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Idaho Operations Office • Idaho National Engineering Laboratory

Semiannual Progress Report For The Idaho Geothermal Program October 1, 1979 To March 31, 1980

R.R. Ihrig, Ed.

July 1980

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Prepared for the
U.S. Department of Energy
Under DOE Contract No. DE-AC07-76ID01570

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Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161
NTIS Price Codes: Printed Copy A03
Microfiche A01

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EGG-2034
Distribution Categories:
UC-66a, b, c, d, e, g, j
Geothermal Energy

SEMIANNUAL PROGRESS REPORT FOR THE IDAHO GEOTHERMAL PROGRAM OCTOBER 1, 1979 TO MARCH 31, 1980

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Published July 1980

**EG&G Idaho, Inc.
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ABSTRACT

This document reports progress of the Idaho Geothermal Program between October 1, 1979 and March 31, 1980. The report summarizes progress on the 5-MW Pilot Power Plant at the Raft River Geothermal Test Site including construction, steady-state and transient analyses by computer modeling, the geothermal water treatment program, and additional experimental and theoretical work on direct contact heat exchangers. It also summarizes asbestos-cement pipe failures in the geothermal fluid supply and injection system. The successful automatic control-mode testing of the Prototype Power Plant is reported. The report outlines a continuing direct applications experiment in aquaculture and briefly describes a proposal to study various ramifications of irrigating agricultural and range

lands with spent geothermal fluid. Also outlined is the second experimental hydraulic fracture treatment of a geothermal well at Raft River as part of the National Well Stimulation Program. The report describes improvements to the Raft River site facilities, and presents progress in providing technical information and assistance in the Outreach, or User Assistance Program. Also presented is a new DOE program, the User Coupled Confirmation Drilling Program, which is intended to reduce the financial risk of hydrothermal reservoir exploration by the private sector. Progress reports are also included on DOE's Program Opportunity Notice (PON) Program demonstration projects and Program Research and Development Announcement (PRDA) Program study projects.

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SUMMARY

The objective of the Idaho Geothermal Program is to develop, demonstrate, and encourage the use of hydrothermal energy.

At the Raft River Geothermal Test Site, construction of the 5-MW Pilot Power Plant continued during the reporting period. The turbine generator support structure was erected, associated underground piping and conduit was installed, and the turbine generator was received in February. Installation is scheduled for April. The thermal loop facility construction continued; small piping and instrumentation installation remains. Three supply pumps failed during attempted testing of the fluid supply and injection system. All three have been refurbished and reinstalled, and will be tested in the early part of the next reporting period. Plant steady-state and transient analyses were completed by computer simulation. Key operating supervisory personnel are on board, and additional staff recruiting is under way. The preparation of operational and maintenance procedures was subcontracted, and this task is 35% complete.

In the water treatment program, tests are being conducted to evaluate methods of preventing scale and corrosion in carbon steel systems, particularly the 5-MW Pilot Power Plant condenser. In support of the Prototype Power Plant project, a test program was outlined for sidestream treatment experiments on chromate removal and reuse by ion exchange, precipitation of silica with iron, removal of calcium by ion exchange, and solids reduction by reverse osmosis. Tests will also define operating parameters for pretreatment of geothermal fluid (cooling tower makeup) in a continuous flow process.

Mechanical installation is complete on the supply and injection system. Instrumentation installation is 60% complete and is scheduled for completion in July. Data on the Transite asbestos-cement pipeline, dating from December 1975, were compiled as part of the feasibility study. Supply pump failures have also been a continuing concern, and DOE is directing a pump development program at other locations.

The initial test phase of the Prototype Power Plant was successfully completed using shell-and-tube heat exchangers and isobutane as the working

fluid. This test demonstrated that the plant performs well in the automatic control mode and also provided component and performance data. The plant operated approximately 87% of the time that geothermal fluid was available.

Environmental monitoring at Raft River during this reporting period included air quality, meteorology, water quality, hydrology, subsidence, socioeconomics, and terrestrial and aquatic ecology. Data gathered will be published in the next reporting period.

Research continued on design correlations for sizing direct contact condensers, especially packed bed condensers, at the University of Utah. This included the development of a theoretical model for condensation on a falling film, which is described in a paper to be presented at the 1980 National Heat Transfer Conference. Contractors were solicited to make a comparative study of heat rejection systems for binary geothermal power plants, and a contractor was selected. A formal work statement is being prepared. Modeling of conventional and augmented surface heat exchangers is being performed to determine if augmented surfaces in heat exchangers are cost effective for geothermal sites with relatively clean water. An initial step in this work, which is essentially complete, is the analysis of simple, smooth tube heat exchangers. Liquid-liquid direct contact heat transfer tests have also been conducted in a perforated plate column. Results indicated improved heat transfer performance.

Experiments in the aquaculture portion of the direct applications program focused on the reproductive phase of adult carp and channel catfish reared in geothermal water during 1979. In the agriculture project, a proposal was submitted to DOE-ID that presented a research plan to answer the legal, technical, and environmental questions surrounding the use of geothermal effluent for irrigation. It also proposed to investigate the use of 5-MW power plant effluent to increase production on area agricultural and range lands.

As part of the National Well Stimulation Program, EG&G personnel supported a second hydraulic fracture experiment—this time on well RRGP-5—which encountered difficulties.

The Raft River Case Study was not funded in this reporting period, but plans were under way in late March to resume the project in the second half of FY-80.

During this reporting period, the Raft River site facilities were improved in several areas. An increased-capacity geothermal heating system was designed and installed, bringing the total of geothermally heated buildings to seven; one is geothermally air conditioned. Some of the most heavily travelled roads were paved, flood control measures were taken to prevent damage by spring runoff, and temporary working space was added for the 5-MW Pilot Power Plant startup and operating personnel. Security fencing and lighting were added, and a contract was signed by DOE to provide improved 24-hour security surveillance for the entire Raft River site.

Also at Raft River, the material handling and property control facilities were greatly improved, and the Data Acquisition and Control System was installed and is partially operational.

The Outreach Program, or User Assistance Program, continued to provide technical information and assistance to an increasing number of requesters. Because of funding limitations, subcontracting of technical assistance will be curtailed for the balance of FY-80.

DOE is initiating the User Coupled Confirmation Drilling Program to reduce the risk and cost of hydrothermal reservoir exploration and thereby speed hydrothermal energy industrialization. The new program is to be initiated in May 1980, and will be managed for DOE Headquarters by the Idaho Operations Office of DOE with assistance from the Earth Science Laboratory of the University of Utah Research Institute, EG&G Idaho, Inc., and the Nevada Operations Office of DOE.

Twelve demonstration projects in the Program Opportunity Notice (PON) Program continued to progress during the reporting period, and five engineering and economic studies continued in the Program Research and Development Announcement (PRDA) Program. EG&G provided program management and technical support.

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RAFT RIVER GEOTHERMAL TEST SITE

The Idaho Geothermal Program, sponsored by the Department of Energy, has conducted field experiments at the Raft River Geothermal Test Site since 1973. Located southwest of the small town of Malta in south central Idaho, the geothermal area is the center of wide-ranging studies into various applications of the area's medium-temperature (150°C) geothermal fluids. Scientists, engineers, and other personnel from DOE's Idaho National Engineering Laboratory (INEL) perform experiments and program support functions.

A major effort at Raft River is to operate and maintain the Prototype Power Plant and the 5-MW Raft River Pilot Power Plant, which is being built to demonstrate the feasibility of using medium-temperature geothermal fluid to generate electric power. Progress of these activities is described below.

ELECTRIC APPLICATIONS

Five-Megawatt Pilot Power Plant

(T. L. Rasmussen)

Construction of the 5-MW plant continued during this reporting period. The turbine generator support structure was erected along with associated underground piping and conduit. The turbine generator was received in February and is scheduled to be set in place in early April.

The thermal loop facility construction continued with remaining work consisting of small piping and instrumentation installation. Facility transfers have been completed on site buildings and the culinary and fire water systems. Construction checks and system operational testing is in progress.

During attempted testing of the geothermal water supply and injection system, all three supply pumps failed. The pumps were removed and

returned to the vendor for refurbishment and retrofit of design improvements. The pumps have been reinstalled, and further testing will be performed in the early part of the next reporting period. Some final instrumentation installation remains to complete this system.

Test planning for initial plant operation and checkouts was initiated and plant steady-state and transient analyses were completed and reported.

Preparations were made for staffing and implementing the plant operating organization. Key operational supervisory personnel are on board, and recruiting of the balance of required staff is under way. Administrative control documentation was developed and implemented. Plans and procedures for plant acceptance testing were developed and the acceptance test program is being performed. The preparation of operational and maintenance procedures was subcontracted to Westec Services, Inc. This task was 35% complete at the end of the reporting period. Spare parts and operational materials (isobutane, propane, nitrogen, chemicals, etc.) were ordered.

The Environmental Monitoring Plan was completed and issued and the described monitoring activities continued. Additional programs in air quality and ground subsidence monitoring during well field operation were started.

Support Engineering (C. J. Blum). The steady-state performance analysis of the Raft River geothermal 5-MW Pilot Power Plant investigated in the previous reporting period was extended to include the transient behavior of the plant. The transient behavior was predicted by the same basic computer simulation used in determining the steady-state performance mapping. Some changes were made to allow the simulation of planned transients such as startup transients, and upset transients such as loss of electricity and valve or pump failures. The plant control systems

modeled included boiler-level control, isobutane pump flow control, turbine bypass flow control, turbine throttle valves, and geofluid temperature control valves.

Generally, the control-action simulation for the controllers has been taken as proportional plus integral. The results of this study are being used to select setpoints and determine action to be taken as a result of failures.

Basically, the transients in three categories were studied: (a) normal transients, (b) transients resulting from failure of a single component, and (c) more severe transients resulting from failure of a subsystem. For this study, no response was made to the initial transient. Instead the system was allowed to reach a new equilibrium resulting from the failure.

Four basic types of normal transients were studied:

1. Thermal loop startup
2. Turbine generator startup
3. Turbine generator shutdown
4. Thermal loop shutdown

To study the consequences of various single-component failures during plant operation, the computer model of the plant was run to simulate:

1. Pump Failure
 - geothermal well pump failure
 - geothermal boost pump failure
 - cooling water pump failure
 - isobutane feed pump failure
2. Control Valve Failure
 - high boiler feed valve failure
 - low boiler feed valve failure
 - isobutane pump bypass valve failure
 - high turbine bypass valve failure
 - low turbine bypass valve failure

The simulated data will be used to identify and evaluate the effects of component failures. The third category of transients studied includes more severe failures than those investigated for the single-component failure category. The cases include complete flow loss of geothermal fluid, isobutane, or cooling water, and total loss of electrical power.

The results of the transient analyses for the 5-MW Pilot Power Plant are summarized as follows:

1. The normal plant transients from cold conditions to thermal loop steady-state to turbine power to turbine shutdown (including an abrupt switchoff) to thermal loop shutdown were predicted to be satisfactory. No problems are anticipated.
2. For a thermal startup or shutdown, stepping the turbine bypass valves during startup or shutdown gives a greater margin of safety, relative to boiler inlet subcooling (boiler inlet flow cavitation and flashing), than does keeping them at one setting through the entire transient.
3. A turbine switchoff creates a small perturbation in the geothermal fluid outlet temperature (a 5.6°C, or 10°F rise in 50 seconds and a similar drop in 100 seconds). This temperature rise will probably cause no problems in operations of the field, but may be significant in setting the three-way loop valve in the injection line.
4. Single pump failures do not create a sufficiently large transient to cause problems when the plant is producing power. The most severe disturbance is a 1.5-MW(e) drop in output power caused when the geothermal fluid flow rate is cut in half.
5. Feed valve failures generally cause a drying out of the boilers. In the high pressure boiler, complete dryout takes approximately 70 seconds; in the low boiler, 4 minutes.
6. When reverse flow takes place out of the high boiler, the control valve unexpectedly increases outflow instead of shutting it off. This flow reversal can occur when the turbine throttle valve is closed and an isobutane pump bypass valve or a high pressure turbine bypass valve fails. Installation of check valves in the boiler feed lines is being considered to prevent the backflow.

7. Total stoppage of geothermal fluid flow results in a cool-down in the high pressure boiler of 83°C (150°F) in 10 minutes, which exceeds the design rate of 28°C (50°F) per hour. The effect of this rapid cool-down on the boiler will be investigated further.
8. Total loss of cooling water flow results in a system heat-up to the high pressure boiler temperature in approximately 10 minutes. This creates a heating rate in the heat exchangers at the same rate as the cool-down rate if the geofluid flow stops.
9. Total loss of electric power creates a condition in which each boiler deviates only slightly from its normal operating temperature.

Water Treatment Program (D. Suclu). 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 hardness and silica reduction, (b) recirculating water treatment for scale control and corrosion inhibition, and (c) treatment of cooling tower blowdown to meet standard environmental requirements.

Results of bench-scale cooling tower tests were published. The results indicated that (a) magnesium chloride can be used for silica reduction, (b) environmental standards can be met, and (c) an effective scale and corrosion control program could not be defined. Because of the failure of the scale and corrosion control tests, a test program was initiated to define the procedures for chemically cleaning and pretreating (prefilming) the carbon steel condenser tubes to minimize or eliminate corrosion (principally pitting) and to define the inhibitor additions required to maintain corrosion control (protective film) and prevent scale deposition.

During the reporting period, the test program was outlined, necessary modifications designed, material purchased, and the initial prefilm test conducted. Contacts were established with Radian Corporation to examine test coupons and aid in the examination of the 5-MW condenser during the cleaning and prefilming of the unit. In addition, a consulting contract was established with Puckorius and Associates for assistance in defining the test program and interpreting results.

The test program outlined for the water treatment studies at Raft River also include spinner tests, which will determine corrosion rates as a function of chloride and corrosion inhibitor levels, and pilot plant-scale water treatment in addition to the bench-scale cooling tower tests. The pilot plant-scale tests will be conducted at the prototype power plant in conjunction with the Permutit Corporation test program. These tests will define operating parameters for pretreatment of geothermal fluid (tower makeup) in a continuous flow process and for the sidestream treatment of cooling tower blowdown for water and chemical reuse. The sidestream system will consist of four stages:

1. Chromate recovery and reuse by ion exchange,
2. Precipitation of silica with iron (supplied by dissolution of iron filings in a 203-mm (8-in.) diameter, 2.44-m (8-ft) long tumbler unit),
3. Removal of calcium by ion exchange, and
4. A reverse osmosis unit to reduce solids.

The sidestream unit will recycle waste water and chemicals, reduce makeup water requirements, and significantly reduce chemical operating cost.

The majority of the material for these tests was received in this reporting period and installation and/or setup started. Testing in these areas had not begun at the end of the reporting period.

Supply and Injection System. The supply and injection (S&I) system (Figure 1) is a piping network designed primarily to carry hot geothermal water from the four production wells to the 5-MW Pilot Power Plant and to carry the cooled water from the plant to the two injection wells. The S&I system also serves to (a) start up and shut down production and injection wells without interrupting the flow to the 5-MW plant and the Experiment Water System (EWS), (b) provide geothermal water directly to the EWS from the production wells and the 5-MW plant, (c) carry geothermal water from the EWS to the injection wells, (d) carry water from the well site ponds to the injection wells, and (e) transport water between well site ponds during times when a pond-to-pond section of the pipeline system is not in production or injection service.

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Figure 1. Raft River fluid supply and injection system.

The interconnecting piping system between the wells and the 5-MW Pilot Power Plant is buried asbestos-cement pipe. Piping and components at the wellheads are aboveground and constructed of carbon steel with provision for thermal expansion. All piping (buried and aboveground) is insulated, except for the buried production line from Well 2 to Well 1 and the buried injection line from the 5-MW plant to Wells 6 and 7. The aboveground piping at the injection wells is insulated for personnel protection. Check valves at the junctions of lines between production wells prevent reverse flow and exhausting of the entire system through a break that might occur between a well and a check valve. Mechanical installation work on the S&I system is complete. Instrumentation

installation is 60% complete, and is scheduled to be 100% complete by July 7, 1980.

A significant amount of operating experience has been gained in this reporting period on the S&I system, and it appears that the limiting factors of greatest importance are the asbestos-cement pipe and the supply pumps.

Transite Pipe—Asbestos-cement (Transite) pipe was chosen for the S&I system to test the feasibility of this apparently lower-cost alternative to steel pipe. The original justification for using asbestos-cement pipe instead of steel or other types of pipe was its lower cost, lack of corrosion, uniform expansion, and lower frictional loss.

Estimates indicated that Transite pipe could be purchased and installed at 55% of comparable steel pipe's cost. Reasons for the lower cost were:

1. Transite pipe can be assembled much faster than welded-joint steel pipe.
2. The expansion of each pipe section can be absorbed in each coupling, so no large expansion loops are required.
3. The pressure drop is much less in the smooth-surfaced Transite pipe than in Schedule 40 steel pipe by a ratio of approximately 0.54 to 1.0, thus reducing pumping costs throughout its lifetime (pressure drops 6.2 psi per mile in 10-inch Transite pipe; 11.5 psi per mile in 10-inch steel pipe). Corrosion of steel pipe over a period of years would generally cause this pressure drop ratio to become even larger. In many cases, this reduced frictional loss allows the use of smaller Transite pipe, further reducing the cost.

System Component Operation Problems—System component problems, other than S&I line related, were documented after personal interviews with involved personnel and review of the daily maintenance log. The unusual event report file at the Raft River Geothermal Test Site was started recently and provided documentation on the more recent events. Report number TREE-1114 (see Appendix for full listing) provided useful data obtained before 1977. A summary of system failures, including number of occurrences and causes, is presented in Table 1.

The many pipe failures documented indicate that asbestos-cement pipe will not absorb thermal shock or water hammer as well as originally believed. Further, the failure rate at couplings indicates that the couplings are not "fast-shock absorbing."

In resolving the cited problems, the S&I system was necessarily shut down for repairs. In each case, the system was cooled slowly, repaired, and reheated slowly. This process required extensive downtime and cautious startup to prevent further failures. A preliminary cost estimate shows the average cost to repair each break or leak to be about \$500. The estimate does not, however, include the cost of work schedule interruption (downtime). It has been estimated, for instance,

that the downtime and schedule interruption caused by a pipe break on 7-24-79 cost approximately \$30,000.

An analysis and cost-effective comparison to determine the feasibility of continued use of this piping material will be performed during the second quarter of CY 1980.

Supply Pumps—Obtaining reliable submersible pumps has been a problem in the Geothermal Program, and a pump development program is under way elsewhere under DOE direction to correct these recurring difficulties.

In early October 1979, three new Centrilift submersible pumps were installed in production wells RRGE-1, 2, and 3. The RRGE-1 production to RRGI-7 injection test was partially completed; however, it was delayed by the fracture stimulation work on RRGP-5. On January 7, 1980 the RRGE-1 production pump failed on restart of the test, after less than 100 hours of operation. The pump was subsequently pulled and returned to Centrilift (Tulsa, Oklahoma) for refurbishment. Concurrently, routine resistance checks on the RRGE-2 and 3 pumps indicated that the RRGE-2 pump, which had never been started, had failed electrically. Based on results of pump testing in their Tulsa facilities, Centrilift recommended that we return the RRGE-2 and 3 pumps for refurbishment, and pumps with the new seals were installed in RRGE-1, 2, and 3.

Pump installation costs are high, requiring expensive work by oil field service companies, materials, and personnel training. Streamlined installation procedures have reduced by one-half the time previously required with significant cost savings to the program.

Prototype Power Plant (G. Mines)

The Prototype Power Plant is a pilot scale geothermal power plant located at the INEL Raft River Geothermal Test Site. The plant is a test facility used to investigate various concepts that have the potential to enhance the commercial production of electrical power from moderate-temperature geothermal resources. The size of the plant (about 60 kW) allows different components to be replaced with alternate components that perform the same function using an advanced or

Table 1. Summary of supply and injection system failures

<u>Type of Failure/Date</u>	<u>Number of Events</u>	<u>Cause</u>
Transite Pipe Ruptures:		
3-9-76	1	Thermal shock
7-8-76	1	Thermal shock
9-25-76	1	Thermal shock
11-11-76	1	Unknown
8-29-77	1	Unknown
10-10-77	1	Defective pipe
2-4-77	1	Unknown
2-15-78	1	Unknown
12-27-78	1	Accidental
1-14-79	1	Iron saddle eroded
7-24-79	1	Water hammer
12-28-79	1	Thermal shock
Sub Total	12	
Coupling/Gasket Leaks:		
1-16-76	1	Coupling moved
1-28-76	1	Coupling moved
7-2-76	1	Collar shifted
7-4-76	1	Collar shifted
7-7-76	1	Collar shifted
10-8-76	1	Broken gasket
10-22-76	1	Broken gasket
10-27-76	1	Broken gasket
8-24-77	1	Broken coupling
8-25-77	1	Broken coupling
9-16-77	1	Broken coupling
1-17-79	1	Pinched seal ring
10-1-79	1	Pinched seal ring
10-6-79	1	Pinched seal ring
Sub Total	14	
Valves:		
11-15-76	1	Air bleed valve broken
12-28-79	1	Unknown
Sub Total	2	
TOTAL	28	

unconventional design concept. In this way, different concepts can be tested in an operational environment that would closely resemble that of a full-scale plant without the costs of building a full-scale unit. The overall test program planned for the Prototype Power Plant consists of several phases in which to test such variables as automatic control, heat exchange components, and working fluids. A flow schematic of the plant is shown in Figure 2.

The principal objective of the testing thus far with the Prototype Power Plant has been to obtain operational experience with the plant and its components, and to demonstrate the operation of the plant in the automatic control mode. Operational experience is limited with binary power plants using isobutane over extended periods. In particular, experience is limited for the relatively low geothermal fluid temperature of 138°C (280°F) and the ambient temperature conditions at the Raft River Site. In the automatic control mode, the plant was to operate with minimal operator surveillance, to control selected plant parameters automatically, and to shut down automatically to a safe configuration in the event of an upset condition that posed a potential hazard to the equipment and/or personnel.

This facility also provides a means of identifying potential problems that might arise during the startup and operation of the 5-MW Pilot Power Plant so that procedures and/or equipment can be modified accordingly.

The initial test phase for the Prototype Power Plant has been completed using isobutane as the working fluid in shell-and-tube heat exchangers. This phase of testing was successful in that all of the main test objectives were achieved. In addition to demonstrating the ability of the plant to run unattended in the automatic control mode, this phase provided component and performance data. One objective of these performance tests was to show the large variations in power output of organic Rankine cycles due to the daily and seasonal variations in the ambient air temperature.

The results and conclusions of the tests are summarized as follows:

1. Plant operation during this period was stable when in automatic control. Even though the plant operated considerably off

the "design" conditions, i.e., boiler pressures ranging from 1379-2068 kPa (200-300 psia), the plant was able to operate and produce electrical power with minimal operator surveillance and down time.

2. The operator surveillance required to operate the plant was reduced from 24 hours each day to less than 8 hours per day, the majority of which was required for data collection.
3. The plant operated approximately 87% of the time that geothermal fluid was available.
4. The maximum plant power output was 59 kW(e) at a turbine inlet pressure of 2117 kPa (307 psia) and a turbine exhaust pressure of 490 kPa (71 psia). The geothermal fluid temperature was 135°C (275°F), and the flow rate was 24 085 kg/h (53 100 lb/h). The design plant power output was 73 kW(e) at a 2158 kPa (313 psia) turbine inlet pressure and 365 kPa (53 psia) exhaust pressure. Although the plant did not reach design turbine inlet conditions because sufficient geothermal fluid flow and temperatures were not available, a major contributing reason was the limitations of the condenser, which was obtained as a surplus heat exchanger and was not specifically designed for the Prototype Power Plant. Extremely cold weather would be required to approach the design condensing conditions with this condenser at a rated turbine inlet pressure and vapor flow (a cooling water inlet temperature of 0.6°C, or 33°F, was estimated to be required).
5. Although the plant never achieved design turbine inlet and exhaust pressure (and corresponding velocity and pressure ratios), the turbine efficiencies were equivalent to, and in some instances exceeded, the value predicted by Barber Nicnols Company (the turbine manufacturer) when turbine conditions approached design values.
6. The plant performance was predictable, given the geofluid and cooling water conditions, provided that the plant operated at a

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Figure 2. Prototype Power Plant flow schematic.

turbine velocity or pressure ratios near the turbine design point.

7. Power output variations due to daily ambient air temperatures were approximately 25% to 30% during the summer and 10% to 15% in the winter. These power variations are typical of binary plants, and demonstrate that if binary power plants are to take advantage of the increased cooling potential in the winter, the turbine must be designed for performance over a range of exhaust pressures rather than at a specific velocity or pressure ratio.
8. If an accurate determination of a binary turbine performance is desired, accurate and repeatable instrument measurements are necessary because of the relatively small enthalpy change (compared to steam cycles) across the turbine.

The primary operational results and problems encountered thus far in operating the Prototype Power Plant are summarized below. These problems have been resolved, or their effects on plant performance minimized.

1. The original feed pump in the plant, as initially constructed, was a diaphragm-type positive displacement pump. This pump was eventually replaced with a centrifugal pump because the pump diaphragm failed repeatedly. No problems have been encountered with the new feed pump.
2. Startup problems were encountered during summer afternoons due to liquid boiling in pump suction piping. The uninsulated liquid piping was warmer than the insulated condenser due to solar heating of the pipe surfaces. Since the system pressure was controlled by condenser and boiler temperature (both vessels insulated), heat had to be added to the condenser unit from an external source to raise condenser (and piping) pressures, and stop the boiling in the liquid process piping.
3. Condenser and plant performance degraded during the auto run, caused by contamination of the working fluid with nitrogen. Nitrogen gas, used to move the working fluid back and forth between storage and the plant, collected in the condenser while the plant was running, and

added its partial pressure of about 69-76 kPa (10 to 11 psia) to the saturation pressure of isobutane at the condensing temperature. Because isobutane had to be added on a daily basis to the plant while running to make up for working fluid losses from leakage, the storage tank was maintained at a pressure equal to or slightly exceeding condenser pressure. This excess nitrogen pressure introduced nitrogen into solution in storage. Nitrogen then came out of solution once the fluid had been added to the plant. The planned solution to the problem is to install a charging system in which nitrogen does not contact the working fluid. Until the charging system is installed, the use of nitrogen has been minimized and excess nitrogen pressure vented off storage after charging the plant with working fluid.

4. A chemical analysis of the isobutane from the plant indicated the pressure of nitrogen and showed that, after about 1350 hours of operation, the isobutane still met the specifications (except for the nitrogen) for an aerosol-grade isobutane propellant.

A later phase of the effort planned for the Prototype Power Plant is experimentation to evaluate the effect of mixed hydrocarbon working fluids on the net efficiency of geothermal binary cycles. The evaluation will be made for the moderate- to low temperature resource (138°C, or 280°F) at the Raft River Site.

Preliminary screening was conducted of several working fluids, consisting of isobutane (IC₄), propane (C₃), isopentane (IC₅), and mixtures of those pure hydrocarbons. This screening consisted of conducting cycle analysis for single boiling and supercritical cycles at various turbine inlet temperatures (to determine optimum conditions) for each fluid mixture. The results of the screening are shown in Figure 3 where net plant work per kilogram (pound) of geofluid is plotted as a function of turbine inlet temperature for each working fluid. Single boiling cycles correspond to the parts of the curves to the left of the vertical dashed lines; supercritical cycles lie to the right. As a reference, the net plant work is shown for the dual-boiling isobutane cycle being used for the 5-MW Pilot Power Plant. The figure shows a significant improvement in net plant power, relative to the dual-boiling isobutane cycle, for all

of the mixtures shown. The best mixture investigated for this resource temperature is 90% propane and 10% isopentane (by weight). This working fluid undergoes an 11°C (20°F) change in temperature during condensation (a good match with the cooling water temperature rise), and indicates a 39% improvement in net geofluid effectiveness relative to the dual-boiling isobutane cycle.

Construction is continuing for plant modifications to incorporate the direct-contact heat exchanger and ORNL condenser into the Prototype Power Plant.

Environmental Considerations

Environmental monitoring at Raft River during the last six months included air quality, meteorology, water quality, hydrology, subsidence, seismicity, socioeconomics, and terrestrial and aquatic ecology. These monitoring programs will be summarized in two reports, which will be published in the next reporting period.

DIRECT CONTACT HEAT EXCHANGERS

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

Direct Contact Condensers vs. Conventional Condensers

Direct Contact Condenser Studies. During this reporting period, research has continued on design correlations for sizing direct contact condensers. Particular attention has been paid to the design of packed bed condensers. This work has included the development of a theoretical model for condensation on a falling film. The theoretical model is described in a paper to be presented at the 1980 National Heat Transfer Conference. The results show that two separate correlations are necessary depending upon whether the thermal wave that is developed in the film reaches the wall or if the entire film is heated. As it is desirable to maximize the heat transfer, the packing size should be limited. A correlation has been developed that establishes the maximum wetted length and average Nusselt Number over the length.

Figure 3. Net geofluid effectiveness at 138°C (280°F), shell and tube heat exchangers.

Economic Studies of Comparative Heat Rejection Systems. During this period, a solicitation was posted for contractors to carry out a comparative study of heat rejection systems for binary geothermal power plants. Eight proposals were received and, with the concurrence of EG&G personnel, a contractor was selected. A formal work statement is now being prepared with the hope of carrying the study through to completion by mid-July 1980.

New Technology

Augmented Heat Exchanger Study. The objective of this work is to determine if augmented surfaces in heat exchangers are cost effective, particularly for geothermal sites, such as Raft River, that have relatively clean water. Comparisons to direct contact heat exchangers will be made. In this regard, modeling of conventional and augmented surface heat exchangers has been done. An initial step in this development is the analysis of simple, smooth tube heat exchangers. This work is essentially complete, and a sample of results is shown in Figure 4. In that figure the areas required for two significantly different pinch-point temperature differences are shown. All other aspects, including mass flow rates, diameters, and brine entrance temperatures, are the same for both cases.

The computational scheme used to determine the areas required is now being adapted to determine augmented surface performance. Both heat transfer aspects as well as pressure drop values are included, so that the effect on the cost of electricity generated by the plant can be determined.

Perforated Plate Internals for Direct Contact Towers. Liquid-liquid direct contact heat transfer tests have been performed in a simple spray column, and, more recently, in a perforated plate column. In tests performed with a perforated plate column, heat transfer performance was significantly improved over that in a spray column for similar operating conditions. Also, heat transfer was better between the two middle plates in the column than that for the entire column, indicating that end effects in the column reduce heat transfer.

Overall volumetric heat transfer coefficients in the range of 19 000 to 58 000 kcal/m³hr°C (1200 to 4000 Btu/ft³hr°F) were obtained in a

183.0-cm (6.0-ft) tall, 15.2-cm (6.0-in.) diameter column. Due to unavoidable fluctuations in operating parameters, heat transfer results varied as much as 15% during some runs. Considering this uncertainty, the agreement between experimental results and theoretical models was considered to be good.

DIRECT APPLICATIONS

(J. F. Sullivan and N. E. Stanley)

Aquaculture

Aquaculture research projects conducted during 1978 and 1979 demonstrated the feasibility of using Raft River geothermal water for rearing juvenile warm-water fish to market size. The objectives of the studies during 1980 are to investigate the reproductive phase of the adult fish reared during 1979 and to assess the development and physiological parameters of the young. This information will complete the biological data on all phases of geothermal aquaculture by monitoring the organisms throughout a complete life cycle. The information is necessary to determine the viability of geothermal hatchery operations as opposed to growout facilities.

The investigation is focused primarily on carp (*Caprinus carpio*) because channel catfish (*Ictalurus punctatus*) require approximately 3 years of culture before reaching reproductive maturity. During this reporting period, the geothermal water temperature entering the fish culture tanks was reduced from 26.7°C to 7.2°C over a 3-month period and then increased at the same incremental rate back to the original temperature. This was an attempt to stimulate natural reproductive activity in the test organisms. The reproductive status of the carp was determined through monthly evaluations of gonadosomatic indices (GSI) and blood serum vitellogenin levels. GSI is the ratio of total body weight to the weight of the ovaries and developing eggs. Vitellogenin is a serum protein produced in the fish liver which is absorbed by the ovaries during egg production. The reproductive status of the Raft River test species was compared with the status of the fish from the original population in Moses Lake, Washington.

During the next reporting period, spawning will be completed and the development of the young

Figure 4. Area required for two different pinch-point temperature differences.

will be examined and compared for geothermal and deionized culture water as a control. The scheduled completion date for the experiment phase and all currently scheduled geothermal aquaculture research is July 15, 1980.

Agriculture

In response to a request by DOE Idaho, a proposal was prepared that presented a research plan designed to answer the legal, technical, and environmental questions surrounding the use of geothermal effluent for irrigation. The proposal presented background information on potential irrigation methods for geothermal effluents, and also presented a research plan for investigating the use of the 5-MW power plant effluent to increase production on area agricultural and range lands.

GEOSCIENCE PROJECTS

Well Stimulation Program

(M. R. Dolenc)

The National Well Stimulation Program, as reported in the preceding Semiannual Report (EGG-2010, listed in the Appendix) is managed by Republic Geothermal, Inc. (RGI). RGI requested the use of the RRGP-5 well for their second fracturing experiment because some early test results (obtained during drilling) suggested that the well had a high flow potential. EG&G was again requested to support the field efforts in conducting the experiment and post-treatment testing.

Fracture Treatment. The experiment was conducted on November 12, 1979, using a massive, planar, vertical fracture design. This treatment used 1211.3 m³ (320 000 gal) of fluid treated with guar and a polymer (to increase viscosity) and 195 000 kg (431 000 lb) of "frac" sand (Oklahoma No. 1 and 20-40 mesh). The treatment was carried out over a 3-1/4-hr period, with pressure response as shown in Figure 5.

A 178-mm (7-in.) cemented liner was set from 963-1397 m (3158-4582 ft) across the naturally fractured zone from 1387-1390 m (4800 ft) as shown in Figure 6. Sand was intentionally placed from 1463 m (4800 ft) to total depth to limit the fracture height to slightly over 61 m (200 ft). This left an open-hole interval from 1397-1463 m (4582-4800 ft) as the target zone to be fractured.

The sand and fluid mixture was pumped at the rate of 50-52 barrels per minute, down 114-mm (4-1/2-in.) tubing through a retrievable packer set at 998 m (3274 ft). (Frac sand grains enter fractures opened by hydraulic pressure. When the reservoir pressure is decreased, the sand grains, or proppant, keep open the fractures and allow fluid to pass through the interstices.)

At about 160 minutes, Super Sand (a special resin-treated sand) was pumped downhole. (When Super Sand has been emplaced, it reacts under high temperature, forming a resin network of sand that contains the proppant in the fracture.) During the water flush that followed, a 3-minute pumping

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Figure 5. Well RRGP-5 hydraulic fracture pressure record, November 12, 1979.

halt as the flush was nearing completion, resulted in a sand-off, or premature plugging of the wellbore with Super Sand. On re-entry into the well after the fracture treatment, a sand bridge was encountered at 1392 m (4566 ft).

During the treatment, a 21-kPa (3-psi) pressure increase was noted in well RRGE-1, confirming the known hydraulic connection between RRGP-5 and RRGE-1. Five portable seismic instruments set up by the University of Utah before the test (as a calibration check) noted no seismic events that could be attributed to the fracture treatment.

Post-Treatment Testing. After the treatment, water was circulated through the wellbore to remove loose sand and clean up the well. Large quantities of sand flowed with the fluid to the surface. This author interprets this to be the result of the 3-minute break period during the flush at the end of the fracture treatment, which resulted in a failure to emplace Super Sand properly and contain the frac sand as designed. Although cleanup continued for nearly 2 weeks before the production pump was installed, frac sand return continued even through pump testing.

Two 6-hour artesian tests conducted after the fracture treatment gave results of 11-14 L/s (180-225 gal/min), indicating little if any change in artesian conditions. Pump tests conducted in December 1979 were also plagued with pumped-back sand. In late March 1980, a 61-hour pump test showed a flow of 41 L/s (650 gal/min), resulting in a drawdown of 1655 kPa (240 psi). Pump failure cut short what would have been a longer test.

These results indicate that RRGP-5 has not returned to its pre-treatment flow capacity. Whether this is due to the frac sand emplacement or that the frac sand was simply driven into the fractures noted as naturally existing cannot be determined at this time.

Case Study

Although the Raft River Case Study was not funded during the reporting period, plans were under way in late March to again return to the project in the second half of FY-80. Reservoir work will be completed and a draft report prepared by the end of the fiscal year.

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Figure 6. Well RRGP-5 pre-fracture wellbore status.

RAFT RIVER FACILITIES UPGRADE

Several significant projects have been completed to improve conditions for people and equipment and increase facility capabilities. These projects include paving approximately 1.3 km of the most heavily traveled roads to improve vehicular travel, reduce dust, and help minimize vehicle maintenance costs.

An increased-capacity geothermal heating system was designed and installed. Seven buildings are currently geothermally heated and one is geothermally air conditioned.

To protect buildings and equipment from the spring runoff flood waters, grading and other flood control measures were taken during the reporting period. Culverts and drains were installed and trees and grass were planted at all

disturbed areas to reduce erosion, improve working conditions, and restore the natural conditions of the area.

Office facilities have been improved and expanded by the installation of two double-wide trailers. These trailers are utilized by site operations and maintenance personnel and provide temporary working spaces for the 5-MW Pilot Power Plant startup and operating crews.

DOE negotiated a security contract with Huff & Huff, Inc., to provide improved 24-hour security surveillance for the entire Raft River Site. To complement this service, a security fence was designed and installed around the offices and facilities of the Site 1 complex. Approximately 1.6 km of fencing now encloses all major facilities at Site 1, and a continuous boundary is provided for the 5-MW Pilot Power Plant. An additional trailer was emplaced to serve as an office to support the security force.

Material handling and property control facilities have been greatly improved and now consist of an 18- by 18-m warehouse and a 91- by 152-m material storage yard. The warehouse has been reorganized and facilities completed to support vehicle maintenance, inside controlled storage of large and small items, and a tool crib. Security lighting and a perimeter fence have been installed around the material storage yard. Material handling procedures are now complete, and two employees from the Materiel Division are assigned to ensure proper material handling in accordance with approved procedures.

The Data and Acquisition Control System has been installed to the extent that remote data collection and process control functions are provided for Experiment Building 610. Currently, this system is supporting the present series of cooling tower water treatment experiments.

OUTREACH PROGRAM—USER ASSISTANCE

(I. A. Engen)

Program Description

DOE funds EG&G Idaho, Inc., to provide assistance, advice, and information to parties interested in the direct application of geothermal energy. User assistance is provided at no cost to

the requester, in an effort to stimulate private sector interest in developing geothermal projects. Assistance is provided, in the Rocky Mountain Basin and Range Region, on a first-come-staff-available basis with an upper limit of 100 hours. The object of the program is to assist potential geothermal energy users in the initial feasibility determination, with the intent of providing sufficient confidence to encourage the user to obtain competent private engineering and consulting services for project development.

Program Utilization

During the reporting period, the volume of requests for information and technical assistance continued the dramatic growth shown in earlier reporting periods. Increased activity and interest in this program is indicated in Table 2.

A limited number of technical assistance activities have been subcontracted to private sector engineering firms to promote development and utilization of private sector expertise, accelerate development of geothermal direct heat projects, and to provide timely results. Seven subcontracts have been issued to private firms in three states, covering assistance in projects that would use geothermal heat for space conditioning in senior citizens facilities, offices, commercial buildings, residences, schools, and hospitals. The use of geothermal heat for ethanol and methane production is also being assessed under subcontracted assistance. Subcontracting of technical assistance during the balance of FY-80 will be curtailed due to funding limitations.

Representative projects receiving user assistance during this reporting period include:

1. Highway and bridge deicing in Glenwood Canyon, Colorado,
2. District heating for a subdivision at Given's Hot Springs, Idaho,
3. Space conditioning of a large commercial structure in Tucson, Arizona,
4. Space conditioning for a hospital facility in Boise, Idaho,
5. Renovation of an exploratory gas well for geothermal ethanol production near Felt, Idaho,

Table 2. User assistance program activity summary, January 1977 to April 1980.

<u>FY</u>	<u>Requests for Information</u>	<u>Requests for Technical Assistance^a</u>
77	24	10
78	131	33
79	295	79
80 (6 months)	240	53

a. Does not include multiple requests by same requester.

6. District heating system for Midwest, Edgerton, Wyoming,
7. District heating for a residential subdivision near Twin Falls, Idaho,
8. Use of water source heat pump technology to provide space heating of fish hatchery facilities near Jackson, Wyoming, and
9. Aquaculture facilities near Boulder, Montana.

USER COUPLED CONFIRMATION DRILLING PROGRAM

(M. R. Dolenc and E. G. Dibello)

An industry survey conducted in the summer of 1979 disclosed that to accelerate commercialization of hydrothermal energy, one of the foremost requirements is to reduce the risk and costs of exploration. In response to this requirement, DOE has initiated the User Coupled Confirmation Drilling Program.

Exploration for hydrothermal reservoirs is a high risk endeavor. To insure that a suspected reservoir will be economic, the developer must drill into the resource, measure the temperature and flow rate, and use sophisticated analysis techniques to estimate the productivity and longevity of the resource. The present high risk level for reservoir confirmation stems partly from the lack of resource knowledge and partly from the fact that present surface geophysical techniques are not well enough developed to ensure a high level of probability that a drill hole will intercept a resource. Hydrothermal reservoirs are

never uniform or continuous, and unproductive holes are sometimes drilled in the middle of the best of resources. Better techniques and more experience in locating wells are needed to decrease the risk of drilling an unproductive well.

However, we must anticipate that some unproductive wells will be drilled. The extent to which successful reservoir confirmation will occur will depend upon (a) the probability of occurrence of the resource, (b) the probability that a well will be sited properly to intercept the resource, and (c) the probability that the well will be drilled and tested properly. Petroleum and minerals resource developers understand and accept these probabilities and do not become discouraged when unproductive holes are drilled. This same attitude must be adopted by the direct heat geothermal industry and by others associated with this program.

The User Coupled Confirmation Drilling Program will speed hydrothermal industrialization by absorbing some of the high risk and cost while developing an experienced industry in the private sector that will reduce future risk and that can carry on development without future federal aid.

Program Objectives

The objective of the User Coupled Confirmation Drilling Program is to foster economically viable use of direct heat hydrothermal energy in the United States by the industrial and private sectors by:

1. Encouraging direct heat utilization development by absorbing a portion of the risk associated with confirmation of hydrothermal reservoirs, while at the same time;
2. Developing an experienced infrastructure of exploration, confirmation and utilization engineering consultants, contractors, and equipment manufacturers who will promote future development.

The federal program is scheduled to phase out as private industrial and financial interests increase their involvement in initiating direct applications development.

Summary Program Description

The User Coupled Confirmation Drilling Program sponsored by the U. S. Department of Energy, Division of Geothermal Energy, will absorb a portion of the high risk and cost of geothermal development by providing cost-sharing of hydrothermal reservoir confirmation for direct heat applications. The program will share the cost of exploration, drilling, flow testing, reservoir engineering, and injection well drilling (if required). Cost-sharing or financing for the utilization system to be installed once the reservoir is confirmed are not covered under this program. The federal percentage of cost-share will be determined by a negotiated formula based upon usability of the thermal fluids intersected by the drilling. For a completely successful project, the DOE cost-share will be 20%, whereas for a completely unsuccessful project, the DOE cost-share will be 90%. The degree of success and the corresponding DOE cost-share are expected to range between these extremes for individual projects.

The new program will be initiated by a DOE Solicitation for Cooperative Agreement (SCA) to be issued in June 1980. A 90-day period will be available thereafter for preparation and submission of proposals. It will be required that proposals detail (a) the geologic evidence that a resource exists at the site of interest, (b) the direct heat use to be made of geothermal fluids if discovered and confirmed, (c) an adequate exploration, drilling, flow testing and data analysis program, and (d) an acceptable cost-share plan based on the degree of success of the

project. Proposals will be reviewed and awards made in accordance with applicable federal regulations. Successful proposers will negotiate a contract with DOE. The contractor's funds can be used to perform the project or, alternatively, a loan can be obtained from a commercial financial institution using the DOE contract as evidence that project risk has been substantially reduced. The project will then proceed under contractor management. After flow testing, the degree of success will be determined through analysis of flow testing results and by application of other provisions that have been negotiated in the contract. The DOE cost-share will then be determined, and DOE will reimburse the contractor, completing the agreement.

The program will be managed for DOE Headquarters by the Idaho Operations Office of DOE with assistance from the Earth Science Laboratory of the University of Utah Research Institute, EG&G Idaho, Inc., and the Nevada Operations Office of DOE.

PON AND PRDA PROJECTS

(E. DiBello, F. Childs, K. Jones, L. Nelson, and 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 the direct application of geothermal energy. 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 that are conducting each demonstration. During this reporting period, EG&G Idaho provided program management and technical support for 12 demonstration projects and five engineering and economic studies. Each project is summarized below.

PON Projects

1. *Ore-Ida Foods, Inc., Ontario, Oregon*

Ontario, Oregon is located 92 km (57 mi) northwest of Boise, Idaho. The Ontario

Ore-Ida Foods, Inc. plant currently uses natural gas and oil. This project would substitute geothermal energy for potato processing heat, space heat, and hot potable water in the amount of about 97 200 MWh/yr (33.2×10^{10} Btu/yr). Production was predicted to be 50 L/s (800 gal/min) at 160°C (320°F) from two production wells. Two production wells and one injection well were planned.

Drilling of the first production well was completed to a total depth of 3065 m (10 054 ft). A bottom hole temperature of 180°C (357°F) was recorded, and an equilibrium temperature of over 205°C (400°F) was calculated. After perforating several zones, the completed well only flowed about 0.82 L/s (13 gal/min) at a water level of 1525 m (5000 ft), and, a few weeks later, developed a surface artesian flow of about 0.06 to 0.12 L/s (1 to 2 gal/min).

This flow was inadequate. Since most of DOE's funding was consumed by this one well, no additional drilling is planned. It was decided to monitor the well while the drilling report was written. When all of the data become available, the well will be evaluated for possible use in the National Well Stimulation Program, the Hot Dry Rock Program, or other applications.

The preliminary design of the plant retrofit was completed.

2. *Monroe City, Utah*

Monroe City is a community of 1500 people, 257 km (160 mi) south of Salt Lake City, Utah. The project planned the drilling of one production and one injection well, and installing a district heating system. The system would initially heat the South Sevier High School, two city buildings, and later expand to include the major areas of Monroe.

The proposed project expected a 120°C (248°F) resource with a maximum flow rate of 32 L/s (500 gal/min), but only obtained 75°C (165°F) at 38 L/s (600 gal/min). The latter flow dried up nearby springs and made its longevity suspect. The reduced

resource dropped the peak system capacity from 6500 kW to 2800 kW, 43% of its expected capability.

Terra Tek, Inc. and Caldwell, Richards and Sorensen, Inc., Monroe City's engineering consultants, completed the preliminary design. They reported that project costs would be about \$921,000 higher than budgeted, and that revenues from the smaller resource might not cover operating costs.

Since Monroe City was incapable of increasing its financial support, DOE would have to double its expenditures if the project were to proceed. Accordingly, DOE-ID requested that Monroe City define an alternate use for production well MC.3. The alternate use should conform to the direct-use PON objectives and stay within the \$500,000 remaining in the budget.

The first corrosion coupon samples were removed from the geothermal fluid after one month. The Utah Division of Environmental Health notified the project that the injection site between the hot springs was approved, subject to establishing a monitoring program.

3. *Haakon School District, Philip, South Dakota*

Haakon School is located in the town of Philip, which is approximately 129 km (80 mi) east of Rapid City, South Dakota. The project has been expanded in scope to include the space heating of the school complex and eight business buildings on the discharge line route. The Environmental Protection Agency required that the Radium 226 levels in the well water be reduced to 5 pCi/L prior to discharge to the Bad River. The project scope was expanded to include a water treatment facility. The water will be treated by injecting a 10% aqueous solution of barium chlorohydrate into the geothermal effluent. After a holding pond settling time of 48 hours, the water will be discharged into the river. Approximately 2000 barrels of fuel oil will be replaced yearly, resulting in a payback of approximately 14 years. The pipeline

installation and building retrofit are in progress and the system is scheduled to be on line for the 1980-81 heating season.

4. *St. Mary's Hospital, Pierre, South Dakota*

St. Mary's Hospital, located in Pierre, South Dakota is currently heated by a fossil-fuel system. This project will demonstrate the feasibility of utilizing low-temperature water from a 665-m (2181-ft) Madison Aquifer well for space, domestic hot water, and ventilation air heating. The well flows at a rate of 24 L/s (375 gal/min), at a temperature of 41°C (106°F), and at 186 kPa (27 psig) residual pressure. The water from the well has a total dissolved solids of 2084 parts per million, a hydrogen sulfide content of 0.7 parts per million, and a Ra-226 level of 19 pCi/L. The well water is discharged through a PVC pipe to the Missouri River. The underground piping system consists of a filament-wound fiberglass carrier pipe surrounded by polyurethane insulation jacketed with a PVC pipe.

The construction phase of the project is now in progress, and it is planned that the system will be operational for the 1980-81 heating season. Cost for the entire project is \$718,000.

5. *Diamond Ring Ranch, Haakon County, South Dakota*

Geothermal water from an artesian well that has flowed since 1959 is being used for grain drying and space heating on the Diamond Ring Ranch in South Dakota. The system retrofit consists of PVC pipelines connecting the wellhead to the various structures requiring heat. After flowing through the central heat exchanger, the geothermal fluid is used as stock water and then discharged into a reservoir system used for both geothermal well and runoff catchment.

The construction was completed in December 1979 at a cost of \$403,000. The startup and monitoring phase of the project is now in progress. Monitoring equipment is being installed and the wellhead is being refurbished.

6. *Elko, Nevada*

The Elko project involves the location and drilling of a production well to extract hydrothermal fluids for direct application. These fluids are to be used for process heat in a commercial laundry and for space heating a motor hotel and a bank building.

The Resource Assessment Phase has been completed. This phase included shallow temperature probe surveys, geological reconnaissance, electrical resistivity soundings, sling ram soundings, and geochemical sampling of city wells and the Elko Hot Springs. In addition, two gradient holes were drilled to a depth of 305 m (1000 ft). Temperature, flow rate, and geology and water samples were taken. Data collected from the two gradient test holes are being evaluated to select the production well site. Production well drilling specifications are now being prepared.

7. *Warm Springs State Mental Hospital, Montana*

The objective of the project 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.

The production well has been completed to a total depth of 456 m (1498 ft). Preliminary flow test data indicated a wellhead temperature of 70°C (160°F) with an artesian flow rate of 2.5 L/s (40 gal/min). The well was acidized with a 15% solution of hydrochloric acid, and preliminary pump test data indicated a flow rate of 13 L/s (200 gal/min) with a 220-m (720-ft) drawdown.

The well cleanout and testing phase of the project is in progress.

8. *Pagosa Springs, Colorado*

The geothermal resource in Pagosa Springs has been used on a limited basis since the

early 1900s. Nearly 30 wells have been drilled for heating and recreational purposes. Flow and disposal rights from some of these wells will be transferred to the demonstration project's district heating system. Most of the town's public buildings will be heated by the geothermal energy with provision for connecting commercial and residential buildings to the system.

Flow tests were made of the Courthouse 1 and 0-2 wells. Data from the latter test were analyzed in detail. A test report and an overall Resource Report were issued. Both reports were reviewed by EG&G and DOE-ID and discussed in a meeting with local residents in Pagosa Springs.

It was decided that two 90-m (300-ft) production wells should be drilled to optimize resource availability and to provide wells of known and reliable construction. The target would be the 60°C (140°F) aquifer penetrated by well 0-2, and the first production well would be drilled close to 0-2. Currently, well 0-2 has some leakage and possibly some structural problems. The drilling will proceed as quickly as possible since the resource must be operational before allowing system construction to begin. It is hoped that construction will be completed late this calendar year.

The revised Environmental Report and the preliminary design were completed and approved. The design continued with the start of the final design task.

9. *Utah Roses, Sandy, Utah*

The Utah Roses greenhouse complex is located in the town of Sandy, which is approximately 17 km (11 mi) south of Salt Lake City, Utah. The complex consists of 23 500 m² (6 A) of greenhouses that produce cut roses for the national floral market. A production well was drilled to a depth of 1525 m (5009 ft) and should produce water at 50°C (122°F) at a pumped flow rate of 22.4 L/s (350 gal/min). The geothermal water will be piped through water-to-air heat exchangers and the heated air distributed in polyethylene tubes throughout the

greenhouse. The water will then be piped in the ground alongside the plants to remove the maximum amount of available heat. The present plan is to discharge the geothermal fluid into a waste canal near the greenhouse complex.

The system will have a simple payback of approximately 9 years. It will be installed during the summer of 1980 and on-line for the 1980-81 heating system.

10. *Utah State Prison, Draper, Utah*

The Utah State Prison is located in Salt Lake County approximately 27 km (17 mi) south of Salt Lake City. The resource surface expression known as Crystal Hot Springs is adjacent to the prison. A geothermal well has recently been drilled at the springs for a commercial greenhouse project and produces water at 88°C (190°F) and an artesian flow rate of 12.6 L/s (200 gal/min). The minimum security section of the prison will be retrofitted to utilize the heat from a well to be funded by DOE. Gravity and magnetic surveys have been completed for the area and test holes are planned for the summer of 1980.

11. *Madison County, Idaho*

Madison County and the city of Rexburg are at the eastern edge of the Snake River Plain, where northeast trending faults, concentrated along the plain boundaries, are the source of many hot springs.

The Madison County geothermal project plans to demonstrate a low-temperature geothermal resource for food processing and district space heating.

Two production wells at 914 and 1830 m (3000 and 6000 ft) were proposed. The deep well was expected to supply 121°C (250°F) water to a potato processing company for use in food processing followed by cascading usage for space heating with a 88°C (190°F) supply temperature.

Two thermal gradient wells were drilled; hydrological test wells HTW-1 and HTW-2. The former was drilled to 384 m

(1259 ft) and the latter to 468 m (1535 ft). A visual TV log and several temperature logs were run. Projected equilibrium temperatures were based on HTW-1 at 14.2°C at 305 m plus 59.2°C/km (57.5°F at 1000 ft plus 3.25°F/100 ft).

A torsion magnetometer survey and an electromagnetic survey were made. The preceding, plus all available data were considered and the site of the first production well was selected and approved. The site is near HTW-1, at the junction of major faults and near Rexburg. A 914-1524 m (3000 - 5000 ft) deep well is planned to intersect the fault between 762 and 1524 m (2500 - 3000 ft). It is anticipated that hotter water can be drawn up from depth along the fault.

The Madison County Energy Commission and AMPCO have exchanged letters to coordinate AMPCO's participation in the project, but formal agreements have been deferred until a resource temperature adequate for potato processing is demonstrated.

12. *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.

During this report period, the environmental and geological assessments were completed, reviewed, recommended for approval, and transmitted to DOE. The need for additional geological mapping of the intended withdrawal area along the Boise Front was agreed upon in March 1980. The mapping was undertaken by Anderson and Kelly Associates of Boise and will be incorporated in a final resource report to be delivered in June 1980. Preliminary Engineering and business plans were submitted to DOE during this term and are undergoing review. These two documents propose a comprehensive project plan and related costs to cover the period from June 1980 through

December 1981. An \$8.3 million project has been designed by CH2M Hill. DOE's cost share has been identified to be \$4.9 million.

Participant cost-share sources are being sought. This was the primary activity of this report period. The various funding alternatives and probable dollar limitations for each alternative are being explored.

A no-cost time extension to the contract was allowed by DOE until June 30, 1980 for the purpose of determining which of the funding alternatives are feasible and implementing those needed. Other terms of the agreement include completion of the resource report, preparation of specifications for drilling three production wells, and recommendations for effluent disposal.

PRDA Projects

The following study projects were in progress as of March 1980. 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. The final report is being prepared.

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

The Energetics Corporation of Dallas, Texas, is conducting a study to evaluate five potential geothermal resource areas for use in the L'eggs plant processes. A preliminary system design is being developed. The study will be completed in the fall of 1980.

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

Bechtel National, Inc. is conducting a study to evaluate the Raft River, Idaho, geothermal resource for use in the production of ethanol. A 76×10^6 L (20×10^6 gal) per year facility utilizing potatoes, wheat, and sugar beets as feedstocks has been designed. The study will be completed in June 1980.

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

The objective of this project is to determine the economic and engineering feasibility of heating and cooling approximately 25% of the University campus with low-temperature geothermal energy. Phase I, which includes reservoir assessment, campus heating load requirements, reservoir modeling, corrosion simulation, disposal recommendations, and environmental/institutional impacts, is essentially complete. Phase II, which includes alternative system selection and preliminary design, has begun. The first

two quarterly reports have been submitted to DOE and have been reviewed.

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

The objective of this study is to assess the economic and engineering feasibility of supplying geothermal heat to several city buildings and a municipal wastewater treatment facility. During the report period, a geological assessment was completed, heating loads for eight city buildings were documented, retrofit alternatives identified, and system alternatives explored. The first two quarterly reports were submitted to DOE and are being reviewed.

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 Dome area. Effort during the term has been concentrated on completing the final report, which will be delivered in June 1980.

APPENDIX A
PUBLICATIONS OF THE IDAHO GEOTHERMAL PROGRAM

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PUBLICATIONS OF THE IDAHO GEOTHERMAL PROGRAM

Table A-1 lists the formal reports published by EG&G Idaho, Inc. for the Idaho Geothermal Program. Printed or microfiche copies of these reports may be ordered from the National

Technical Information 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

Report Number	Author	Date	Title
TREE-1008	J. F. Kunze, ed.	10-76	Geothermal R&D Project Report for Period April 1, 1976 to June 30, 1976
TREE-1016	J. F. Kunze	1-77	The Potential for Utilizing Geothermal Energy for Space Heating in Reconstructed Sugar City, Idaho
TREE-1023	D. T. Neil	11-76	Geothermal Shell and Tube Heat Exchanger Augmentation
TREE-1030	J. F. Kunze	12-76	Geothermal R&D Project Report for Period July 1, 1976 to September 30, 1976
TREE-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
TREE-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
TREE-1085	W. C. Kettenacker	3-77	Two-Dimensional Simulation of the Raft River Geothermal Reservoir and Wells
TREE-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)

<u>Report Number</u>	<u>Author</u>	<u>Date</u>	<u>Title</u>
TREE-1112	S. E. Turner	4-77	HECDOR—A Heat Exchanger Cost and Design Optimization Routine
TREE-1114	J. F. Kunze et al	4-77	Asbestos-Cement Pipeline Experiment at the Raft River Geothermal Project
TREE-1134	J. F. Kunze	5-77	Geothermal R&D Project Report for Period October 1, 1976 to March 31, 1977
TREE-1162	L. L. Mink et al	10-77	Geothermal Potential of the West Boise Area
TREE-1164	C. J. Shaffer	8-77	Floating Power Optimization Studies for the Cooling System of a Geothermal Power Plant
TREE-1176	R. L. Miller	10-77	Results of Short-Term Corrosion Evaluation Test at Raft River
TREE-1182	I. A. Engen	2-78	Residential Space Heating Cost: Geothermal vs Conventional Systems
TREE-1256	J. F. Kunze	3-78	Geothermal R&D Project Report for Period April 1, 1977 to September 30, 1978
TREE-1278	G. L. Blake, ed.	7-78	Semiannual Progress Report for the Idaho Geothermal Program, October 1, 1977 to March 31, 1978
TREE-1295	G. L. Blake, ed.	11-78	Semiannual Progress Report for the Idaho Geothermal Program April 1 to September 30, 1978
TREE-1312	J. F. Whitbeck et al	1-79	Measurement and Control Techniques in Geothermal Power Plants
TREE-1340	S. G. Spencer et al	4-79	1978 Annual Report, INEL Geothermal Environmental Program

Table A-1. (continued)

<u>Report Number</u>	<u>Author</u>	<u>Date</u>	<u>Title</u>
TREE-1359	L. F. Burdge et al	10-79	Semiannual Progress Report for the Idaho Geothermal Program, October 1, 1978 to March 31, 1979
TREE-1365	O. J. Demuth	7-79	Analysis of Binary Thermodynamic Cycles for a Moderately Low-Temperature Geothermal Resource
TREE-1370	J. F. Sullivan et al	9-79	Raft River Geothermal Aquaculture Experiment-Phase II
EGG-2001	S. G. Spencer B. F. Russell J. F. Sullivan	9-79	Vol. 1 - Potential Use of Geothermal Resources In The Snake River Basin: An Environmental Overview Vol. 2 -Annotated Bibliography
EGG-2005	N. E. Stanley R. C. Schmitt	1-80	Effects of Irrigation on Crops and Soils with Raft River Geothermal Water
EGG-2010	R. R. Ihrig, ed.	3-80	Semiannual Progress Report for the Idaho Geothermal Program April 1 to September 30, 1979
EGG-2013	J. G. Keller	3-80	Geothermal Direct Applications Hardware Systems Development and Testing - 1979 Summary Report