direct heat industries	32
15.	Top ten technology requirements to accelerate hydrothermal energy commercialization, as viewed by the electric and direct heat industries	33
16.	Projected national expenditures through FY 1987 for direct heat applications development	36
17.	Projected national manpower needs through FY 1987 for direct heat applications development	36

TABLES

1.	Type and Results of Perturbation Imposed on Treatment Nests	24
2.	Distribution of the Number of Young Fledged Per Nest	25
3.	Ranking Summary of All Industries Sampled	29
4.	Assumed Direct-Heat Project Cost and Time Values	35
A-1.	EG&G Idaho, Inc.: Formal Reports	45

SUMMARY

The objective of EG&G Idaho's Geothermal Program is to develop, demonstrate, and encourage the beneficial uses of hydrothermal energy.

At Raft River, geothermal well testing continued—data from RRG1-3 tests were reevaluated, and recent test data from wells RRGE-2, RRGP-5, and RRG1-6 were analyzed. The RRGE-2 to RRG1-7 test was completed. The Raft River wells were logged to obtain additional information on borehole geophysics and well condition. In August, EG&G supported the world's first hydraulic fracture treatment of a geothermal well by treating RRGP-4 by a dentritic fracture process.

The Raft River Case Study was funded in FY-79 to develop an understanding of similar hydrothermal systems. This is a cooperative effort of EG&G and the U.S. Geological Survey. When sufficient data have been gathered, a joint report will be published, probably in FY-80.

Experiments in direct applications produced promising results in aquaculture, agriculture, fluidized-bed space heating, and fluidized-bed food drying. Results of new experiments in essential oil extraction and geothermal assisted biomass-to-ethanol conversion were also encouraging. These experiments have demonstrated, on a small scale, the feasibility of using hydrothermal energy in these applications.

The prototype power plant's plant-control upgrade was completed in May, and a new centrifugal feed pump replaced the problem-prone diaphragm-type pump. Plant operation was turned over to the Raft River field operations group. The direct contact heat exchanger is being constructed, and installation design is underway for the exchanger and the ORNL condenser. The binary cycle operation was stable over a wide range of operating conditions.

Major progress was made on construction of the 5-MW pilot plant and associated structures. The cooling tower is almost complete, permanent electrical wiring is installed, and the supply and injection system thermal loop tie-in is complete. A turbine generator Title II design review was held, and EG&G received bids for building the structure

and underground components. DOE designated EG&G the operational contractor for the 5-MW plant, and operating personnel recruiting began. As part of an engineering support effort, a new, steady-state plant performance model was updated to examine the 5-MW plant's performance. A final report is being prepared. In the water treatment program, several chemical systems and methods were evaluated to determine their practicality in treating spent geothermal fluid for use as cooling tower makeup water. The tests considered environmental standards and scale formation.

Additional useful information and design refinements were obtained by experiments with direct contact heat exchangers at the University of Utah. New studies began in binary cycle power plant layout, including studies of binary cycles and direct contact cycles. In another new area, the performance of binary cycles using surface heat exchangers with augmentation are compared with direct contact cycles. Work on contributions to the Geothermal Sourcebook on direct contact binary geothermal power plants will extend into FY-80 and should be completed in the next reporting period.

Environmental monitoring at Raft River continued in this reporting period, including studies in air quality, meteorology, water quality, hydrology, and terrestrial and aquatic ecology. The socioeconomic environment of Cassia County, Idaho was investigated to determine the effects of geothermal development. Researchers completed preliminary work, and the 1980 continuation of the study will develop more comprehensive impact predictions. Also, plans were made to install a three-station seismic network at Raft River in FY-80 to evaluate induced seismicity.

Forty-eight individuals from five industrial groups prioritized a list of technical barriers to the acceleration of hydrothermal energy commercialization. The results are tabulated in this report. Although the intent of this survey was to learn how industry views technology problems of hydrothermal energy development, several nontechnical barriers were mentioned frequently. These, too, are presented.

Another study projected the capital and manpower costs of placing 6800 MW of direct applications development on-line by 1987. All factors considered, a national expenditure of \$2000/kW, or more than \$20 billion can be expected through 1987.

Twelve demonstration projects in the Program Opportunity Notice (PON) Program made modest progress during the reporting period, two studies in the Program Research and Development Announcement (PRDA) Program were completed, and six PRDA studies are in progress.

SEMIANNUAL PROGRESS REPORT FOR THE IDAHO GEOTHERMAL PROGRAM APRIL 1 TO SEPTEMBER 30, 1979

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 (Figure 1). The Idaho Geothermal Program, sponsored by the Department of Energy (DOE), has conducted field experiments at Raft River since 1973. Scientists and engineers from DOE's Idaho National Engineering Laboratory (INEL) have tested various applications for the valley's medium-temperature (150°C) geothermal fluids.

During the period covered by this report, April 1 through September 30, 1979, crews conducted various testing programs on the geothermal wells as described herein.

Summary of Raft River Geothermal Wells

(D. M. Callan, D. Goldman, K. McCarthy, S. Petty)

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

RRGE-2 to RRGI-6 Test. Production from RRGE-2 and injection into RRGI-6 for 500 hours began on March 20, 1979. The flow/injection test was conducted at a constant rate of 38 l/s. Data not corrected for transient thermal conditions resulted in a Q/s_{10} and maximum drawdown at RRGE-2 of $9.2 \times 10^{-3} \text{ l/s} \cdot \text{kPa}^{-1}$ per log cycle and 1931 kPa, respectively. The uncorrected data for RRGI-6 resulted in a Q/s_{10} and a maximum buildup of $4.4 \times 10^{-1} \text{ l/s} \cdot \text{kPa}^{-1}$ per log cycle and 1600 kPa, respectively. The maximum surface temperature of the discharge from RRGE-2 was 117°C.

RRGP-5 to RRGI-6 Test. Pulse testing by production from RRG-5 and injection into RRGI-6

started on May 10, 1979. Testing was at 52.7 and 44.2 l/s with frequent problems with plugging of strainers at RRGI-6. After pulse testing, a 21-day production/injection test was conducted at 39 l/s. Before corrections for temperature changes, pressure data for RRG-5 showed a Q/s_{10} value of $3.2 \times 10^{-1} \text{ l/s} \cdot \text{kPa}^{-1}$ per log cycle, while RRGI-6 had a Q/s_{10} value of $3.4 \times 10^{-1} \text{ l/s} \cdot \text{kPa}^{-1}$ per log cycle.

After the long-term testing recovery phase, a pulse test was made at 39.8 l/s, again producing from RRG-5 and injecting into RRGI-6. The test started on June 26 and recovery ended June 30, 1979.

The maximum surface temperature of the geothermal fluid produced from RRG-5 was 129°C and the injected fluid temperature at RRGI-6 was 122°C. Maximum drawdown during the 21-day test was 1811 kPa. At the injection well, pressure increased to a maximum of 1911 kPa.

RRGE-2 to RRGI-7 Test. Injection well RRGI-7 was tested by injecting geothermal fluids produced from well RRGE-2 from August 9-15, 1979. The purpose of the test was to evaluate the injection capabilities of RRGI-7 and determine if the injection capacity could be improved by hydraulic fracturing.

Before pulse testing, RRGE-2 artesian-flowed for 3 days at approximately 6.3 l/s into RRGI-7 to establish isothermal borehole conditions. Two constant-rate, variable-head pulse tests were run: one at 47.3 l/s on August 9, and another at 39.1 l/s on August 10. These were followed by a constant-rate, variable-head, long-duration test at 28.4 l/s from August 11-15. There were no problems with well plugging during the test, but well losses, calculated to be 410 kPa, occurred at 300 minutes. No aquifer boundaries were recognized from the data. Thermal effects markedly affected the data but could be corrected

Figure 1. Location of Raft River geothermal site.

Figure 2. Location of Raft River wells.

for. The log mean of the pressure increase during the long-term test was $3.8 \times 10^{-1} \text{ l/s} \cdot \text{kPa}^{-1}$ per log cycle.

One pulse test was stopped after 5 hours, which was 3 hours short of scheduled pulse duration, because line strainers became plugged by debris in the injection line.

The injection capacity of this well is considered to be much greater than originally thought, possibly even exceeding the capacity of RRG-6.

Summary of Additional Borehole Geophysics

The U.S. Geological Survey Water Resource Division Borehole Geophysics section ran non-commercial logs in the Raft River wells. Open-hole acoustic televiwer logs were run in RRG-6, RRG-7, RRG-1, and RRG-4. The fracture data from these logs will be modeled by EG&G Idaho 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, spectral, and flowmeter logs.

A commercial temperature and cement bond log of RRG-1 showed no apparent change in well condition after approximately 4 years of flow.

Well Stimulation Program

(Max R. Dolenc)

The National Well Stimulation Program, managed by Republic Geothermal, Inc. (RGI) and

supported at Raft River by EG&G Idaho, Inc., performed the world's first hydraulic fracture treatment of a geothermal well by treating the RRG-4 well at Raft River. On August 20, 1979, the RRG-4 well was treated by using 1 275 656 l of guar- and polymer-treated water and 49 169 kg of sand (22 861 kg of 100 mesh sand and 26 308 kg of 20-40 mesh sand).

The interval stimulated in RRG-4 was in leg B from 1433-1494 m. The 61 m treated was left open-hole. The well was treated at a rate of 138 l/s in four stages of 317 968 l each, using a dentritic fracture process.

The formation broke down at approximately 16 200 kPa, and the latter stages of the fracture took fluid at pressures of 11 030 to 12 410 kPa.

A 24-hour artesian test was conducted on the well on August 24-25, 1979, directed by RGI and supported by EG&G. Initial flow rates varied from 4.73-14.2 l/s.

A second artesian flow test was performed in early September. The well was flowed for 150 hours at rates varying from 7.26 l/s at the beginning of the test to 3.8 l/s at the end of the test. A constant backpressure was maintained throughout the test.

At the end of the report period, plans were being made to stimulate the RRG-5 well. Technical data suggest that this well may have been damaged during drilling and that flow can be improved by stimulation. RGI will again design and conduct the experiment and EG&G will provide field support.

RAFT RIVER CASE STUDY

(Max R. Dolenc)

The Raft River Case Study was funded in the latter half of FY-79 to develop an understanding of a typical fracture-controlled, liquid-dominated, moderate-temperature hydrothermal system. A review committee of experts in hydrology, geology, and reservoir engineering evaluated the geotechnical data that have been gathered by EG&G and the U.S. Geological Survey (USGS) over the past years. Additional data recommendations were to run a reflection seismic survey of the Raft River area and to evaluate the Bridge Fault structure by trenching. The USGS was responsible for these items. EG&G was requested to provide

field support for those activities and to continue evaluating the geothermal reservoir. A cooperative effort on reservoir modeling between both groups (EG&G and the USGS) was recommended. The University of Utah Research Institute (UURI) was requested to design and coordinate a mercury-arsenic soil survey to evaluate near-surface fault relationships.

Upon completion of the data gathering period, a joint report will be published by the USGS and EG&G. This report will be published some time in 1980.

DIRECT APPLICATIONS

Aquaculture

(J. F. Sullivan)

The aquaculture growth study, initiated at Raft River and the University of Idaho during late 1978, was completed successfully during the reporting period. The objective of the research was to determine if low- or moderate-temperature water could be used to culture aquatic species suitable for human consumption. A companion control facility was established for comparison at the University of Idaho.

Specific objectives of the study included investigation of: (a) growth rates, (b) dietary requirements of the test organisms, (c) metabolic rates, (d) histological and physiological parameters, and (e) bioaccumulation of heavy metals and fluoride.

Common and mirror carp (*Cyprinus carpio*) were selected as culture species because of their high productivity, ease in rearing, and adaptability to extensive culture. Carp have been cultured for 3000-4000 years in the Far East and are the most widely cultured human food fish. Extremely hardy organisms, carp exhibit rapid growth rates, are omnivorous, and efficiently convert low-grade foodstuffs into high quality protein.

Channel catfish (*Ictalurus punctatus*), the most widely cultured fish in the United States were also selected for culture in the geothermal facility. The market for catfish is well established and has grown dramatically from 145 152 kg of farm-raised catfish in 1960, to 31 752 000 kg by 1976, with local farm sales consuming the largest percentage of the cultured product.

Growth of the fish was assessed on three diets: (a) a commercial trout diet, (b) dried activated biomass material, and (c) a basal ration. The biomass material, supplied by J. R. Simplot Co., in slurry form, was derived from secondary waste treatment operations and consisted of a bacteriological single-cell protein. The biomass slurry was dried at the Raft River Geothermal Site in an experimental geothermal fluidized bed dryer prior to isocaloric incorporation into the biomass ration.

Preliminary organoleptic sampling detected no adverse effects of the geothermal culture media on texture or flavor of the fillets. Proximate analyses of samples of fish flesh from both sites indicated no significant differences to date in percentage of crude protein, total nitrogen, crude fat, fiber, ash, dry matter, and moisture between the University of Idaho and Raft River fish.

An unexpected benefit of culture in geothermal water was realized in that mortality was negligible (<0.1% total); no outbreaks of disease or unexplained deaths occurred at the Raft River site. The reasons for minimization of disease outbreak and enhanced growth appear to be related to the salinity and/or hardness of the water and its effect on osmo-regulation.

The carp exhibited egg development in late spring and were spawned by hormone induction in July and naturally in August. Between 82 and 125 hours post fertilization, virtually all fry died prior to completion of yolk sac absorption. Gonadosomatic indices collected throughout egg and embryo development indicated abnormally small eggs (mean weight 0.93 g as opposed to literature values of 1.2 to 4.5 mg for "small" eggs and 7.0 to 9.0 mg for "large" eggs). Egg color and size indicate that incomplete vitellogenesis probably occurred.

Percent fertilization, eye-up viability, and hatching success were low, but within acceptable limits. Gross evaluation of the fry indicated lack of mouth formation. Additionally, heart beats were observed but blood did not appear to circulate within the organisms. Histological examination of the tissues is necessary to substantiate this observation, and will be performed during the next reporting period.

Research to date indicates a strong potential for geothermal grow-out facilities; the fish remained healthy and demonstrated high growth rates. The question of reproductive failure has yet to be resolved.

Both species of fish were placed on a programmed growth schedule whereby feeding rates were calculated by predicting the growth increase for each two-week growth period. The predicted daily increment increase in weight gain was summed.

daily in determining the total weight for feeding rates. Predicted growth increases for each two-week period ranged for 30-75% and 25-45% for catfish and carp, respectively. All fish were inventoried every two weeks for actual growth rates.

Monthly histological and physiological comparisons of the test control fish were performed to detect potential subtle changes in the fish reared in geothermal water. Complete post mortem examinations were performed including hematocrit determinations, refractive index of serum proteins, and histological examination of all major organs. Metabolic rates of the control and treatment fish were also assessed each month by measuring their oxygen consumption.

Growth rates exhibited by carp and channel catfish in geothermal water are shown in Figures 3 and 4, respectively. Catfish 11-1/2 months old weighed an average of 597 g when the growth

chambers became size-limited and data collection terminated. At this time, the catfish had reached market size (568 g) in substantially less time than the 16-17 months required for extensive commercial facilities.

Data on carp growth were collected through mid-May, when the mean fish weights ranged from 713 to 930 g and the carp were reproductively active. No commercial intensive carp culture growth data are available for comparison.

No detrimental physiological conditions were detected in the fish grown directly in geothermal water. No significant differences were observed in the internal organ histology during examination of muscle, intestinal tract, heart, kidney, liver, spleen, brain, and swim bladder tissues. Oxygen uptake studies, which measure metabolic rate, show no differences between the fish grown in geothermal or freshwater.

Figure 3. Effect of various diets on growth rate of carp cultured in Raft River geothermal water.

Figure 4. Effect of various diets on growth rate of channel catfish cultured in Raft River geothermal water.

Agriculture

(N. E. Stanley)

The objective of the agricultural irrigation experiment during this reporting period was to examine possible degradation of upper aquifer waters by leachates from geothermal irrigated fields. The objective of earlier experiments was to examine the beneficial use of energy-expended geothermal fluids in crop growing practices. The earlier work successfully demonstrated the feasibility of using geothermal fluids for culturing selected crops, and also revealed the need for

periodic leaching irrigations to maintain favorable soil salt balance and high crop productivity. These leaching irrigations caused concern over the possible degradation of receiving waters in the upper aquifers. In response to this need for information, a 2-year extension of the irrigation experiment was designed, and the first phase was initiated during this reporting period.

The objectives of the current experiment are: (a) to evaluate leaching requirements associated with geothermal irrigation practices, (b) to characterize drainage and/or leachates from geothermal irrigated fields and, (c) to develop

irrigation management practices commensurate with achieving satisfactory crop growth, favorable soil salt balances, and minimal environmental impacts.

The field experiments are being conducted over two growing seasons. During the first season, which was initiated on May 15, 1979, an established forage crop was cultured on two adjacent 5.26-ha plots using management practices and irrigation schedules similar to those employed by area farmers. Approximately 1.5 m of geothermal water was applied to the test plot and 1.2 m of comparison water from a shallow irrigation well was applied to the comparison plot. Identical irrigation schedules were specified for each plot, but pumping problems required a 12-day mid-summer shutdown of the comparison water system which resulted in the lower total application to the comparison plot.

Weekly analyses were performed on water samples from each irrigation source. Analyses included conductivity, pH, fluoride, and chloride. The water sampling program indicated that no significant change in the chemical composition of either water source occurred during the irrigation season.

Two samples of each plant species cultured on the geothermal irrigated plot and one sample from the comparison plot were collected during the first harvest and analyzed for fluoride content. One each of the geothermal plot samples was washed with distilled water prior to drying and analysis to determine the surface and internal fluoride content of the plants. The results showed 5 to 10 times more fluoride in geothermal irrigated plants. Washing with distilled water did not reduce the fluoride content indicating that fluorides are absorbed and concentrated rather than accumulated on the surface of plants.

Twenty permanent soil/leachate sampling sites were established on the test plots and on adjacent nonirrigated land during the reporting period. At the end of the irrigation season, a 3.7-m-deep hole was augered at each sampling site and soil samples were collected at 305-mm increments to characterize the soil profile and determine disposition of waterborne salts applied through conventional irrigation practices. Soil sample analyses were in progress at the end of the reporting period.

Experimental design for the second (1980) growing season calls for a one-season irrigation procedure. The irrigations will be managed to meet the crop evapotranspiration requirements, and a controlled leaching fraction will be applied to maintain the lowest feasible soil moisture tension and soil solution osmotic pressure. Leachates from the test plots will be sampled and characterized to predict the impacts of disposing of geothermal power plant effluents by irrigation upon leachate receiving waters. A proposal will also be developed to evaluate the feasibility of surface irrigation for disposal of geothermal effluents from the Raft River 5-MW power plant.

Components and Systems Development

(J. G. Keller and R. C. Schmitt)

Fluidized Bed Space Heater Experiment. The objective of this experiment was to examine the space heating application of the fluidized bed technique using low- to moderate-temperature, highly scaling geothermal water. The fluidized bed heat exchanger (Figure 5) was a water-to-water unit successfully tested at East Mesa in Imperial Valley, California. Although not designed for use as a water-to-air exchanger, this unit was tested with and without a fluidized bed to compare any variations in overall heat transfer coefficients and heat output capacity. With a fluidized bed, the overall heat transfer coefficient increased about 30-40% for similar air and geothermal water flow rates. With the bed present and operating under similar conditions, heat output increased 20-30%.

Airstream heat output was measured while independently varying the geothermal water flow and the airstream flow rates. As shown in

Figure 5. Fluidized bed space heater.

Figure 6, heat output is biased in favor of airstream flow. The graph also shows that increases in airstream flow rate directly affect heat output, while changes in geothermal water flow rate produce virtually no effect in heat output, especially at low water flow rates. Heat output does increase as geothermal water flow rate increases, but only until fluidization occurs and bed isothermal conditions are met. After that, heat output changes are negligible.

Note that for smaller bed particles (1.0 mm mean particle diam), fluidization occurred earlier and no change in heat output was recorded for varying geothermal water flow rates at constant airstream velocity. Tests without bed material showed an almost 20% reduction in heat output for any given water flow rate. Higher flow rates showed greater reduction in heat output. Without a bed, the highest air flow rates showed reduced heat output with increasing water flow rates as a result of air turbulence.

Tests were conducted intermittently over a period of several months. Any heat exchanger corrosion that resulted from long periods of downtime under oxygenated conditions (heat exchanger drained and open to the atmosphere) completely disappeared after startup.

As shown in Figures 6 and 7, both heat output and overall heat transfer coefficient increase with increasing air flow rates for any given geothermal water flow. Tests with and without a fluidized bed reveal a 29-38% increase in overall heat transfer coefficient and a 20-29% increase in overall heat output capacity.

The tests show that wherever scaling, corrosion, or contamination cannot be tolerated, fluidized bed space heaters allow geothermal water to be used by residences, commercial firms, and industrial process heat users.

Fluidized Bed Dryer Experiment. In this reporting period, this experiment's objective centered on modifying the system to improve performance and dry an additional waste material.

The waste products of some food processing industries are of considerable value for animal feed or fertilizer. These waste products must be dried for preservation and to reduce their weight and volume for transportation. The potential for using geothermal energy in drying operations

prompted the development, in 1978, of an experimental-scale dryer, based on the fluidized bed principle and using geothermal hot water as the heat source. In the earlier work, the dryer was tested on two waste products: caustic dry-peeled potato waste and activated biomass material. During the current reporting period, the dryer was modified (Figure 8) to increase output, and its operation was tested on steam-peeled potato waste supplied by the American Potato Company. The waste material, in 50-gallon drums, was held in cold storage until the experiment was begun.

In this experiment, a fluidized sand bed served as the drying medium in all tests. Although the drying procedure is the same for different waste product slurries, each dried product has a characteristic particle size, which is also dependent on dryer operating conditions. In the earlier tests on caustic dry-peeled potato waste and biomass material, a large percentage of the product was lost by venting to atmosphere. Not only did this decrease the overall product output, but it increased the time necessary for bed displacement (i.e., when product displaces the initial fluidized sand bed and the final product becomes relatively sandless). The venturi, which was added for this experiment, largely eliminated these problems.

Fluidized air was introduced into the venturi and delivered to the bottom of the bed for fluidization. Air movement through the venturi created a negative pressure zone at the pipe connected to the cyclone and promoted a pulling effect on the fines at the cyclone output. The result was twofold:

1. A product output increase through reduction in product loss to the atmosphere, and
2. A decrease in the time required for bed displacement.

The final product was analyzed for protein value, which differed only slightly from the caustic dry-peel material dried in the earlier tests.

Complete experimental procedure and results will soon be published in a formal report, "Fluidized Bed Dryer Experiment," by L. T. Cole and R. C. Schmitt. Conclusions are that a fluidized bed dryer, using geothermal hot water as the heat source, is an effective way of drying slurry-like products, and it shows the

Figure 6. Fluidized bed space heater output at various geothermal water and air flow rates, and at different bed particle sizes.

Figure 7. Fluidized bed space heater overall heat transfer coefficients at various geothermal water and air flow rates, with and without fluidized bed, and at different bed particle sizes.

Figure 8. Fluidized bed experimental dryer.

potential for drying many industrial liquid products. Also, slight modifications of the system can make it possible to dry solid products such as grain, beet pulp, and onions. Although this fluidized bed dryer design is not suggested as the only acceptable process, the concept does show great promise in industrial drying as demonstrated by this project.

Essential Oil Experiment. The objective of this experiment was to examine the use of geothermal fluids in a typical steam distillation operation.

Essential oils, which are volatile flower and vegetable oils, are extracted from plant tissue with solvents or by steam distillation and are used in perfumes and flavorings. Of the many kinds of essential oils that could have been used in this experiment, peppermint was selected because it is readily available in the area.

Idaho produces 12-13% of the total national supply of spearmint oil and 11-12% of the nation's peppermint oil. Each grower distills his own crop and sells it to either a blender-refiner or directly to the end user. The collocation of geothermal resources and mint growing areas makes the use of geothermal steam an attractive energy source for steam distillation and suggests the possibility that this process could capture a significant portion of the industry.

Of critical concern is the quality of the oil produced by direct contact with geothermal steam, since quality and flavor are the sole criteria by which mint oils are judged and sold. A prime concern in this experiment, therefore, was to determine whether geothermal steam contaminates, or changes in any way, the flavor and quality of these economically important products. The main objectives of the experiment were:

1. To establish the feasibility of using geothermal steam in the essential oil industry,
2. To analyze essential oils produced from direct contact with geothermal steam to determine if oil quality would be impaired, and
3. To gain expertise in the steam distillation process that would be useful in other applications.

Standard equipment was purchased for the steam distillation of essential oils. The steamer cart, condenser, and receiver vessel were made of aluminum and were of commercial size.

The peppermint plants were harvested in the early morning, when dew would help maintain the moisture content of the cut plants. The crop was then placed in cold storage until the experiment could begin. Processing was identical to conventional methods and consisted of the following steps:

1. *Steaming*—Plants were placed in the steamer cart and subjected to a "breakthrough" steaming period at high temperature and pressure to break plant cell walls and release the oil. Temperature and pressure were then lowered to simmer the plants and maintain the oil extraction process.
2. *Condensing*—Steam and oil vapor, at about atmospheric pressure, condensed at the top of a shell-and-tube condenser designed for condensing flow on the shell side. A vent tube prevented overpressure.
3. *Receiving*—The condensed steam and oil vapor flowed from the condenser into the receiving vessel where the oil floated and was collected. Water in the receiving vessel was maintained at the optimum temperature for separation of oil and water.

Trial runs were made using steam from two Raft River wells: RRGE-1 and -2. Oil samples from the first trial run, using steam from RRGE-2, appeared to be slightly off-color, which was thought to be caused by freezing of the plants during cold storage. Later trial runs showed, however, that freezing caused no adverse effects on oil quality. Oil extracted by steam from RRGE-1 at about 132°C was clearer than samples from the first trial run.

Oil samples were analyzed and compared to a control sample. Plants for the control sample were taken from the same field as the experimental plants and processed by the grower using similar equipment, but using steam generated by fossil fuel. The control sample was not frozen and processing did not deviate in any way from standard conditions.

Results showed that extraction of peppermint oil by steam distillation using geothermal steam as a heat source did not adversely affect the overall quality of the oil. Later trial runs were made and results are still pending, but we expect samples of even higher quality than those obtained using RRGE-1 steam.

Geothermal Assisted Biomass Conversion. The objective of this activity is to examine the use of geothermal heat and fluids in the process of converting biomass to alcohol fuel. The two principal elements are the lignocellulose conversion and the small-scale unit tests.

In the lignocellular conversion program, laboratory phases began in June 1979, performed by the contractor, Colorado State University. Initial studies have been promising. The studies determined that water, instead of ethanol-water mixtures, can be used to remove the solubilized lignin fraction after autohydrolysis. This will greatly reduce the need to recycle ethanol through the system. It has also been determined the geothermal water of the Raft River type does not

inhibit either enzymatic conversion or fermentation. No outside water source, therefore, will be needed.

In mid-summer 1979, a small-scale unit was built at the Raft River geothermal site to help answer some of the uncertainties surrounding state-of-the-art geothermal assisted biomass conversion. By the end of August, the unit successfully produced a quantity of 95% (190 proof) ethanol. This small-scale geothermal assisted biomass-to-ethanol pilot unit (Figure 9) demonstrates the application of geothermal fluids to chemical processing plants.

This unit produces 95% ethanol by distilling sugar beet-derived beer which contains 8-10% alcohol. The beer is preheated by the still "bottoms" to near its vapor saturation point before entering the still. Geothermal fluid heats the reboiler by circulating through a shell-and-tube heat exchanger. In the reboiler, the still bottoms are partially vaporized and pass upward through the distillation column, contacting the down-flowing liquids.

INEL-A-14 733

Figure 9. Small-scale geothermal assisted biomass-to-ethanol pilot plant schematic.

The distillation column has two sections: the bottom, or rectifying section, is 4 feet long and contains ceramic saddle packing; the top, or stripping section, is 10 feet long and contains stainless steel pall rings.

The feed enters the column between the rectifying and stripping sections. Vapors leaving the top of the column are condensed in the closed loop condenser. About 90% of the condensed liquid is returned to the still as reflux; the remaining 10% is removed as a 95% ethanol-5% water mixture.

Because the ethanol-water mixture forms a constant-boiling azeotrope, 96% ethanol, a still cannot produce 100% ethanol at atmospheric conditions. In a production plant, anhydrous alcohol would be produced by mixing the 95% ethanol-5% water solution with an azeotrope "breaker" such as benzene and then passed through additional distilling equipment. The temperature required for azeotrope breaking is compatible with that of geothermal fluids, and a production plant could use geothermal heat for this step as well as for the initial distillation.

ELECTRIC APPLICATIONS

Prototype Power Plant

(G. Mines)

The prototype plant-control upgrade to provide shutdown in the event of any hazardous condition was completed in May 1979. These modifications allow the plant to be operated continuously with minimal operator surveillance. During the checkout of these modifications, the plant had to be shut down twice due to feed pump diaphragm failure. Further testing was postponed until the feed pump could be replaced.

A centrifugal pump was selected to replace the diaphragm-type isobutane feed pump. The centrifugal pump was selected over the previously proposed vertical turbine pump because of its quicker delivery and minimal modifications needed for installation. The new feed pump was installed and the plant started up in mid-July 1979. The plant has been operating continuously since that time whenever geothermal fluid was available, except for a 2-week period in August to repair faulty wiring. The plant has also been down for short periods, generally less than 24 hours, due to power outages, new equipment installation, work on auxiliary systems, manpower limitations, etc.

During the 10 weeks of operation in this reporting period, the prototype plant produced power for a total of 550 hours. The peak power output during this period was 45 kW, and the total power produced was 13 350 kWh or an average of 24.3 kW. The large difference in peak and average power output was caused by operating the plant at varying geothermal fluid inlet conditions. The geothermal fluid inlet temperature and flow rate varied with the well supplying water and with other site test water requirements.

This period of operation was also used to turn the daily operation of the prototype plant over to the Raft River field operations group. The binary cycle operation was very stable and the plant operated well over a variety of geothermal conditions, including some far from the design point.

The design of the direct contact heat exchanger was completed and construction is under way. The installation design was also started for the direct contact heat exchanger and ORNL condenser.

Five-Megawatt Pilot Plant

(T. L. Rasmussen)

In April, the start of this reporting period, construction was the main activity. In progress were the office and control buildings, maintenance building, fire water pump house, cooling water pump house, and concrete footings in the tank farm area. Cooling tower construction was also under way.

As the weather warmed in May, construction was accelerated and installation started on piping, electrical conduits, and lightning protection. By the end of May, the RRGP-2-to-RRGI-6 long-term test was complete, and the flow portion of the RRGP-5-to-RRGI-6 long-term test was 70% complete. The remaining 30% was finished in June.

In June, the Title II design for the structure and underground conduit of the turbine generator was completed and submitted for review. Construction at the site continued on schedule. Major progress was made on construction of the cooling tower and structural steel erection in the process area. The buildings there were nearing completion and the large piping in the process area was almost completely installed. Construction began on three lined ponds at sites 4, 6, and 7. Piping modifications to RRGI-7 were completed and the thermal loop tie-in for the supply and injection system was initiated. During the month, the Idaho Department of Water Resources was given a presentation and tour of Raft River and a subsequent meeting was held between EG&G, DOE, and the IDWR in Burley, Idaho to discuss project plans, permits, and injection alternatives at Raft River.

During July, the DOE Inspector General visited the 5-MW facility and gave the project a very high rating. The cooling tower was nearly complete, and a plant simulation was run under steady-state conditions. Work continued on preparing the main substation for high-voltage feeder line installation.

A 96-hour test from RRGP-2 to RRGI-7 was completed in August. Tests indicated that RRGI-7 has greater injection capacity than projected. Also during August, Burns and Roe Pacific transmitted the remaining Title II design documents for the

turbine generator. EG&G received bids for construction of the structure and underground conduit and pipe, and received Schedule X materials. Supply and injection system subcontracts were awarded for wells 2, 3, and 5. Two fire pumps were set in place; one was diesel engine-driven and the other was electric motor-driven.

In September, the end of this reporting period, the start of the test of RRGE-1 to RRG1-6 and -7 was delayed because of late delivery of the power transformer for the Centrilit pump at RRGE-1 caused by a factory defect. Close management follow-up minimized the delay, and the transformer was rebuilt and installed in time to begin the test on September 28. A draft report on steady-state plant performance was completed, and on September 28, the contract for turbine structure construction was awarded to Biggers Construction Company. Production pumps were installed deeper at wells 1, 2, and 3; mechanical modification subcontracts on RRGE-1 were completed; and all subassemblies were prefabricated. All are scheduled for completion by October 10. Permanent wiring was pulled to all buildings and subordinate areas, and the power company installed the incoming high-voltage line, fused disconnects, and isolating switches. Work on the S&I system thermal loop tie-in was completed on September 30. DOE designated EG&G the operational contractor for 5-MW RRPR, and efforts began on recruiting operating personnel.

Support Engineering (C. J. Bliem). A study was undertaken to examine the performance and operability of the 5-MW Pilot Plant. This work will include steady-state plant performance mapping for various geofluid inlet temperatures and flow rates, fouling, and ambient conditions. In addition, certain plant transients (both manual and upset) will be examined. Final reports on both of these activities will be produced in the next reporting period.

The first phase of this study entailed updating the existing digital simulation of the entire system to reflect the actual plant hardware. This update included a new cooling tower model, new turbine performance reflecting the manufacturer's predictions, and changes of all heat exchanger modeling. The results of the new model compared very well with manufacturer's specifications, other analytical predictions of heat exchanger performance, and the earlier nominal design cycle.

The steady-state mapping is complete, and a report is being prepared to present the results of this phase of the study. Figure 10 shows the effect of changing geofluid inlet temperatures and flow rates on generator output at summer extreme conditions and the design fouling in all heat exchangers.

The net geofluid effectiveness (net energy produced, exclusive of field pumping charges, per unit mass of geofluid flowing through the plant) is shown in the dashed lines. Note that although less energy is produced from each kilogram of geofluid as the geofluid temperature decreases, the effectiveness is relatively independent of geofluid flow rates at a given temperature for the summer conditions shown in Figure 10.

The line across the top of the curve is the limit of plant operation resulting from the fixed hardware in the plant. The left portion of this curve, labeled (a), indicates a limit due to reaching the maximum recommended velocity of the geofluid in the heat exchanger tubes. The right portion of this curve results from limits caused by the isobutane feed pumps. This is the limit at which the pump will operate with a 1.75-kPa (25-psi) pressure drop in the valve controlling the flow into the high-pressure boiler. The system is built to accommodate more stages in these pumps, which would allow this limit to be raised and allow production of more power.

This plant will be operated on the floating power concept, so that performance will be increased at winter ambient conditions when the cooling water, and thereby the condensing temperature, will be decreased. The increase in generator output at winter extreme ambient conditions, over summer, will be approximately 1.6 MW independent of geofluid temperature, flow rates, and fouling conditions. The generator power will be approximately 12% higher in the summer when the heat exchangers are clean, and will be about 9% higher in the winter.

The design point for the plant is shown in Figure 10 at 143°C (290°F). Geofluid temperature at the plant inlet will probably be about 138°C (280°F). The lowered geofluid temperature causes a generator output reduction of approximately one-half MW. This power can be recovered,

Figure 10. Raft River 5-MW(e) pilot power plant generator output under summer conditions and design heat exchanger fouling conditions.

however, by increasing the geofluid flow rates by around 16%. Note that the effectiveness is not changed by this flow rate increase (that is, the net output increases at the same rate as the geofluid flow rate).

One important result of this study is that with fixed plant conditions, the dual-boiling cycle responds to decreases in geofluid temperatures with the same type of adjustments that would be made if the plant were designed at the lower temperature. For example, the optimum split in flow between the high and low pressure boilers diverts more flow to the low pressure boiler as the geofluid inlet temperature decreases. The fixed dual-boiling binary plant is "self-adjusting" to

decreases in geofluid temperatures that will occur with time as a resource decreases.

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

A series of tests using bench-scale cooling towers was run to evaluate chemical

characteristics of several different pretreatment programs. The test towers were designed to simulate the operating conditions in the 5-MW pilot plant's chemical treatment system, cooling tower, and condenser.

The tests generated preliminary corrosion data as a function of cycles of concentration and

chromate levels, and concentration of dispersant required to prevent scale deposition.

Several chemical systems that treat blowdown to meet environmental standards by precipitation of chromate and zinc were evaluated. The use of ion exchange to recover and reuse the chromium was also evaluated on a laboratory scale.

DIRECT CONTACT HEAT EXCHANGERS

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

System Studies

System studies carried out during this period included initiating a study of binary power plant layout. These plant studies will include conventional binary cycles as well as direct contact cycles. Heat rejection systems will be studied using conventional heat exchangers with both dry and wet cooling towers, hybrid cooling towers designed for direct condensation, and direct contact condensers with dry and hybrid cooling towers. All system studies are based on 50-MW(e) plants, although geothermal field characteristics typical of both the Imperial Valley and Raft River will be included.

Direct Contactors

Work has continued on the liquid-liquid direct contact heat exchanger to refine design procedures. Experimental work has included the development of temperature instrumentation capable of measuring the difference in temperature between single drops and the continuous phase. In addition, a dispersed phase injector plate was installed in the 6-in. (150-mm) diam column that is identical to that designed and installed in the 500-kW(e) direct contactor designed for Barber-Nichols. The injector works as designed, producing 3-mm-diam drops.

Experimental work has been carried out using the new injector plate. Data gathered to date indicate slightly better performance than predicted from the work of Plass et al. This indicates that the design of the 500-kW(e) direct contactor may be slightly conservative.

Work has also been initiated on a sieve-plate type direct contactor. Comparison studies will be made of its performance and that of the spray column.

Direct Contact Condenser Studies

Experimental studies of packed bed condensers continued during this reporting period. An

improved correlation of the experimental data from those reported earlier was developed, yielding

$$St = \frac{2.3 K^{0.5}}{J_a^{0.6} H^{0.6} C^{0.3}} \quad (1)^a$$

where

$$St = \frac{\bar{h}_a}{\left(\frac{\dot{m}}{A_L}\right) C_{PL} a_w}$$

$$J_a = \frac{h_{fg}}{C_{PL} (T_{SAT} - T_{LIN})}$$

$$K = k_c/k_L$$

$$C = \frac{\dot{m}_L C_{PL}}{\dot{m}_c C_{Pc}}$$

$$A = \text{Cross-sectional area of column}$$

$$H = Z/d$$

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

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

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

$$P = \text{Density}$$

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

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

$$T = \text{Temperature}$$

$$SAT = \text{Saturation}$$

$$k = \text{Thermal conductivity}$$

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

$\dot{m}$	= Mass flow rate
$\bar{h}$	= Heat transfer coefficient based on surface area
V	= Vapor properties
L	= Liquid properties
c	= Condensate properties

Due to difficulties encountered in obtaining the best correlation, which would be applicable to all fluid combinations, a theoretical model for condensation of an immiscible falling film has been developed. The work to date is in general agreement with the correlation equation heat transfer coefficient. Completion of the model should allow further refinement of the correlation equation for packed bed condensers.

Heat Transfer Augmentation Comparisons

A new area of work has been initiated in which the performance of binary cycles using surface heat exchangers with augmentation are being compared with direct contact cycles. Augmentation devices can take many forms and include internally-finned tubes or conventional tubes with twisted tape inserts. In locations such as Raft River, where the geothermal water is relatively clean and does not cause appreciable fouling, this may be a cost-effective approach to reduce pinch-point temperature differences. If the relatively clean waters contain large amounts of noncondensibles, a surface-type heat exchanger may be very desirable compared to a direct-contact-type device.

Work in this area is focusing initially on modeling a simple concentric tube counterflow heat exchanger. This is accomplished by taking successive sections through the heat exchanger. Local film coefficients are calculated for each section so that energy balances between the two fluids can be calculated for each section.

Particular attention is directed toward calculating the pressure and the heat transfer at each node. This is required because augmentation devices generally result in large pressure drops and large increases in heat transfer. In the modeling, both friction factor and Nusselt number are treated as a function of Reynolds number. This is a typical characterization of augmentation devices.

The analysis of the heat exchanger is being developed as a subroutine. It will and can be incorporated into the geothermal system analysis program GEOTHM. Cycle performance can then be compared with direct contact devices.

Contribution to Geothermal Sourcebook

The contribution to the Geothermal Sourcebook on direct contact binary geothermal power plants was completed and revised during this reporting period. The revisions made the style consistent with the remainder of the Sourcebook and incorporated recent developments.

J. Whitbeck proposed a more thorough summary report, and efforts were expended to initiate such a document describing in detail the entire direct contact program and related programs at the University of Utah and related programs. This work will extend into 1980 and will be completed by October 1, 1980.

ENVIRONMENTAL CONSIDERATIONS

(J. F. Sullivan and T. L. Thurow)

Environmental monitoring continued at Raft River during the last six months, including air quality, meteorology, water quality, hydrology, and terrestrial and aquatic ecology. This section briefly discusses the progress of these studies; however, details are presented in the annual environmental report.

Aquatics

Aquatic studies on the Raft River, initiated in 1978, continued during the reporting period. These studies will document baseline conditions of the Raft River, the only perennial stream in the valley, to be used if a pipeline break should cause geothermal fluids to enter the river. The investigations centered around three sites: one upstream (above), one at, and one below the Raft River site. The upstream and downstream sections were the most similar with respect to substrate type and were composed of 50% rubble on an area basis. The station adjacent to the geothermal site was dominated by sands and gravel with approximately 30% rubble.

Biological data emphasized included the fish community standing crop and the benthic invertebrate community. The fish communities differed considerably between the three sites. The upstream section standing crop was dominated by mountain and Utah suckers (*Catostomus platyrhynchus* and *C. ardens*, respectively) while longnose dace (*Rhinichthys cataractae*) dominated the other two sites. While the downstream site had few mountain suckers and reidside shiners (*Richardsonius balteatus*), the area adjacent to the geothermal site had considerable numbers of both species.

Approximately 60% of the benthic invertebrate samples have been sorted; however, the method of data analysis to be used requires complete sample processing before any definitive statements can be made.

Raptors

The investigation concerning the effects of controlled disturbance on ferruginous hawks (*Buteo*

regalis) as may occur during geothermal energy development was conducted during the spring and summer of 1979. This constituted the second year of the 2-year perturbation study begun in the spring of 1978.

A total of 34 active ferruginous hawk nests were found in Raft River Valley during 1979. Of these, 21 nests were used as controls and 13 nests were used as treatment nests. The types of perturbation imposed on the treatment nests and the nesting results are summarized in Table 1. The mean flushing distance represents the distance between the investigator and the nest when the attending adult flushed. When this occurred, the investigator approached no further and left the area immediately.

Nine of the 13 treatment nests were successful and fledged 24 young for a mean fledging rate of 2.67 per nest. When all treatment nests (successful and unsuccessful) are considered, the average fledging rate is 1.85 per nest. All of the control nests were successful in fledging young. The average fledging rate of the 21 control nests was 3.81. The difference of 1.1 young per nesting attempt between successful treatment and control nests was found to be significant ($P = 0.01$).

Of particular interest is the trend that appears in the data (Table 2); in 1979, 15 of the 21 control nests (71%) fledged either 4 or 5 young per nest, while 3 was the maximum number of young fledged by any treatment nest.

Three of the four territories deserted during the 1978 phase of the study were not reoccupied during 1979, an observation that could have long-range population implications if that trend were followed over several years. Additional study is required to substantiate this observation.

The natural behavior of this sensitive raptor was observed under both disturbed and undisturbed conditions to determine the level of perturbation that the ferruginous hawk will tolerate without decreasing nesting success or production rates. Utilizing such information in siting criteria for well and/or power plant locations should enable resource development to take place compatibly with species normally sensitive to such development.

TABLE 1. TYPE AND RESULTS OF PERTURBATION IMPOSED ON TREATMENT NESTS

<u>Treatment</u>	<u>Number of Visits^a</u>	<u>Mean Flushing Distance and Range^b (m)</u>	<u>Nest Result</u>
Walk	19 (5)	138 (20-400)	Fledged 3
Walk	21 (7)	66 (20-150)	Fledged 2
Walk	19 (2)	164 (70-300)	Deserted
Walk	26 (10)	196 (10-350)	Fledged 3
Walk	24 (3)	118 (25-255)	Fledged 3
Drive	24 (3)	90 (15-270)	Fledged 3
Drive	28 (1)	162 (35-400)	Fledged 3
Drive	28 (1)	54 (15-180)	Fledged 2
Drive	6 (3)	153 (20-400)	Deserted
Noise	NAC		Deserted
Noise	NA		Fledged 2
Noise	NA		Fledged 3
Noise	NA		Deserted

a. Number in parentheses indicates visits when the adults flushed at >500 m or were not present.

b. Calculated only on values when adults flushed at <500 m.

c. Not applicable; nests perturbed by noise were not regularly visited by investigators.

TABLE 2. DISTRIBUTION OF THE NUMBER OF YOUNG FLEDGED PER NEST

Number Young Fledged	Number of Nests 1979	
	Control	Treatment
5	5 (24) ^a	0 (0)
4	10 (48)	0 (0)
3	4 (19)	6 (46)
2	1 (5)	3 (23)
1	1 (5)	0 (0)
0	0 (0)	0 (31)

a. Percentage of nests in each category.

Mammals and Songbirds

With the exception of the blacktailed jackrabbit census performed in conjunction with the raptor studies, no research or monitoring was conducted on mammals during the year. Songbird research was limited to strengthening the species list for the valley. No further research concerning terrestrial vertebrates or invertebrates was conducted in the Raft River Valley during the reporting period.

Flora and Soils

A 4-year vegetation terrestrial ecology study of the plant communities and soils of the Raft River site was completed in 1979. The purpose of the study was to quantify the response of the vegetation to variations in the meteorological, edaphic (soils), and other environmental factors.

Nineteen 0.02-ha permanent plots were sampled each year by scribing an 8-m-radius circle and placing 25 one-square-meter quadrants every third step around the circle within the plot boundaries. The constituency of the vegetation community was found to vary significantly with the amount of moisture available. For example, grass frequency increased when perennial forbs and annuals

decreased, such as during the extremely dry year of 1977. A total of 105 species were identified during the study. Baseline data produced by this research provides a basis for quantifying possible future changes in the plant community. The data is currently being analyzed for specific trends and patterns.

Socioeconomics

The socioeconomic environment of Cassia County, Idaho was investigated during 1979 encompassing data from 1977-1979. The research purpose was to describe the existing socioeconomic environment, project the future socioeconomic environment in the absence of any significant geothermal resource development, assess the attitudes of area residents concerning proposed development, and provide a scenario of direct and indirect socioeconomic impacts that could be associated with geothermal resource development.

The Cassia County economy is based primarily on producing and processing agriculture products. Among counties in Idaho, Cassia County ranks second in wheat and barley production, third in sugar beets, and fourth in potatoes. The agricultural base in the southern part of the

county is livestock and feed grain production. Potatoes and sugar beets are the primary crops in the northern part of the county. Almost 90% of the farms in the county irrigate at least part of their cropland. Irrigation water was applied to more than 80 940 ha in 1974, or about 114 ha per farm. The importance of irrigated agriculture in the county is clear; any significant industrial development that requires substantial quantities of water (i.e., a significant electric power producing project) would undoubtedly have to bid water away from agricultural users because of the moratorium on development of new groundwater supplies and the existing commitment of surface waters.

Per capita income for Cassia County in 1977 was \$4,982, compared with an average per capita income of \$5,350 for Idaho. As measured by total income, Cassia County accounts for 2% of the total income for Idaho. Total employment for the county was just short of 10,000. Farm proprietors and farm workers composed 23% of total county employment. The county unemployment rate averages approximately 5%. Citizens of the communities of Albion, Malta, Elba, and Almo were surveyed during September 1979 to assess their opinions of the communities in which they live and potential changes. In general, area residents are relatively satisfied with the quality of life in their community. They would, however, like to see an increase in the range and quality of public and private services and an increase in employment opportunities. Residents generally favor development of the area's geothermal resources and the potential industrialization that would occur, provided that consideration is given to the environment and the people of the area. Over 40% of 115 respondents indicated that they would be available for full-time, year-round work.

The 1980 continuation of the study will develop more comprehensive and detailed impact predictions associated with the development of geothermal resources in the southern portion of Cassia County. Specific objectives of the research will be to identify employment options associated with geothermal development, assess the impacts related to the projected population influx, and create a set of realistic development scenarios that will reflect the socioeconomic impacts associated with projected resource development.

Monitor Wells

Water levels in five monitor wells and three USGS coreholes were monitored during injection tests in the spring and summer. Of the wells monitored, only MW-4 (305 m deep) showed definite response to injection. During two 21-day injection tests at RRGI-6, the water level in MW-4 rose an average of 0.4 m per week as a result of injection. There is some indication that other monitor wells may also have been affected by injection; this is being investigated. A detailed analysis of the monitor wells, their response to injection, and conclusions will be presented in the 1979 monitor well report, to be published in April 1980.

Continuing Environmental Monitoring Programs

The water resources of Raft River Valley are periodically sampled. This program includes semiannual sampling of shallow groundwater and surface water, routine monitoring of irrigation wells and the Raft River, and detailed sampling geothermal wells and the monitor wells.

A weather station installed at the Raft River site east of RRGE-2 monitors wind speed and direction, precipitation, ambient temperature, and dewpoint temperature. Air quality is also monitored.

Specific elevation surveys (second order; first class) were begun in 1979 to measure subsidence activity. This research will be continued in 1980 and the data will be correlated with changes in the water level or artesian pressure in monitor wells.

Plans were formulated and a contract let to establish a three-station seismic network at Raft River to evaluate induced seismicity. Seismic data had been gathered previously, but data were intermittent. The present plans are for data to be telemetered to UURI for analysis and interpretation. It is anticipated that the stations will be installed in the spring of 1980.

The results of these continuing monitoring programs are discussed in the annual environmental report.

ENERGY TECHNOLOGY REQUIREMENTS TO ACCELERATE HYDROTHERMAL ENERGY COMMERCIALIZATION

A number of independent research and development projects have provided a basis for hydrothermal energy commercialization. Industry is beginning to realize the benefits of this energy source, and large investments are being committed to hydrothermal energy use even though all of the technical and institutional problems are not yet resolved.

In this reporting period, an industry survey determined the most significant technical barriers that still must be resolved to accelerate the commercialization of hydrothermal energy. Results of the survey are reported in a draft document entitled "ET Requirements to Accelerate Commercialization of Hydrothermal Energy." Institutional barriers such as time required to obtain permits, leasing, and tax considerations are included in this document because some industries indicated that the major barriers to commercialization are nontechnical.

First, current DOE-funded technology projects were reviewed in depth. Then, technical problems and barriers to commercialization were identified. This information was obtained from working groups, advisory committees, Geothermal Resources Council (GRC) meetings, Electric Power Research Institute (EPRI) meetings, review of papers, and from interviews with knowledgeable individuals. Although industry provided the primary input to the list of problems and barriers, opinions of individuals in government and from national laboratories were also recorded. Both electric and direct heat interests contributed. Opinions were not "judged" before they were listed—they had only to meet the basic requirement of being technical barriers and not institutional in nature.

The result of this identification process is the 26-item list shown in Figure 11. Industry representatives were then asked to prioritize list items, which appeared in random order to eliminate bias. Some items were combined to minimize the number of decisions needed.

Forty-eight individuals from five different industrial groups completed the prioritization survey. Industries polled were developers, utilities, A&E firms, direct heat users, and financial firms.

Each individual survey was scored with a numerical value of from 0 to 25 for each element, or technical requirement, in the matrix. Scores for the corresponding elements from each individual in a given industrial group were summed to obtain a composite score for that technical element. The technical elements were then ranked in order of the highest to lowest composite scores. This process was repeated for each of the five industrial groups, which gave a ranking of importance of the various technical requirements for each of the five groups. The scores for each technical element in the five industrial groups were then summed to obtain an overall score for each element. This total score for each element determined the ranking of that element for all the industries sampled (Table 3).

"Increase Reservoir Confidence" rated in the top five technical requirements for all individual groups, and "Reduce Hydrothermal Field Development Costs and Improve Well Flow Rates" was rated in the top five by 4 of the 5 industrial groups (Figure 12). "Determine Economics and Reliability of a Commercial Size Binary Plant (50 MWe)" was rated in the top 10 technical requirements by all five industrial groups. "Develop 10-20 MWe Power Systems," "Reduce the Risk and Cost of Exploration," and "Control Scaling" were also rated in the top 10 by 4 of the 5 industrial groups (Figure 13).

Individuals interested primarily in "electric" use of this energy source were then separated from those interested primarily in direct heat, and their scores were compared with the list shown in Table 3. Figure 14 shows the top five technology requirements to accelerate commercialization of hydrothermal energy as viewed by the combined electric and direct heat industries. A summary of all combined and electric utilities agreed on all of the top five elements. Industries with direct heat interests strongly endorsed three out of the top five of the summary, and the other two elements were related to direct heat applications. Figure 15 lists the top ten technology requirements and shows that the electric utilities and those with direct heat interests agree on 9 and 8 out of 10, respectively, with the summary.

Although the major thrust of this survey was to identify and prioritize technical requirements for

1. Improve reliability of downhole pumps
2. Reduce cost of heat exchangers
3. Reduce corrosion and erosion
4. Improve injection capability
5. Develop 10-20 MWe power systems
6. Reduce cost of component testing in hydrothermal environment
7. Improve the technology for power plant cooling systems
8. Improve non-metallic materials (seals, coatings, tools, cables)
9. Improve systems modeling capability (reservoirs through power cycles and injections)
10. Improve capability for determining reservoir recharge
11. Reduce effluent pollution (H_2S , mercury, radium, arsenic)
12. Improve capability to predict or control induced seismicity and subsidence
13. Develop low temperature refrigeration and air conditioning equipment
14. Improve capability of downhole instruments and log interpretation (geophysical and geochemical)
15. Establish confidence in the economics and reliability of direct heat systems
16. Determine economics and reliability of a commercial size binary plant (50 MWe)
17. Reduce the risk and cost of exploration
18. Improve the availability of existing geoscience and resource data (low, moderate, and high temperature)
19. Control scaling
20. Reduce hydrothermal field development costs and improve well flow rates
21. Reduce cost of and improve technology for drilling (fluids, motors, bits, cements, and packers)
22. Develop 1-5 MWe wellhead generators
23. Increase reservoir confidence (reservoir engineering and assessment techniques)
24. Improve understanding of reservoir chemistry (rock and fluid)
25. Increase electrical power cycle efficiency
26. Reduce cost of hardware for direct heat applications

INEL-A-14 868

Figure 11. Random-order list of technology requirements to accelerate hydrothermal energy commercialization, as presented to industry for prioritization.

TABLE 3. RANKING SUMMARY OF ALL INDUSTRIES SAMPLED

Ranking	Technology Requirements to Accelerate Commercialization
1.	Increase reservoir confidence (reservoir engineering and assessment techniques)
2.	Reduce hydrothermal field development costs and improve well flow rates
3.	Reduce the risk and cost of exploration
4.	Determine economics and reliability of a commercial size binary plant (50 MWe)
5.	Control scaling
6.	Reduce cost of and improve technology for drilling
7.	Improve injection capability
8.	Improve capability for determining reservoir recharge
9.	Develop 10-20 MWe power systems
10.	Reduce effluent pollution (H_2S , mercury, radium, arsenic)
11.	Increase electrical power cycle efficiency
12.	Reduce corrosion and erosion
13.	Establish confidence in the economics and reliability of direct heat systems
14.	Improve capability of downhole instruments and log interpretation
15.	Improve reliability of downhole pumps
16.	Improve systems modeling capability
17.	Develop 1 - 5 MWe wellhead generators
18.	Improve understanding of reservoir chemistry
19.	Improve capability to predict or control induced seismicity and subsidence
20.	Improve availability of existing geoscience and resource data
21.	Reduce cost of heat exchangers
22.	Improve technology for power plant cooling systems
23.	Improve nonmetallic materials (seals, coatings, tools, cables)
24.	Reduce cost of hardware for direct heat applications
25.	Develop low temperature refrigeration and air conditioning equipment
26.	Reduce cost of component testing in hydrothermal environment

Summary	Developers	A&E Firms	Financial Firms	Utilities	Direct Heat Users
☐	☐	☐	☐	☐	1. Improve reliability of downhole pumps
☐	☐	☐	☐	☐	2. Reduce cost of heat exchangers
☐	☐	☐	☐	☐	3. Reduce corrosion and erosion
☐	☐	☒	☐	☐	4. Improve injection capability
☐	☐	☐	☐	☐	5. Develop 10-20 MWe power systems
☐	☐	☐	☐	☐	6. Reduce cost of component testing in hydrothermal environment
☐	☐	☐	☐	☐	7. Improve the technology for power plant cooling systems
☐	☐	☐	☐	☐	8. Improve non-metallic materials (seals, coatings, tools, cables)
☐	☐	☐	☒	☐	9. Improve system modeling capability (reservoirs through power cycles and injections)
☐	☐	☐	☒	☐	10. Improve capability for determining reservoir recharge
☐	☐	☐	☐	☐	11. Reduce effluent pollution (H ₂ S, mercury, radium, arsenic)
☐	☒	☐	☐	☐	12. Improve capability to predict or control induced seismicity and subsidence
☐	☐	☐	☐	☐	13. Develop low temperature refrigeration and air conditioning equipment
☐	☐	☐	☐	☐	14. Improve capability of downhole instruments and log interpretation (geophysical and geochemical)
☐	☐	☐	☒	☒	15. Establish confidence in the economics and reliability of direct heat systems
☒	☒	☐	☐	☒	16. Determine economics and reliability of a commercial size binary plant (50 MWe)
☒	☒	☒	☐	☒	17. Reduce the risk and cost of exploration
☐	☐	☐	☐	☐	18. Improve the availability of existing geoscience and resource data (low, moderate, and high temperature)
☒	☐	☒	☐	☒	19. Control scaling
☒	☒	☒	☐	☒	20. Reduce hydrothermal field development costs and improve well flow rates
☐	☒	☐	☐	☒	21. Reduce cost of and improve technology for drilling (fluids, motors, bits, cements, and packers)
☐	☒	☐	☒	☐	22. Develop 1-5 MWe wellhead generators
☒	☒	☒	☒	☒	23. Increase reservoir confidence (reservoir engineering and assessment techniques)
☐	☐	☐	☐	☐	24. Improve understanding of reservoir chemistry (rock and fluid)
☐	☐	☐	☐	☐	25. Increase electrical power cycle efficiency
☐	☐	☐	☐	☒	26. Reduce cost of hardware for direct heat applications

INEL-A-13 855

Figure 12. Top five technology requirements to accelerate hydrothermal energy commercialization, as viewed by five different industries.

Summary	Developers	A&E Firms	Financial Firms	Utilities	Direct Heat Users	
☐	☐	☐	☐	☒	☐	1. Improve reliability of downhole pumps
☐	☐	☐	☐	☐	☐	2. Reduce cost of heat exchangers
☐	☐	☐	☒	☒	☐	3. Reduce corrosion and erosion
☒	☒	☒	☐	☒	☐	4. Improve injection capability
☒	☒	☐	☒	☒	☒	5. Develop 10-20 MWe power systems
☐	☐	☐	☐	☐	☐	6. Reduce cost of component testing in hydrothermal environment
☐	☐	☐	☐	☐	☐	7. Improve the technology for power plant cooling systems
☐	☐	☐	☐	☐	☐	8. Improve non-metallic materials (seals, coatings, tools, cables)
☐	☐	☐	☒	☐	☐	9. Improve system modeling capability (reservoirs through power cycles and injections)
☒	☐	☒	☒	☐	☒	10. Improve capability for determining reservoir recharge
☒	☐	☒	☐	☐	☐	11. Reduce effluent pollution (H ₂ S, mercury, radium, arsenic)
☐	☐	☐	☐	☐	☒	12. Improve capability to predict or control induced seismicity and subsidence
☐	☐	☐	☐	☐	☐	13. Develop low temperature refrigeration and air conditioning equipment
☐	☒	☐	☐	☐	☐	14. Improve capability of downhole instruments and log interpretation (geophysical and geochemical)
☐	☐	☒	☒	☐	☒	15. Establish confidence in the economics and reliability of direct heat systems
☒	☒	☒	☒	☒	☒	16. Determine economics and reliability of a commercial size binary plant (50 MWe)
☒	☒	☒	☐	☒	☒	17. Reduce the risk and cost of exploration
☐	☐	☐	☐	☐	☐	18. Improve the availability of existing geoscience and resource data (low, moderate, and high temperature)
☒	☒	☒	☒	☒	☐	19. Control scaling
☒	☒	☒	☐	☒	☒	20. Reduce hydrothermal field development costs and improve well flow rates
☒	☒	☒	☐	☒	☐	21. Reduce cost of and improve technology for drilling (fluids, motors, bits, cements, and packers)
☐	☒	☐	☒	☐	☐	22. Develop 1-5 MWe wellhead generators
☒	☒	☒	☒	☒	☒	23. Increase reservoir confidence (reservoir engineering and assessment techniques)
☐	☐	☐	☒	☐	☐	24. Improve understanding of reservoir chemistry (rock and fluid)
☐	☐	☐	☐	☐	☒	25. Increase electrical power cycle efficiency
☐	☐	☐	☐	☐	☒	26. Reduce cost of hardware for direct heat applications

INEL-A-13 854

Figure 13. Top ten technology requirements to accelerate hydrothermal energy commercialization, as viewed by five different industries.

Summary	Electric	Direct Heat	
☐	☐	☐	1. Improve reliability of downhole pumps
☐	☐	☐	2. Reduce cost of heat exchangers
☐	☐	☐	3. Reduce corrosion and erosion
☐	☐	☐	4. Improve injection capability
☐	☐	☐	5. Develop 10-20 MWe power systems
☐	☐	☐	6. Reduce cost of component testing in hydrothermal environment
☐	☐	☐	7. Improve the technology for power plant cooling systems
☐	☐	☐	8. Improve non-metallic materials (seals, coatings, tools, cables)
☐	☐	☐	9. Improve systems modeling capability (reservoirs through power cycles and injections)
☐	☐	☐	10. Improve capability for determining reservoir recharge
☐	☐	☐	11. Reduce effluent pollution (H ₂ S, mercury, radium, arsenic)
☐	☐	☐	12. Improve capability to predict or control induced seismicity and subsidence
☐	☐	☐	13. Develop low temperature refrigeration and air conditioning equipment
☐	☐	☐	14. Improve capability of downhole instruments and log interpretation (geophysical and geochemical)
☐	☐	☒	15. Establish confidence in the economics and reliability of direct heat systems
☒	☒	☐	16. Determine economics and reliability of a commercial size binary plant (50 MWe)
☒	☒	☒	17. Reduce the risk and cost of exploration
☐	☐	☐	18. Improve the availability of existing geoscience and resource data (low, moderate, and high temperature)
☒	☒	☐	19. Control scaling
☒	☒	☒	20. Reduce hydrothermal field development costs and improve well flow rates
☐	☐	☐	21. Reduce cost of and improve technology for drilling (fluids, motors, bits, cements, and packers)
☐	☐	☐	22. Develop 1-5 MWe wellhead generators
☒	☒	☒	23. Increase reservoir confidence (reservoir engineering and assessment techniques)
☐	☐	☐	24. Improve understanding of reservoir chemistry (rock and fluid)
☐	☐	☐	25. Increase electrical power cycle efficiency
☐	☐	☒	26. Reduce cost of hardware for direct heat applications

INEL-A-13 856

Figure 14. Top five technology requirements to accelerate hydrothermal energy commercialization, as viewed by electric and direct heat industries.

Summary	Electric	Direct Heat	
☐	☒	☐	1. Improve reliability of downhole pumps
☐	☐	☐	2. Reduce cost of heat exchangers
☐	☐	☐	3. Reduce corrosion and erosion
☒	☒	☒	4. Improve injection capability
☒	☐	☒	5. Develop 10-20 MWe power systems
☐	☐	☐	6. Reduce cost of component testing in hydrothermal environment
☐	☐	☐	7. Improve the technology for power plant cooling systems
☐	☐	☐	8. Improve non-metallic materials (seals, coatings, tools, cables)
☐	☐	☐	9. Improve systems modeling capability (reservoirs through power cycles and injections)
☒	☒	☒	10. Improve capability for determining reservoir recharge
☒	☒	☐	11. Reduce effluent pollution (H ₂ S, mercury, radium, arsenic)
☐	☐	☐	12. Improve capability to predict or control induced seismicity and subsidence
☐	☐	☐	13. Develop low temperature refrigeration and air conditioning equipment
☐	☐	☐	14. Improve capability of downhole instruments and log interpretation (geophysical and geochemical)
☐	☐	☒	15. Establish confidence in the economics and reliability of direct heat systems
☒	☒	☐	16. Determine economics and reliability of a commercial size binary plant (50 MWe)
☒	☒	☒	17. Reduce the risk and cost of exploration
☐	☐	☐	18. Improve the availability of existing geoscience and resource data (low, moderate, and high temperature)
☒	☒	☒	19. Control scaling
☒	☒	☒	20. Reduce hydrothermal field development costs and improve well flow rates
☒	☒	☒	21. Reduce cost of and improve technology for drilling (fluids, motors, bits, cements, and packers)
☐	☐	☐	22. Develop 1-5 MWe wellhead generators
☒	☒	☒	23. Increase reservoir confidence (reservoir engineering and assessment techniques)
☐	☐	☐	24. Improve understanding of reservoir chemistry (rock and fluid)
☐	☐	☐	25. Increase electrical power cycle efficiency
☐	☐	☒	26. Reduce cost of hardware for direct heat applications

INEL-A-13 857

Figure 15. Top ten technology requirements to accelerate hydrothermal energy commercialization, as viewed by the electric and direct heat industries.

accelerated commercialization of hydrothermal energy, additional information was gathered on institutional problems. The issues mentioned most frequently are listed below:

1. Federal regulations and approval delays
2. Inadequacy of tax and rate of return incentives for a new, improved technology
3. Legal and financial aspects associated with reservoir risk
4. Faster resolution of environmental restraints
5. Compliance with the myriad of federal and state regulations
6. Diffusion of authority of permitting
7. Inefficiencies and "red tape"
8. Broad ignorance of the economic potential by users and their lenders.

NATIONAL GEOTHERMAL DIRECT HEAT APPLICATIONS MANPOWER AND EXPENDITURE REQUIREMENTS THROUGH FY 1987

(Ben C. Lunis)

Commercialization of geothermal energy requires the development of an extensive new industry consisting of an infrastructure of developers, financiers, designers, builders, and operators. An analysis has been made of the capital and manpower needed through 1987, to place 6800 MW of direct applications development on line. The number and sizes of projects have been estimated, success ratios assumed, project types identified, and average development costs assigned to obtain an overview of cost and manpower needs. Following is a brief discussion of this activity.

Average costs per kW and development times were assumed for three generic systems: district heating, industrial parks, and single industry, and are shown in Table 4.

The systems are sized from 100 MWt to 5 MWt or less. Depending on the time required for

resource development, design, and construction, these were evaluated to determine the year in which they are most likely to be operational. Average costs for each system have been applied, and labor and material costs were apportioned. Starting in 1980, it is expected that expenditures in the order of \$85 million will grow to \$775 million in 1987 and continue to increase thereafter (Figure 16). Converting these amounts to equivalent manpower needs, design, construction, administration, and other support personnel will probably grow to more than 11 120 man-years in 1987, as shown in Figure 17. These evaluations considered only the cost of the geothermal systems needed to operate plants. To obtain an indication of the national expenditure that will be required for geothermal systems, plus the plants in which the systems operate, an average value of \$2000 per kW can be applied. On this basis, it is expected that industry will have invested over \$20 billion through the year 1987.

TABLE 4. ASSUMED DIRECT-HEAT PROJECT COST AND TIME VALUES

Item	Average Development Time (years)	Average Cost (\$/kW)
District Heating	3 ^a	700
Industrial Parks	3 ^a	500
Single Industry >25 MWt	3 ^a	300
Single Industry 5 to 25 MWt	2 ^a	300

a. After the first well is proven. Resource development requires 1-2 years

Figure 16. Projected national expenditures through FY 1987 for direct heat applications development.

Figure 17. Projected national manpower needs through FY 1987 for direct heat applications development.

PON AND PRDA PROJECTS

(E. DiBello, F. Childs, K. Jones, L. Nelson, J. Strawn)

The Commercialization Support Branch of EG&G Idaho's Geothermal Program provides technical assistance to DOE for the Program Research and Development Announcement (PRDA) and Program Opportunity Notice (PON) Program. Both programs were instituted to hasten the commercialization of geothermal energy's direct application. The PRDA Program consists of a series of studies designed to investigate the engineering and economic feasibility of geothermal direct applications. The PON Program is a demonstration project program in which project costs are shared between DOE and the private companies, municipalities, or organizations conducting each demonstration.

During this reporting period, EG&G Idaho provided program management and technical support for 12 demonstration projects and eight engineering and economic studies. Each project is summarized below:

PON Projects

Ore-Ida Foods, Inc., Ontario, Oregon. The Ontario Ore-Ida Foods, Inc., plant, 92 km (57 mi) northwest of Boise, Idaho, processes potatoes, corn, and onions and currently uses natural gas and oil for process heat. This demonstration project was designed to substitute geothermal energy for potato-processing heat, space heat, and hot potable water. Heat loads are now about 97 200 MWh/yr (33.2×10^{10} Btu/yr). The resource was predicted to be 50 l/s (800 gal/min) at 160°C (320°F) from two production wells. A central group of 11 heat exchangers and one injection well was planned.

DOE reviewed and approved Ore-Ida's environmental report. Neither an environmental assessment nor an environmental impact statement was required. Ore-Ida reviewed 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.

Drilling of the first production well commenced on August 19, 1979 and reached a total depth of 3065 m (10 054 ft). A bottom hole temperature of

180°C (357°F) was recorded. To date, however, sufficient quantities of fluid have not been produced to warrant retrofit of the processing plant. Alternatives for continuation of the project, including well stimulation, are being considered.

Monroe City, Utah. Monroe City is a community of 1500 people, 257 km (160 mi) south of Salt Lake City, Utah. The local economy is based primarily on agriculture. The project will entail drilling one production, 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 41 l/s (1650 gal/min). 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 2700 kW.

DOE reviewed and approved the Monroe City environmental report. Neither an environmental assessment nor an environmental statement was required.

Two test holes (MC.1 and MC.2) were drilled by the University of Utah under the State-Coupled Program. Based on the available resource data, the production well site was selected, the land was leased, and the 450-m (1500-ft) production well (MC.3) was completed. A flow of 38.6 l/s (612 gal/min), at 75°C (165°F) has been demonstrated. Preliminary system design, costing, and planning for injection well drilling was under way at the end of the report period.

Haakon School District, Philip, South Dakota. The town of Philip is located approximately 129 km (80 mi) 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 approved by

DOE. A 1300-m (4266-ft) well was drilled and flow tested. The well is capable of sustaining a long-term artesian flow rate of 19 l/s (300 gal/min), while maintaining sufficient wellhead pressure. The flowing temperature of the resource is 70°C (157°F). Corrosion testing has been completed and final design review will be conducted in January 1980. The heating system is scheduled to be on-line for the 1980-81 heating season.

St. Mary's Hospital, Pierre, South Dakota. St. Mary's Hospital in Pierre, South Dakota is currently heated by a fossil-fuel system. This project will demonstrate the feasibility of using low-temperature water from a 666-m (2186-ft) Madison well for space heating. Since the aquifer characteristics in this area were not well known, water quality and well production characteristics have been closely monitored since the well was completed. Based upon the water temperatures and quality, heating and ventilating system modifications were designed to utilize the geothermal fluid.

DOE approved the environmental report, and the well drilling phase of the project was completed at a cost of approximately \$250,000.

Well test data indicated a maximum static wellhead pressure of 3309 kPa (480 psig) and a flow of 24 l/s (375 gal/min) at 186 kPa (27 psig) and 41°C (106°F). The system design has been completed and DOE has approved initiation of the retrofit of hospital heating system.

Diamond Ring Ranch, Haakon County, South Dakota. Geothermal water from an artesian well that has flowed since 1959 will be used for grain drying and space heating 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. Then it will be discharged into a reservoir system now used for both geothermal-well and runoff catchment. The environmental report and final system design were completed for the project, and construction began in July. The project is scheduled for completion in December, followed by the startup and monitoring phase.

Elko, Nevada. The Elko project involves the location and drilling of a production well to extract hydrothermal fluids from the Elko KGRA. These fluids are to be used to displace the primary fuel used to operate a commercial laundry, a motor hotel, and an office building.

One production well will be drilled to a depth of 213-609 m (700-2000 ft) and the resource characteristics will be determined. After heat has been extracted, the water will be injected into a well of similar depth.

The project is in the resource assessment phase. A temperature probe survey, geologic reconnaissance, electrical resistivity soundings, sling ram soundings, and geochemical sampling of city wells and the Elko Hot Springs were completed.

The environmental report has also been completed. Neither an environmental assessment nor an environmental impact statement will be required.

Warm Springs State Mental Hospital, Montana. The project objective is to develop the geothermal resource at Warm Springs (near Butte, Montana) to provide domestic water and space heating at the Warm Springs State Mental Hospital. Water from the production well will be pumped through two plate-type heat exchangers and discharged into a wetlands disposal area.

DOE has approved the environmental report, and a geophysical survey, conducted by the Montana College of Mineral Science, consisted of gravity and resistivity surveys. A review and interpretation of existing geologic and geophysical literature supplemented the geophysical survey.

The production well site was selected and the well completed to a total depth of 381 m (1250 ft). Preliminary flow test data indicated a wellhead temperature of 70°C (160°F) at 3.2 l/s (50 gal/min) artesian flow.

Pagosa Springs, Colorado. The geothermal resource in Pagosa Springs has been used on a limited basis since the early 1900s. Since then, nearly 30 wells have been drilled for heating and recreational purposes. These wells are drilled to depths of less than 152 m (500 ft) and produce

water ranging in temperature from 54 to 77°C (130 to 170°F). Flow from several existing wells in the town will be used for the proposed district heating system. In general, all public buildings in the town will be heated with geothermal energy. Other commercial or residential buildings that can logically be served from the distribution pipelines will also eventually connect to the system.

DOE approved the environmental report and the resource evaluation flow-test plan. Well monitoring equipment is being installed and a file of existing hydrological and geological data has been compiled. The project is coordinating with appropriate regulatory agencies and a survey of prospective users has been conducted. The conceptual design was reviewed and the preliminary design phase is under way.

Utah Roses, Sandy, Utah. The Utah Roses facility in Sandy, Utah consists of a 23 225-m² (250 000-ft²) commercial greenhouse that produces cut roses for the national floral market. This project is designed to demonstrate to the public the potential offered by geothermal space heating in a highly populated area. Geothermal water from a production well will be piped through water-to-air heat exchangers in the greenhouse. The heated air will be distributed in polyethylene tubes throughout the greenhouse. Present plans call for the discharge of the geothermal fluid into a waste water canal.

The environmental report was approved. Neither an environmental assessment nor an environmental impact statement will be required. A 1525-m (500-ft) production well is scheduled for completion in December 1979. Preliminary test data indicated a bottom hole temperature of 66°C (150°F). Flow testing will be conducted in January 1980.

Utah State Prison, Draper, Utah. The site of the Utah State Prison project is in the southern portion of Salt Lake County, near Draper, Utah. Located just west of the Wasatch Range, the surface expression of the resource is known as Crystal Hot Springs.

The preliminary system design for the Utah State Prison minimum security block includes plans for a space heating system with a design load of 705 kW and a culinary water system with a design load of 500 kW.

One production well and one injection well (if needed) are anticipated. Siting of the production hole will be based on the results of a detailed gravity survey and thermal test hole drilling program. The injection well will be drilled if water quality parameters preclude surface disposal, in which case the water could be disposed of in near-surface alluvial aquifers.

The first phase of the project has just begun; the detailed gravity survey is in progress and plans are being made for a test hole drilling program.

Madison County, Idaho. The Madison County geothermal project will demonstrate the economic and technical feasibility of using a low-temperature geothermal resource for food processing and district space heating.

Madison County and Rexburg are at the eastern edge of the Snake River Plain, which has been characterized as a young volcanic rift. Northeast trending faults, concentrated along the plain boundaries, are the source of many hot springs.

In consideration of the available data, a geothermal resource of 177 to 231°C (350 to 450°F) is believed to exist at a depth of 2438 to 2743 m (8000 to 9000 ft) below the Snake River Plain. The target depth of the production well will be between 1524 and 2134 m (5000 and 7000 ft) to encounter a resource of at least 121°C (250°F).

Two production wells at 914 and 1830 m (3000 and 6000 ft) are planned. The deep well will supply 121°C (250°F) water to a potato processing company for use in food processing.

Madison County will then receive the partially spent water from the processing plant, at 88°C (190°F) and will supplement it with water from the 914-m (3000-ft) well, if required. Madison County will use the water for a space heating system.

The environmental report has been submitted and approved. Two thermal gradient holes have been drilled to 457 m (1500 ft). The resource data will be evaluated before drilling the first production well.

Boise, Idaho. The objective of the Boise City/Boise Warm Springs Water District Geothermal Project is to develop a geothermal space

heating system to serve the largest possible commercial and residential market in the Boise central business district and neighboring residential areas.

The geothermal resource for the project is localized along the Boise Front which marks a major linear physiographic break between the foothills to the northeast, and the Boise River floodplain to the southwest.

The project is being administered by Boise Geothermal, which is a joint venture of Boise City and Boise Warm Springs Water District. The project consists of two parts. The first is a follow-on to the Boise Warm Springs Water District's heating system, which has been operating since the 1890s and currently serves 220 residences with 77°C (170°F) water from two wells.

The second part of the project is a new system that will draw the resource from a separate part of the Boise Front. It will supply heat to the central business district and the State Capital Mall area.

The completed system capacity will be a nominal 315 L/s (5000 gal/min) designed to take advantage of a temperature drop from 77 to 49°C (170 to 120°F).

Preliminary work on geological and environmental studies began in March, 1979. Both studies have been completed and are undergoing review. A market and rate analysis will be completed in October 1979 to establish an operational rate structure for the resulting heating district. Upgrading of the two existing wells, which service approximately 220 residences, has been completed. A comprehensive project plan is being drafted for the remainder of the contract term, which will cover the period from April 1980 to October 1982.

PRDA Projects

Final reports for the following study projects were published:

1. *Geothermal Energy Applications in an Integrated Livestock Meat and Feed Production Facility for Mountain Home, Idaho*

Directed by Energetics Marketing and Management Associates, Ltd., of San

Francisco, California, this study details the requirements for the early commercialization of geothermal energy in an integrated livestock meat and feed production system.

2. *Western South Dakota Usage of Geothermal Energy from the Madison Formation*

This study, conducted under the direction of Edgemont School District 23-1, investigates methods for utilizing the available geothermal water in Edgemont, South Dakota, for heating the school complex in that community.

The following study projects were in progress as of September 1979. Final reports for these projects will be available in 1980.

1. *Residential and Commercial Space Heating and Cooling with Possible Greenhouse Operation: Baca Grande Development, San Luis Valley, Colorado*

This study is being conducted by Coury and Associates, Inc., of Lakewood, Colorado. The objective of the study is to investigate the multipurpose commercial application of moderate-temperature geothermal waters at the Baca Grande Community Development in the San Luis Valley.

2. *Direct Application of Geothermal Energy at the Legg's Products Plant, Las Cruces, New Mexico*

This study is being conducted by the Energetics Corporation of Dallas, Texas. Project scope includes an evaluation of the potential applications of geothermal energy to hosiery manufacturing at the Las Cruces Legg's plant.

3. *Direct Application of Geothermal Energy for Ethanol Production for Automotive Fuel Usage*

This study is being conducted under the direction of Bechtel National, Inc. The engineering and economic feasibility of utilizing the geothermal resource at Raft River, Idaho, is being evaluated. A Phase I report for this study is available.

4. *Evaluation of Direct Hot Water Geothermal Applications on the University of New Mexico Campus*

This study is being conducted by staff members of the University of New Mexico. The objective of the project is to establish the engineering and economic feasibility of providing geothermal space heating and cooling for approximately 25% of the university campus. The first quarterly report for this project is available.

5. *Municipal Geothermal Heat Utilization Plan for Glenwood Springs, Colorado*

This study is being completed under the direction of the Denver Research Institute. The study will assess the geothermal resource in the Glenwood Springs area and examine the feasibility of supplying heat to several city buildings.

6. *Geothermal Space Heating in Poplar, Montana*

This study is being conducted by PRC, Toups Inc., and the Council of Energy Resource Tribes. The primary objective of the project is to define the feasibility of using the Madison Aquifer resource for district heating in the Poplar home area. The Phase I report for this project is available.

APPENDIX A
PUBLICATIONS OF THE IDAHO GEOTHERMAL PROGRAM

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Table A-1 lists the formal reports published by employees of the Idaho Geothermal Program. Printed or microfiche copies of these reports may be ordered from the National Technical Informa-

tion Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

TABLE A-1. EG&G IDAHO, INC.: FORMAL REPORTS OF THE IDAHO GEOTHERMAL PROGRAM

<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 200 to 400°F

TABLE A-1 (continued)

TREE Number	Author	Date	Title
1112	S. E. Turner	4-77	HECDOR-A Heat Exchanger Cost and Design Optimization Routine
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
1295	G. L. Blake, ed.	11-78	Semiannual Progress Report for the Idaho Geothermal Program, April 1, to September 30, 1978
1312	J. F. Whitbeck et al	1-79	Measurement and Control Techniques in Geothermal Power Plants
1340	S. G. Spencer et al	4-79	1978 Annual Report, INEL Geothermal Environmental Program
1359	L. F. Burdige et al	10-79	Semiannual Progress Report for the Idaho Geothermal Program, October 1, 1978 to March 31, 1979

TABLE A-1 (continued)

<u>TREE Number</u>	<u>Author</u>	<u>Date</u>	<u>Title</u>
1365	O. Jack Demuth	7-79	Analysis of Binary Thermodynamic Cycles for a Moderately Low- Temperature Geothermal Resource
1370	J. F. Sullivan et al	9-79	Raft River Geothermal Aquaculture Experiment-Phase II