EGG-2140

Distribution Categories: UC66-a, b, c, d, e, g, j
Geothermal Energy

EGG--2140

DE82 007874

SEMIANNUAL PROGRESS REPORT FOR THE IDAHO GEOTHERMAL PROGRAM APRIL 1 THROUGH SEPTEMBER 30, 1981

John T. Parker, Ed.

Published January 1982

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

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

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

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ABSTRACT

This document summarizes progress of the Idaho Geothermal Program from April 1 to September 30, 1981. The report summarizes modifications incorporated in the 5-MW Pilot Power Plant at Raft River Geothermal Test Site, system operational testing and maintenance activities at that plant, and the water treatment program's corrosion studies. Progress is reported on performance tests of the ORNL condenser and the direct-contact heat exchanger in the Prototype Power Plant. Production-injection tests associated with pump installation in monitor wells at Raft River are reported. Case studies conducted and publications prepared for the program of low-to moderate-temperature hydrothermal resource development are also reported. The report describes monitoring activities and studies of the environmental program at Raft River and discusses two new areas of research under the Environmental Support Injection Research Program: pressure monitoring, and dispersion

studies. It also summarizes progress of three successful proposers under the User-Coupled Confirmation Drilling Program. A program to encourage use of geothermal energy at Federal facilities was developed and initiated. Investigation of direct use of hydrothermal energy is reported. Progress is reported on the Marketing Assistance Program, through which technical information and assistance are provided to potential users and developers of geothermal resources. Also reported is progress on DOE's Program Opportunity Notice (PON) Program demonstration projects and the Program Research and Development Announcement (PRDA) Program study projects.

Geothermal applications development for the M-X missile system's Renewable Energy Systems (RES) package is reported. This program was terminated during this period.

SUMMARY

The objectives of the Idaho Geothermal Program, sponsored by the Department of Energy, are to develop, demonstrate, and encourage the use of hydrothermal energy. This document outlines progress during the semiannual reporting period of April 1 to September 30, 1981.

During this reporting period, the 5-MW Pilot Power Plant at the Raft River Geothermal Test Site was prepared for startup. All startup modifications have been completed, all construction component tests have been performed, and only three system operation tests remain to be done. DOE-ID approval has been received to proceed with startup testing.

Two new pumps were received and installed in Supply Wells RRGE-1 and RRGE-2, and modifications at Injection Wells RRG1-6 and RRG1-7 are underway.

In the Materials Evaluation and Water Treatment Program, approximately 40 alloys were tested for corrosion in aerated brine, and a report summarizing the results is being prepared. Galvanic corrosion tests were run on three dissimilar materials, but the data obtained have not yet been analyzed. In a 6-month corrosion test of four potential tubing materials, Sea Cure and 70/30 copper nickel did not pit and showed excellent resistance to general corrosion. Investigation into methods for removing silica from geothermal brine continued during this reporting period.

At the 60-kW Prototype Power Plant, two sequences of tests have been conducted with the direct contact heat exchanger (DCHX). The first was directed toward evaluating the performance of the DCHX column. Data taken are presently being analyzed. Completion of the second sequence, with the objective of measuring the effects on plant performance of introducing non-condensable gases into the cycle in the DCHX, awaits the setup and calibration of chemical analysis equipment needed for the tests.

A new working fluid charging and storage station was installed, and the heat exchangers for the supercritical modifications were thermally designed, specified, and ordered.

A number of binary geothermal cycles using three mixed hydrocarbon working fluids were analyzed for a 182°C geothermal resource to evaluate the performance augmentation of regenerative preheating techniques. Where basic cycles without regenerative preheating showed a loss in geofluid effectiveness when a geofluid outlet temperature of 71°C was maintained to prevent silica precipitation in the injection wells, in the same cycles with regenerative preheating, nearly all the loss of performance was regained while maintaining the 71°C outlet temperature.

A study to determine whether any unforeseen or detrimental operating characteristics would be encountered in cold-weather operating revealed no major problems.

During this reporting period, the geoscientific data collected at Raft River since 1974 were compiled into a single document, *The Raft River Geoscience Case Study*, to be published in November 1981.

Production and injection testing during this period was confined to short-duration tests, primarily associated with the installation of the new shaft pumps.

Monitor well and water chemistry data were collected as part of the continuing effort to determine the impact of geothermal development on shallow aquifers. No noticeable changes in groundwater level or water chemistry were attributed to the pumping and injection tests conducted in mid-March and late August of 1981.

During the reporting period, no microseismic events were recorded within 40 km of the Raft River Sampling array intended to detect microseismic activity associated with fluid withdrawal and injection.

Temperature and precipitation during the reporting period were near normal, except for record precipitation in May.

The air quality monitoring program continued during this reporting period.

Monitoring of the ferruginous hawk and golden eagle populations continued during this period. As

expected, both species continued to decline during 1981. This decline is related to the black-tailed jackrabbit population cycle.

Under the Low- to Moderate-Temperature Reservoir Engineering Program, two major publications were developed during this reporting period—the *Case Studies of Low- to Moderate-Temperature Hydrothermal Energy Development* (IDO-10098), and the *Low- to Moderate-Temperature Hydrothermal Reservoir Engineering Handbook*. Both projects were prepared as a joint effort of EG&G Idaho and Lawrence Berkeley Laboratory for the Idaho Operations Office of the Department of Energy.

Two new areas of research were initiated in the Environmental Support (Injection) Program: (a) pressure monitoring, and (b) dispersion studies. The pressure monitoring research is designed to relate observable pressure changes in a geothermal reservoir and associated groundwater aquifers to observed and anticipated solute movement as a result of spent geothermal fluid injection. The objective of the dispersion research program is to increase the accuracy of models that predict the movement of geothermal fluids in fractured rock systems.

A cooperative agreement was signed with the Wine Valley Inn, Calistoga, California, under the User-Coupled Confirmation Drilling Program. Work is underway on this project and on those at Geoproduts Corporation and the City of Alamosa under this program. One project remains in negotiation.

A Federal Building Program plan was developed and initiated in compliance with the Energy Security Act of 1980 to encourage the use of geothermal energy at Federal facilities located near geothermal resources. Energy use data indicate potential geothermal energy applications of significant scope and savings.

Comparison of advanced binary electric power plant performance with that of conventional binary and dual flash steam plants has shown significant performance improvement for resource temperatures in excess of 260°C. Power plant and field surface equipment capital costs have been developed for the advanced binary power plants.

Additional detail has been developed for the use of hydrothermal energy for industrial process heat by 24 screened potential users. The application of this additional data will provide increased accuracy in determining the site-specific economics for each potential user industry.

Under the Marketing Assistance Program, one additional exhibit was placed, bringing the total for the year to nine. Forty requests for technical assistance and 157 requests for technical information were received during the reporting period. The number of technical assistance requests still outstanding is 22. Under the Community Assistance effort, 10 communities were selected for consultory assistance in examining financing vehicles available for district heating systems. An *Institutional and Financial Guide to Geothermal District Heating* has been prepared.

During this period, EG&G provided program management and technical support for 12 demonstration projects in the Program Opportunity Notice (PON) Program and five engineering and economic studies in the Program Research and Development Announcement (PRDA) Program.

The M-X/RES project has been terminated following the administration decision to base the missile in existing silos. The main accomplishment for the reporting period was a draft report on advanced binary power plants and hybrid fossil/geothermal plants. Equipment for a possible 20 MW(e) power plant was sized for the purpose of generating "order-of-magnitude" costs. Further work was done in the area of geothermal space conditioning systems and equipment that could be used at an operating base.

Publications completed during this reporting period include the annual Raft River Environmental Report; the annual Monitoring Well Report; a paper on operation of the prototype plant, presented at the 16th IECEC Conference; a paper, "Analyses of Mixed Hydrocarbon Binary Thermodynamic Cycles for Moderate Temperature Resources," also presented at the 16th IECEC Conference; a report, *Condensing Curves for a Number of Mixed Hydrocarbon Working Fluids*; and a report, *Epidemiology of the Madison Aquifer, South Dakota*.

CONTENTS

ABSTRACT	ii
SUMMARY	iii
INTRODUCTION	1
FIVE-MEGAWATT PILOT POWER PLANT	1
Raft River Facility Operations	2
CONVERSION TECHNOLOGY	2
Materials Evaluation and Water Treatment Program	2
Prototype Power Plant	3
Advanced Conversion System	5
RAFT RIVER RESERVOIR ENGINEERING	5
RAFT RIVER ENVIRONMENTAL PROGRAM	6
LOW- TO MODERATE-TEMPERATURE RESERVOIR ENGINEERING PROGRAM	7
ENVIRONMENTAL SUPPORT PROGRAM: INJECTION PROGRAM RESEARCH	8
USER-COUPLED CONFIRMATION DRILLING PROGRAM	9
GeoProducts Corporation, Susanville, California	9
City of Alamosa, Colorado	9
Wine Valley Inn, Calistoga, California	9
FEDERAL BUILDING PROGRAM	11
HYDROTHERMAL R&D EVALUATION	11
Advanced Binary Power Plants	11
Industrial Process Heat Data	11
MARKETING ASSISTANCE PROGRAM	16
Program Description	16
Program Results	16
PON AND PRDA PROJECTS	17
PON Projects	18

Ore-Ida Foods, Inc., Ontario, Oregon	18
Monroe City, Utah	18
Haakon School District, Phillip, South Dakota	18
St. Mary's Hospital, Pierre, South Dakota	18
Diamond Ring Ranch, Haakon County, South Dakota	19
Elko, Nevada	19
Warm Springs State Hospital, Montana	19
Pagosa Springs, Colorado	19
Utah State Prison, Draper, Utah	20
Madison County, Idaho	20
Utah Roses, Sandy, Utah	20
Boise, Idaho	20
 PRDA Projects	 21
Engineering, Marketing, and Economic Study of a 4.5 Million-Gallon Geothermal Fuel Alcohol Plant for the Vale Geopark Site	21
Resource, Engineering, and Economic Study for Direct Heat Applications of Geothermal Energy at the Salida (Colorado) Geothermal Project	21
Commercial Production of Ethanol in the San Luis Valley, Colorado	21
Resource, Engineering, and Economic Study for the Great Western Malting Co. Geothermal Project	21
Research and Development of Information on Geothermal Direct Heat Application Projects	21
 PON/PRDA Support	 22
PON Semiannual Review	22
GRC Special Session	22
 M-X/RES GEOTHERMAL APPLICATIONS DEVELOPMENT	 22
 REFERENCES	 24
 APPENDIX A—PUBLICATIONS OF THE IDAHO GEOTHERMAL PROGRAM	 25

FIGURES

1. Typical DCHX working fluid and geofluid temperature profiles	4
2. Casing plan, GeoProducts Corporation WEN-W Well, Wendel Hot Springs, California	10
3. Net brine effectiveness (low salinity)	12
4. Plant capital cost (low salinity)	13
5. Field surface equipment capital cost (advanced binary system—low salinity)	13
6. M-X binary power plant—20-MW module	23

TABLE

1. Industrial process heat data	14
---------------------------------------	----

SEMIANNUAL PROGRESS REPORT FOR THE IDAHO GEOTHERMAL PROGRAM APRIL 1 THROUGH SEPTEMBER 30, 1981

INTRODUCTION

The Idaho Geothermal Program, sponsored by the Department of Energy (DOE), has conducted field experiments and demonstrations at the Raft River Geothermal Test Site since 1973. Located in south-central Idaho, this area is the center of wide-ranging studies into various uses of its medium-temperature (150°C) geothermal fluids. Activities there involve electric power generation, conversion technology (including research into direct-contact heat exchangers), various direct applications, studies of water treatment methods, reservoir engineering, and environmental protection.

Personnel from DOE's Idaho National Engineering Laboratory (INEL) perform experiments and support functions at Raft River and, from DOE's facilities in Idaho Falls, assist DOE in conducting studies and in monitoring and administering various other programs. Among these are programs for providing technical assistance and information to potential developers of geothermal energy resources. Progress of these activities is summarized in this report.

FIVE-MEGAWATT PILOT POWER PLANT (L. Walrath)

The Objective of this activity is to demonstrate the technical, economical, and environmental feasibility of using geothermal fluids with temperatures lower than 150°C to generate electric energy. The facility is a 5-MW(e) (gross power) pilot plant using standard state-of-the-art components and an organic Rankine cycle. The program provides for all elements of management, engineering, testing, and operation of the plant.

During the reporting period, the plant was prepared for startup. Equipment deficiencies noted during component testing were corrected,

and final operating procedures were marked up in conjunction with system operational tests.

All startup modifications have been completed and included the following:

- Heat tracing of the Process Area
- Vapor compressor cooling water modifications
- Electrical modifications of the Water Treatment System.
- Interlock between the generator heater and the generator main breaker
- Support blocks under the vapor compressor
- Underfrequency relay in the substation panel
- Pressure sensitive cutout for Pumps P-801 and P-802
- Steel pipe supports for the geothermal piping
- Thermowells in the Isobutane Flare System to replace sight glasses
- Pressure cutout switches in the control room for stopping the geothermal injection line actuators
- Isobutane strainer ΔP gauges
- Flare System drip leg flame arrester
- Modification of isobutane tank excess flow valves for manual operation
- An air dryer in the air supply line to the Flare System
- Additional access platforms in the Process Area.

All construction component tests have been completed, and the only system operation tests remaining to be done are those of the Isobutane Process System and the Turbine-Generator System. Also, the Injection System is being modified and when completed will need to be system tested.

A final readiness review was conducted on September 10, 1981, to evaluate plant readiness for fill of the process isobutane system and subsequent testing. DOE-ID approval has been received to proceed with the startup testing.

The annual Raft River Environmental Report was completed and issued. An H₂S ambient air monitor has been retrofitted and installed at Raft River. This equipment will collect baseline data on H₂S entering the valley from the Wasatch Front and will be operating during plant startups. Editing of the Raft River Geoscience Case Study has been completed, and the document will be published in November 1981. The annual monitor well report was completed and published in September. A reservoir engineering sampling plan for the startup test has been prepared and will be implemented during the startup test.

RAFT RIVER FACILITY OPERATIONS

(L. Walrath)

The objective of this project is to provide general and systems maintenance functions for the 5-MW(e) Power Plant and associated support systems. Items covered include instrumentation calibration and maintenance, electrical and computer maintenance, and general site and systems maintenance. Warehousing, facility upkeep, and operational support of the Raft River well field and the power plant are provided in this account.

The machine shop and the instrument and electrical shops were moved from the Site 1 area into the maintenance building at the 5-MW(e) site. The new guard station building was put in place, and the electrical hookup was completed. A controlled parking area for employees, visitors, and government vehicles was constructed.

Two new Peerless line shaft pumps were received at the site. The 500-hp, 305-m (1000-ft)

pump was installed in RRGE-1, and the 350-hp, 305-m (1000-ft) pump was installed in RRGE-2. These two pumps deliver 70.65 L/s (1120 gpm) and 42.9 L/s (680 gpm), respectively. Following the installation of the pumps, a flow test was run from supply wells RRGE-1, RRGE-2, and RRGE-3 to injection wells RRG-6 and RRG-7. This test accomplished a scheduled major milestone at Raft River. During testing, filter plugging at the injection pumps caused unstable flow conditions. A procedure change and system modification were prepared to correct the problem. The change involves having the geothermal water flow to a reserve pit rather than in a completely closed system. Modifications at well sites RRG-6 and RRG-7 were started. This included excavating, fabricating concrete forms, pouring concrete, and fabricating valve, pipe, and strainer assemblies to incorporate the revised injection flow process. This modification will be completed prior to the scheduled startup time.

CONVERSION TECHNOLOGY

(J. F. Whitbeck)

Materials Evaluation and Water Treatment Program

(D. F. Suci)

The objective of this program is to define proper material selection for the various components in heat rejection systems using treated geothermal or other highly saline brines, and to determine chemical requirements for prevention of scale and corrosion in these systems.

A spinner test apparatus was used to evaluate corrosion of approximately 40 alloys in aerated brine having chloride levels of 10,000 and 80,000 ppm at 35°C. Of those 40 materials, 70/30 copper nickel and Sea Cure, as well as several very costly alloys (such as Hastelloy and Inconel), had very low corrosion rates and, in the 30 day spinner tests, showed essentially no pitting. A report that summarizes these results is being prepared. Galvanic corrosion tests were also run to evaluate the corrosion effects of dissimilar materials for the 60-kW Prototype Power Plant. Materials involved were carbon steel, 90/10 copper nickel, and aluminum bronze. Galvanic corrosion influenced material loss rates for the carbon steel coupons. The data have not been analyzed; results will be included in subsequent progress reports.

Pilot cooling towers were used in a 6-month corrosion test of four potential tubing materials. Sea Cure, 70/30 copper nickel, Admiralty Brass, and a 12% chrome iron-based alloy were exposed to a pretreated (processed for silica and hardness removal) and cycled cool geothermal brine. Data show that Sea Cure and 70/30 did not pit and had excellent resistance to general corrosion. The Admiralty Brass and the 12% chrome alloy pitted severely. Sea Cure appears to be an excellent condenser tubing material. A report on the corrosion work is in preparation.

Silica must be removed from geothermal brine and other high-silica-bearing water before using the water as a coolant. Tests of silica removal methods showed that while ion exchange is not economical for treating makeup water, it may be applicable in a sidestream treatment process if cooling water can be used at an increased number of cycles of concentration. The use of sand for silica removal shows some promise, but results to date have been inconclusive. Data indicate that dissolution of iron from scrap iron, where the silica precipitates along with iron hydroxide as the pH of the solution is increased to about 8.6, is a potentially economic alternative for silica removal.

Prototype Power Plant

(O. J. Demuth and G. Mines)

Two tests sequences have been conducted with the direct-contact heat exchanger (DCHX) and with the Oak Ridge National Laboratory fluted tube condenser using the 60-kW Prototype Geothermal Facility at the Raft River Site. The first sequence was directed toward evaluation of the thermodynamic and hydraulic performance of the DCHX column. Data taken are presently being analyzed and will be presented separately in a topical report. Typical working fluid (WF) and geofluid (GF) temperature profiles in the column are shown in Figure 1. These profiles were obtained during a period when the column was operating near its maximum throughput conditions (as limited by column operational stability and excessive isobutane loss in the effluent geofluid stream). Figure 1 illustrates a very small approach temperature difference between the working fluid and geofluid (pinch point) occurring at the upper end of the preheating section of the sieve trays. (Energy balances performed on the data suggest that pinch points were well under 0.5°C for some of the runs.)

The second test sequence had the objective of measuring the effects on condenser (and plant) performance of noncondensable gases introduced into the cycle in the DCHX. These noncondensable gases (primarily nitrogen) originate in the geofluid (at a concentration of about 50 ppm), come out of solution in the DCHX, and pass into the condenser as a mixture with the working fluid vapor. Unless the condenser is vented, the noncondensibles accumulate there and reduce the overall heat transfer coefficient markedly, causing an increase in condensing temperature. Plant performance is affected by the increase in condenser pressure that results from the increase in working fluid vapor pressure as well as by the presence of a significant noncondensable gas partial pressure. As an example, during one 7-hour period without condenser venting and with constant cooling water flow and temperature, the condenser total pressure increased by about 1.7 atmospheres as the noncondensable partial pressure built up to a level of about 1/4 atmosphere. By the end of this reporting period, chemical analysis equipment to measure noncondensable and water levels in the working fluid streams or noncondensable and working fluid levels in the geofluid streams had arrived on site but had not been set up. This test sequence will be completed when the analysis equipment is set up and calibration has been completed.

The data acquisition and storage and performance-analysis computer programs for the DCHX tests were put on the Raft River computer. The analysis program is being used to review the data taken to date.

A new working fluid charging and storage station was installed that allows the working fluid to be added to the plant without the use of nitrogen gas to pressurize the storage tank. The system also allows a second working fluid component to be added to the plant independently. This system was set up primarily for the working fluid mixture testing.

The heat exchangers for the supercritical modifications were thermally designed, specified, and ordered. These heat exchangers are shell and tube units that will be used in the next phase of the prototype test program involving the supercritical operation using working fluid mixtures. The design of this plant modification was initiated and approximately 90% completed during the reporting period.

Figure 1. Typical DCHX working fluid and geofluid temperature profiles.

In August, 1981, a paper was presented at the 16th Intersociety Energy Conversion Engineering Conference (IECEC) on the operation of the prototype plant during the automatic test run period.

During this report period, the Ed Wahl Company performed and reported a study on potential modifications to the prototype direct contact heat exchanger that could improve the mass transfer/heat transfer characteristics of sieve tray columns. This study is currently being reviewed.

A paper titled *Analyses of Mixed Hydrocarbon Binary Thermodynamic Cycles for Moderate Temperature Resources* was presented at the 16th IECEC in August 1981 and is included in the proceedings of that meeting.

Advanced Conversion Systems (O. J. Demuth)

This task, initiated late in the previous semi-annual reporting period, provides for the evaluation of various advanced technologies and concepts for converting geothermal energy to electrical energy.

A report, EGG-GTH-5466, titled *Condensing Curves for a Number of Mixed Hydrocarbon Working Fluids*, was completed and submitted to DOE in July 1981. The condensing curves were those used in the mixed hydrocarbon working fluid cycle analyses (mentioned above under "Prototype Power Plant"), and were assembled to provide background information for studies of heat rejection systems for advanced geothermal power plants using mixed hydrocarbon working fluids.

A number of binary geothermal cycles using three mixed hydrocarbon working fluids were analyzed for a 182°C geothermal resource to evaluate the performance augmentation of regenerative preheating techniques such as turbine bleed and turbine exhaust recuperation. Working fluids considered include (by mass) 88% isobutane/12% isopentane, 96% isobutane/4% heptane, and 95% propane/5% hexane. Previous studies have shown these to be the best performing working fluids for the 182°C resource temperature.

Studies of the basic cycles without regenerative preheating show a loss in geofluid effectiveness (net plant power, W-hr/kg geofluid) of 7 to 14% when a geofluid outlet temperature of 71°C was maintained to prevent silica precipitation in the injection wells. Examination of the same cycles with recuperator or turbine bleed regenerative preheating of the working fluid shows that nearly all of the loss of performance can be regained by regeneration while maintaining the 71°C geofluid outlet temperature. The mixture judged to be the most promising of the three investigated, 96% isobutane/4% heptane, showed the same geofluid effectiveness for the regenerated case with the 71°C geofluid outlet temperature restriction as for the nonrestricted case without regeneration. An important added benefit of regeneration is the decrease in the amount of heat rejected in the cycle, thus decreasing the cooling tower size and cooling water makeup requirements by as much as 14%.

A brief probing study was made to investigate the recuperated plant behavior during winter operation using 96% isobutane/4% heptane, and assuming the same plant components as defined for summer operation at 4137 kPa (600 psia) turbine inlet pressure (peak performance conditions). The study was intended to determine whether any unforeseen or detrimental operating characteristics would be discovered for cold-weather operation. No major problems were revealed. The geofluid effectiveness increased by 28% as the ambient wet-bulb temperature was decreased from 16°C to about -11°C while holding the working fluid flow constant. While the geofluid flow rate changed insignificantly, the geofluid outlet temperature dropped from 71°C to 62°C. Therefore, at specific sites for which wet-bulb temperatures reach sufficiently low values, silica precipitation may present a problem requiring a change in operating procedure (such as changing the working fluid flowrate or turbine inlet conditions) at the coldest ambient temperatures.

RAFT RIVER RESERVOIR ENGINEERING (B. F. Russell)

The reservoir engineering research conducted includes three primary technical efforts: geothermal reservoir engineering, monitor well support,

and geochemistry. In general, a significant effort was undertaken to prepare for the startup and operation of the 5-MW(e) facility.

The geothermal reservoir engineering work included the compilation of the geoscientific data collected at Raft River since 1974 into a single document. This *Raft River Geoscience Case Study* details information regarding geology, geophysics, hydrology, and geochemistry. An extensive appendix is also provided to augment the data in the body of the report. The document will be published and made available during November 1981. The *Raft River Geoscience Case Study* concludes that fractures play a dramatic role in fluid production. The reservoir is anisotropic, with the major axis of hydraulic conductivity coincident to the Bridge Fault Zone; this is typical of many Basin and Range systems.

Production and injection testing at Raft River over the past 6 months was confined to short-duration tests, primarily associated with the installation of the new Peerless & Line shaft pumps. These pumps were installed during the month of August. The injection system was modified to allow the spent fluids to flow into the lined injection ponds immediately prior to injection downhole. The benefits of this procedure, primarily a function of available plant operation options, greatly outweigh the weaker aspects of the modification. A geochemical-hydrologic analysis to evaluate the effects of the modification was initiated and will continue during plant startup and operation.

Work performed on Raft River monitor well support is covered in the following section on the Raft River Environmental Program.

The geochemical data collected from previous research was loaded into a computer data bank to provide greater accessibility and easier analysis. Research is continuing in the area in conjunction with the development of a better understanding of the hydrogeology of the Raft River area.

RAFT RIVER ENVIRONMENTAL PROGRAM (T. L. Thurow)

The Raft River Geothermal Environmental Program is designed to assess beneficial and detrimental impacts to the ecosystem resulting

from the development of moderate temperature geothermal resources in the valley. The results of the research contribute information needed to develop an understanding of the ecology of the region. This insight provides a basis for making management decisions that reduce the potential for long-term environmental problems. Much previous research has been conducted over the past 6 years that categorizes the baseline environmental parameters.^{1,2} This section summarizes the environmental monitoring and research efforts during the past 6 months.

Monitor well and water chemistry data were collected as part of the continuing program that is designed to provide information that enables evaluation of the impact of geothermal development on the shallow aquifers. A detailed discussion of these data can be found in the annual progress reports.^{3,4} Seven monitor wells are located in the Raft River geothermal resource area. The depth and location of these wells were planned so that groundwater response to geothermal production or injection can be detected before it becomes noticeable at the irrigation or domestic wells. Each monitor well is equipped with a continuously reading water level recorder.

Groundwater level changes consist of long-term trends and annual seasonal fluctuations. The shallow aquifers of the Raft River Basin have had a declining long-term trend due to extensive irrigation demand. Historically, the seasonal water level reaches its peak at the end of April. At this time, recharge from snowmelt starts to decrease, and the irrigation demands of agriculture begin. Consequently, the water levels decline through the end of September. A steady water level rise is seen from the beginning of October until the end of April, ending an apparent annual cycle. In general, the data collected during the reporting period followed the expected seasonal trends. Water chemistry showed no change. The pumping and injection tests in mid-March and late August were erratic and of relatively short duration; no noticeable changes in groundwater level or water chemistry were attributed to these tests.

The seismic monitoring program in the Raft River Valley consists of three stations recording microseismic events. This continuing monitoring program is necessary to detect if any microseismic activity associated with fluid withdrawal and injection is being induced. During the reporting period, no microseismic events were recorded

within 40 km of the Raft River sampling array. A first order, second class land survey designed to detect subsidence of the well field was conducted during the March production test. Preliminary data indicated that a dilation of up to 20 cm had occurred near the injection wells. This observation could not be confirmed, either on the same day after other readings were taken or during subsequent tests in April, May, and October. Therefore, it is currently believed by the surveyor that the apparent rise in ground elevation recorded in March was an anomalous sighting that may have been due to distortion caused by heat waves.

The weather station east of RRGE-2 continually monitors wind velocity and direction, precipitation, ambient air temperature, and dew point. These data are used to provide information needed by other research programs. Temperature and precipitation during the reporting period were near normal except during the month of May, when a record amount of precipitation for any one month (10.35 cm) was received.

The air quality monitoring program is designed to collect baseline data and to enable identification of impacts associated with suspended particulates released due to geothermal development. Four stations are located in the valley and have been operated on a continuous schedule during the reporting period. Samples are collected every 6 days for a 24-hour period. The total suspended particulate (TSP) concentrations are correlated with the hourly average wind data from the sample period to identify sources of particulates. Background particulates are generated primarily by construction, farming, and vehicular activity at or near the geothermal site. All TSP concentrations are well below the maximum levels allowed by the National Ambient Air Quality Standards. An H₂S monitor was installed late in the reporting period. This equipment continuously records H₂S concentrations in the Raft River Valley and aids in establishing baseline levels for comparison with levels recorded after the 5-MW(e) plant begins operation. Current H₂S levels are associated with inversions that cause H₂S generated by industries along the Wasatch Front in Utah to move into Raft River Valley.

Monitoring of the ferruginous hawk (*Buteo regalis*) and the golden eagle (*Aquila chrysaetos*) populations continued. These raptors have been declining across the west and are very sensitive to human disturbance. This program is designed to

assess what impact, if any, the increased human activity and development of the valley have on the population. To accomplish this, the nesting success of these raptors is monitored. The population and the fledging rate of both species continued to decline in the valley, as expected, during the 1981 season. This decline is directly correlated to the black-tailed jackrabbit (*Lepus californicus*) population cycle. In 1978 the jackrabbit population was at a peak density of about 309 individuals per km². This abundant prey base provided ample food for the ferruginous hawk and golden eagle, encouraging many pairs to nest and enabling a high fledging success. In 1981, the jackrabbit population was down to 91 individuals per km². This reflects the pattern of a steady downward trend that was triggered by an epizootic outbreak in the rabbit population. This decline is part of the natural 10-year predator/prey cycle and has not been impacted by geothermal development in the region.

Environmental research for FY-82 will assess the effects of plant operation on the environment, resample many of the environmental parameters measured during the previous research in the valley, and summarize in detail the results of the whole environmental program.

LOW- TO MODERATE-TEMPERATURE RESERVOIR ENGINEERING PROGRAM

(B. F. Russell)

During FY-81, the objective of this program was to ensure that appropriate methods of reservoir testing and analysis are available to facilitate the development and use of low- to moderate-temperature hydrothermal resources. The INEL activities have now shifted toward long-term, high-risk research pertinent to the resource definition and development.

Two major publications were developed during the report period to assist industry. These were the *Case Studies of Low- to Moderate-Temperature Hydrothermal Energy Development*, IDO-10098, and the *Low- to Moderate-Temperature Hydrothermal Reservoir Engineering Handbook*.

Case studies were conducted for the following localities:

- St. Mary's Hospital, South Dakota
- White Sulphur Springs, Montana
- Pagosa Springs, Colorado
- Utah Roses, Utah
- Monroe, Utah
- Susanville, California

Each case study discusses geology, hydrology, geothermal background, exploratory programs, production drilling, aquifer testing, and current project status, and presents conclusions. The report also provides a critique of procedures used in the developments and makes recommendations for similar future hydrothermal projects.

Work was completed on the draft *Low- to Moderate-Temperature Hydrothermal Reservoir Engineering Handbook*. This handbook will serve as a guideline to developers and consultants for evaluation of reservoir characteristics. Presently, the document is undergoing a peer review by industry. Comments from this review will be collected for incorporation in the final product to be published later this year. The handbook addresses the following major topics:

- Reservoir classification
- Reservoir engineering
- Conceptual modeling
- Testing during drilling
- Theory of testing
- Test planning and methodology
- Geochemistry
- Reservoir monitoring

Both projects were prepared in a joint effort of EG&G Idaho and Lawrence Berkeley Laboratory for the Idaho Operations Office of the Department of Energy.

ENVIRONMENTAL SUPPORT PROGRAM: INJECTION PROGRAM RESEARCH

(B. F. Russell and M. R. Dolenc)

Two new areas of research were initiated in the Environmental Support (Injection) Program: (a) pressure monitoring, and (b) dispersion studies.

The pressure monitoring research is designed to relate observable pressure changes in a geothermal reservoir and associated groundwater aquifers to observed and anticipated solute movement as a result of spent geothermal fluid injection. The initial phase of this task was to acquire a numerical model for use in predicting chemical contamination in potable resources. Two computer models were studied, the Survey Waste Injection Program (SWIP) available from the USGS and a Mass Balance/Energy Balance code to simulate pressure response and the velocity field within the hydrothermal system. The latter code appears to be the better one for this program because of code size, logic problems with SWIP, and the need for multispecies.

The objective of the dispersion research program is to increase the accuracy of models that predict the movement of geothermal fluids in fractured rock systems. Emphasis is being placed on improving the accuracy of dispersion coefficients in the fluid models. A literature search of available dispersion coefficient data from both laboratory and field tests has been completed. Experiments are being designed to obtain additional needed data in volcanic and fractured rocks.

In conjunction with the dispersion coefficient work, the Prickett and Lonnquist code was adapted to an Apple Minicomputer. The program is used to simulate nonleaky artesian conditions for a reservoir with given hydraulic characteristics. One extension of the original code that has been implemented is an option for variable grid spacing. This permits greater detail near pumping wells. The program automatically scales all aquifer coefficients on the basis of grid spacing entered by the user. The orientation of the program is toward the casual user with some hydrologic experience. The final product should be an easily used tool to make rather simplified simulations of groundwater flow.

An internal report entitled *Epidemiology Study of the Madison Aquifer, South Dakota* was prepared. This report was an initial assessment of the use of Madison Aquifer as a domestic water source and a correlation of such use to mortality rates for cancer, heart disease, cerebrovascular disease, and natural causes. Although preliminary in nature, the report notes that no significant differences were detected in mortality rates of counties overlying the Madison Aquifer and those not overlying the aquifer.

Woodward-Clyde Associates, under contract to EG&G, prepared a detailed report on a multiple-completion injection-monitoring well for a typical Basin and Range environment. That report will be completed and released to the general public during the next quarter.

Work will continue in FY-82, with the main efforts directed toward pressure monitoring research and dispersion coefficient work for injection wells.

USER-COUPLED CONFIRMATION DRILLING PROGRAM

(J. A. Strawn and M. R. Dolenc)

The User-Coupled Confirmation Drilling Program is a program designed to absorb some of the risk and costs of exploring for, drilling, and testing hydrothermal resources by cost-sharing those elements of the well development process.⁵ During this reporting period, this program became an active drilling program. Cooperative agreements were signed earlier with Geoproduts Corporation and the City of Alamosa, and a cooperative agreement with Wine Valley Inn, Calistoga, California was signed during this period. One project remains in negotiation at this time.

Geoproduts Corporation, Susanville, California

Geoproduts Corporation plans to dehydrate wood residues and preheat boiler feedwater in a 55-MW hybrid geothermal wood-waste power plant at a location 30.6 km east of Susanville, California (Ref. 5).

The WEN-W geothermal well was spudded on August 1, 1981, and completed to a depth of 1779 m (5837 ft) on September 18, 1981. The well was completed open hole from 1545 m (5068 ft) to total depth, with a 13-3/8-in. surface casing to 307 m (1006 ft) and a 9-5/8-in. intermediate string partially cemented at 1545 m (5068 ft), as shown in Figure 2. A lightly-gelled mud was used for drilling until the first major lost circulation zone was encountered at 1617 m (5305 ft). Aerated water was used for the final 12 m (39 ft) before flashing through the rotary seals prevented drilling further.

A short term (160 minutes) artesian flow test revealed a flow of 40 L/s (635 gpm) with a flow line temperature of 111°C. An Amerada bomb also indicated a downhole temperature of 119°C. A preliminary specific capacity of 0.183 to 0.238 L/s/kPa (20 to 26 gpm/psi) has been calculated from the data.

During November, a long-term artesian test will be conducted, and plans for drilling the injection well will be prepared.

City of Alamosa, Colorado

The City of Alamosa hopes to find a 93°C resource flowing at least 44 L/s (700 gpm) for use in a barley malting plant. The project is located in the San Luis Valley of southern Colorado.

The drilling site has been prepared and drilling will begin early in November. Colorado Well Services will drill the well to a projected depth of 2438 m (8,000 ft).

Wine Valley Inn, Calistoga, California

The Wine Valley Inn, Calistoga, California, is a project proposing to use geothermal fluid as energy for space heating, as a domestic hot water supply, and for heating of pools and spas. The project site is within the city limits of Calistoga, California. Plans are to intercept a reservoir at approximately 152 to 305 m (500 to 1000 ft) with a temperature of 82°C.

Ground breaking ceremonies for the geothermal project were held on September 3, 1981, with officials from DOE/DGHT and DOE/ID attending.

Figure 2. (Casing plan, GeoProducts Corporation WEN-W Well, Wendel Hot Springs, California.

The Environmental Evaluation has been completed, and testing of the Wilson No. 1 well is scheduled to start during November. However, the project has been temporarily suspended pending restructuring of the management team.

FEDERAL BUILDING PROGRAM

(T. W. Lawford & B. C. Lunis)

A Federal Building Program plan was developed and initiated in compliance with the Energy Security Act of 1980 to encourage the use of geothermal energy at Federal facilities located near geothermal resources. Reduced energy costs and energy independence are the main objectives of the program. Representative types of geothermal applications were selected, and Federal facilities that could use geothermal energy were identified for each category. Energy use data were assembled, and the resulting information indicates potential geothermal energy application of significant scope and savings. Military installations appear to have the greatest possibilities, and so, as a first level of effort, information is being compiled to encourage use of geothermal energy at bases located mostly in the western states. Similar information will be prepared for other agencies. Program funding limits activities to matching geothermal resources and Federal uses, and to briefly analyzing the technical and economic feasibility of using geothermal energy at specific sites. Additional efforts to develop the geothermal systems will be provided on an "at-cost" basis, and effort is being expended to encourage this type of involvement.

HYDROTHERMAL R&D EVALUATION

(T. W. Lawford and M. K. Shane)

The goal of this project, an extension of the "Hydrothermal Market Share Estimate" (Ref. 5, p. 8), is to evaluate the effectiveness of DOE geothermal R&D programs in bringing hydrothermal power on line by the year 2000. Toward this end, EG&G Idaho developed additional data on the applications of hydrothermal energy for advanced binary electric power plants and industrial users of direct process heat.

Advanced Binary Power Plants

A series of advanced binary electric power plant cycles developed for the MX-RES project (described in the last semiannual report, Ref. 5, p. 18) have been used to define performance and cost parameters for advanced binary power plants. Figure 3 compares the performance of these advanced binary plants with conventional binary and dual flash steam plants. Significant performance improvements over the conventional binary plants have been noted for resource temperatures in excess of 260°C.

Power plant capital costs have been developed for the advanced binary power plants by costing major equipment items and systems in a manner similar to that used for the more conventional plants. The power plant capital costs shown in Figure 4 are in January 1980 dollars to be compatible with those of the other power plant types.

Field surface equipment capital costs, which include surface piping and valves, were also developed for the advanced binary power plants, as shown in Figure 5. The costs of surface equipment for the advanced binary plants is less than that for conventional binary plants by virtue of the lower brine flow requirements for the advanced plants.

Industrial Process Heat Data

Additional detail has been developed for the use of hydrothermal energy for industrial process heat by 24 screened potential users. The application of this additional data will provide increased accuracy in the determination of the site specific economics for each potential user industry. The additional data, shown in Table 1, encompasses the three areas described below.

Heat exchanger rejection temperatures are based on the lowest process temperature and represent a reasonable temperature difference between the exiting geothermal fluid and the incoming process fluid in a counterflow heat exchanger.

The "use factor" information was developed by questioning personnel in a small sample of each of the screened SIC industries. The number of shifts per day, days per week, and weeks per year have

Figure 3. Net brine effectiveness (low salinity).

Figure 4. Plant capital cost (low salinity).

Figure 5. Fluid surface equipment capital cost (advanced binary system—low salinity).

Table 1. Industrial process heat data

SIC Code	Title	Process Temperature (°C)	Energy Intensity Per Establishment (10 ¹² J/yr)	Heat Exchanger Rejection Temperature (°C)	Use Factor ^a	Energy Intensity Multiplication Factor for Space Heating
2011/13	Meat packing plants, sausages, etc.	60-95	12.67	65	0.65	1.230
2022/23	Cheese & condensed milk	40-205	24.28	45	0.45	1.120
2034/37	Dehydrated & frozen fruits & vegetables	70-175	36.96	75	0.65	1.079
2046	Wet corn milling	50-175	399.1	55	0.96	1.007
2062/63	Cane & beet sugar refining	45-140	1040	50	0.24	1.003
2075/77	Soybean, animal, & marine oils	70-175	57.02	75	0.48	1.051
2082/85	Beer & distilled liquor	75-205	136.2	80	0.48	1.021
2421/35	Softwood veneer & plywood	100-120	145.7	105	0.65	1.020
2611/21/ 31/41/53/ & 61	Pulp & paper products	65-190	1330	70	1.0	1.002
2812/19/ 22/23/24	Chemical products	45-175	603.9	45	0.96	1.005
2833/34	Medicinals & pharmaceuticals	65-120	33.79	70	0.48	1.086

Table 1. (continued)

SIC Code	Title	Process Temperature (°C)	Energy Intensity Per Establishment (10 ¹² J/yr)	Heat Exchanger Rejection Temperature (°C)	Use Factor ^a	Energy Intensity Multiplication Factor for Space Heating
2865	Cyclic crudes & intermediates	120-175	233.3	125	1.0	1.012
2879	Industrial organic chemicals	95-175	54.91	100	1.0	1.053
2873	Nitrogenous fertilizers	145-190	86.58	150	1.0	1.034
3011	Tires & inner tubes	120-170	31.68	125	0.71	1.092
3371	Concrete block & brick	75-180	13.73	80	0.24	1.212
3275	Gypsum products	150-165	196.4	155	0.95	1.015
3295	Minerals, ground & treated	70-120	28.51	75	0.44	1.102
	Ethanol plants	100-175	1352	105	0.93	1.002
0181	Nurseries & greenhouses	40-95	137.3	45	0.50	—
025	Poultry & eggs	65-95	—	65	0.36	—
0279	Fish farms	20-40	—	25	1.0	—
1311	Tertiary oil recovery	120-205	—	125	0.95	—

a. Based on 8,760 hours/year.

been used as input, and the result is based on the ratio between total plant hours per year and 8,760 hours per year.

The "energy intensity multiplication factor for space heating" assumes that the geothermal fluid is used for the process and also for space heating of a typical 4645-m² (50,000-ft²) plant with a heat load of 2.787 Btu/h/m² (30 Btu/h/ft²).

MARKET ASSISTANCE PROGRAM

(W. J. Toth, I. A. Engen)

Program Description

Under the DOE Commercialization Program, which is to be discontinued in FY-82, EG&G Idaho, Inc. provided technical information and assistance to anyone interested in the direct applications of geothermal energy. Information was provided to the public, private, and technical sectors either directly on request, indirectly through the State Commercialization Teams, or generally through exhibits, displays, workshops, and presentations at conferences and meetings. Information consisted of general brochures and pamphlets, application-specific fact sheets, detailed design data, and copies of technical reports and papers.

Technical assistance, which consisted of engineering and economic feasibility analyses, was provided in a consulting manner to requesters in Idaho, Montana, Wyoming, North and South Dakota, Utah, Colorado, New Mexico, Nebraska, and Texas. Such assistance was limited to 100 man-hours on a first-come, staff-available basis and was performed either by in-house engineering staff or by subcontracted architectural-engineering firms. By assisting requesters with such technical information and preliminary feasibility analyses, energy users were encouraged to explore the development of geothermal resources as a viable alternative and replacement for fossil fuels.

The Market Assistance Program also includes other specialized efforts that are directed at particular sectors of the energy-consuming public. In the Community Assistance effort, communities with potential for geothermal district heating are

provided with information on public and private funding sources and with assistance in applying for funding from these sources. In the District Heating Product Team effort, EG&G Idaho has participated with other DOE contractors to provide specialized technical assistance to communities selected under the HUD/DOE District Heating and Cooling Solicitations.

Through the Industry Advisory Team activities, which are coordinated by EG&G Idaho, selected industrial sectors such as the food industries are provided with technical information, displays and exhibits, technical papers at industry conferences, workshops, short courses, seminars, and technical assistance in order to increase awareness that geothermal energy can be used to provide process heat. Through this program, potential users of geothermal energy have been informed and assisted in their initial efforts to develop and use geothermal resources.

Program Results

With most of the fiscal year's exhibiting being done during the first half of the year, only one additional exhibit was placed, bringing the total for the year to nine (eight were required). The Hill Air Force Base Energy Fair drew 75,000 people, bringing the total number of people available to view the exhibit materials to over 275,000 for the year. In addition, exhibit materials were provided to two state teams for local energy fairs. The binary electrical generation model was loaned to the NASA Goddard facility for a high-technology show and to the Brookhaven National Laboratory for the summer for use in their museum of technology. Fact sheets, in some cases more than 500, were supplied to each of the State Teams.

Forty requests for technical assistance and 157 requests for technical information were received during the reporting period, bringing the totals for the fiscal year to 73 and 294, respectively. During the previous reporting period, EG&G Idaho began coordinating these efforts more closely with the State Teams. All technical assistance requests now go to the State Teams initially, and those requiring expertise not immediately available to the State Teams are forwarded to EG&G Idaho for further assistance. The net result initially was a decrease in the number of requests to EG&G Idaho, but an increase in involvement required for each assistance effort. Following the trends of

previous years, interest in the private and public sectors has continued to grow, so that despite the State Teams involvement the number of technical assistance requests nearly equaled that of each of the previous 2 years. The number of information requests did decrease during the year, primarily due to the State Teams' assistance.

During the reporting period, increased subcontracting activity, additional manpower availability, and the withdrawal or referral to other agencies of a number of requests has reduced the number of outstanding technical assistance requests to 22. These commitments will be honored in FY-82 as part of the technical assistance program phase-out.

Representative projects receiving technical assistance in this reporting period include:

- Space heating and process water for a concrete plant in Bismarck, North Dakota
- Downhole heat exchanger evaluations for a subdivision developer in Idaho Falls, Idaho and an office building in Glenwood Springs, Colorado.
- Proposal review for space heating in the South Dakota State Capitol Building at Pierre, South Dakota.
- Distribution and space heating systems for selected facilities at Nebraska Western College, Scottsbluff, Nebraska.
- Geothermal greenhouse heating at Avon, Montana; Midwest, Wyoming; and Butte City, Idaho.

Under the Community Assistance effort, 10 communities have been selected by Eliot Allen and Associates, EG&G Idaho, Inc., and the respective State Teams for consultancy assistance in examining financing vehicles available for district heating systems. Preliminary presentations have been made, except for Las Cruces, New Mexico. Community response has been good. Stanley, Idaho; White Sulphur Springs, Montana; Thermopolis, Wyoming; and Dickinson, North Dakota have expressed a desire for further assistance. An *Institutional and Financial Guide to Geothermal District Heating* has been prepared and will be distributed to the State Teams for other communities not in the program.

Efforts to assist awardees under the HUD/DOE District Heating and Cooling Program have included technical assistance considerations for Missoula, Montana; Provo, Utah; and Thermopolis, Wyoming. The first two were found to have insufficient resources to warrant further effort. The latter was found to have geothermal considerations included in the scope of the award. A direct-use presentation was made to the Santa Ana Pueblo in New Mexico.

The Industry Advisory Team has offered presentations to a number of food associations, with only limited interest being expressed. A presentation has been given to the Al-Sar-Ben Section of the Institute of Food Technologists. A second presentation has been scheduled for the Intermountain Section of the same association in January. The Team met in Boise, Idaho at the end of September and decided to redirect its efforts towards the greenhousing industry. The Geothermal Applications Bibliography noted in the last progress report (Ref. 5) is also to be published.

The multifaceted approach of the Market Assistance program has proven to a be very effective method of presenting geothermal energy as a viable energy source and in stimulating interest in geothermal development. In FY-82, the new administration's emphasis will dictate the phase-out of most of the above efforts and the reorientation of efforts to stress the transfer of geothermal high technology to the technical engineering community. In this manner, it is felt that the free market forces will carry on the development of geothermal energy resources.

PON AND PRDA PROJECTS

**(F. Childs, R. Sanders,
and J. Strawn)**

The EG&G Idaho Geothermal Program Office provides technical assistance to DOE for the Program Research and Development Announcement (PRDA) Program and the Program Opportunity Notice (PON) Program. Both programs were instituted to assist the development 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 consists of demonstration projects in which project costs are shared

between DOE and the private companies, municipalities, or organizations that are conducting the demonstrations. 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

Ore-Ida Foods, Inc., Ontario, Oregon. The project for the Ore-Ida Foods, Inc., plant at Ontario, Oregon, planned to provide 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 gpm) at 160°C from two production wells.

Bottom hole temperature of the initial production well was 182°C, but flow was inadequate—only about 0.82 L/s (13 gpm) with a water level at 1525 m (5000 ft). Because of the cost overrun for the well, no additional drilling is planned.

CH₂M Hill, Los Alamos National Laboratory, EG&G Idaho, and Ore-Ida conducted five formation breakdown tests on the Ore-Ida No. 1 well.

Despite previous tightness, the shallowest perforated zone, 1823 to 1829 m (5980 to 6000 ft), accepted the injected water at over 31.55 L/s (500 gpm) with a well head pressure of 9653 kPa (1400 psig).

The tests proved that a low-cost plug and abandon by pumping cement from the top was feasible (no workover rig needed). An attempt to seal off the shallow sandy zone with perforation sealing balls so that deeper volcanics could be fractured was unsuccessful. Project closeout will be initiated since no improvement in flow was obtained.

Monroe City, Utah. The project planned to install a core district heating system that could later be expanded to include the major areas of Monroe.

The production well produced 75°C at 38 L/s (600 gpm), but this was only 43% of its expected

capability. In addition, at the preliminary design stage, 100% project cost overrun and inadequate operating revenues were predicted.

During this report period, the city has not been able to find an economic alternative use for the resource. Project closeout will be started since the cooperative agreement expired in July, 1981.

Haakon School District, Phillip, South Dakota. The project was expanded to include eight business buildings on the discharge line route in addition to the space heating of the school complex. The Environmental Protection Agency required that the Ra-226 levels in the well water be reduced to 5 pCi/L prior to discharge to the Bad River by the injecting a 10% aqueous solution of barium chloride into the geothermal effluent and holding in a settling pond for 48 hours.

The school system was on-line for the 1980-81 heating season, and system monitoring is in progress.

Periodic clogging of the static mixer and discharge line is being caused by barium sulfate, which precipitates from the sulfate-rich water being used in the aqueous solution. EG&G Idaho conducted a feasibility field test of a pilot model system which used a barium sulfate bed to remove the Ra-226.

Initially the barium sulfate bed removed 99.9% of the Ra-226, but its effectiveness deteriorated too quickly for economic full-scale application. A mixer which can be cleaned more easily and a throwaway discharge line will be investigated as a modification of the original system.

An improved method of analysis for Ra-226 has been developed by Dr. Claude W. Sill of EG&G Idaho. It separates Ra-223 from Ra-226 so that a single radiation count can be used rather than the two counts separated by a 22-day waiting period that were necessary with the isotope mixture.

St. Mary's Hospital, Pierre, South Dakota. This project demonstrates the feasibility of using very-low-temperature water from the Madison Aquifer for space, domestic hot water, and ventilation air heating. The well flows at a temperature of 41°C.

The system functioned properly during the 1980-81 heating season, and the monitoring phase

of the project is in progress. In addition to providing heat to the 7432-m² (80,000-ft²) "old" building, the geothermal system, with a heat pump, also provides heat to the "new" 6503-m² (70,000-ft²) hospital building. The geothermal system provides all space heating down to -12.2°C and domestic hot water and boiler water preheat up to 37.8°C.

A pinhole leak developed in a 0.91-m (3-ft) piece of 6-in.-diameter black iron pipe just downstream from the pressure-reducing valve coming off the wellhead. The horizontal pipe was replaced and was found to have severe internal corrosion flaking. The corrosion pattern indicated the presence of stagnant water halfway filling the pipe at some time, and possibly the presence of oxygen. The pipe was sent to the South Dakota School of Mines and Technology for analysis. About 45 m (150 ft) of the pipe will be replaced.

Diamond Ring Ranch, Haakon County, South Dakota. Geothermal water from an existing artesian well is being used for grain drying and space heating on the Diamond Ring Ranch in South Dakota. 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 system functioned properly during the 1980-81 heating season, and the monitoring phase of the project is in progress.

In preparation for fall reactivation, cracks were soldered at the tube ends of two tube and fin heat exchangers in the mobile home to repair freezing damages from last year. Also, four small leaks in the owner's house were fixed. The recirculating loops were then pressure tested to assure that there will be no loss of the relatively expensive anti-freeze solution which will be used instead of water.

Elko, Nevada. The Elko Geothermal Project will use hydrothermal fluids for process heat in a commercial laundry and for space heating a motor hotel and a bank building.

The geothermal production well, EHC GP-1, was drilled in August, and flow testing was completed in September. The well is 260 m (852 ft) deep. It has 12-in.-diameter casing to a

depth of 78.9 m (259 ft) and an 8-in.-diameter casing, which overlaps the 12-in. casing from 73.8 m (242 ft) to a depth of 165.2 m (542 ft). Open hole completion was used below the 8-in. casing. A 24-h artesian test was conducted at a flow rate of 30.3 L/s (480 gpm) with a 62.1 kPa (9 psig) backpressure at 82.2°C. A 24-h pump test at 49.53 L/s (785 gpm) and 82.2°C was used to predict a 5-yr continuous-flow drawdown of 42.1 m (138 ft).

The chemical analysis showed a TDS of 600 mg/L with a Ra-226 level of 4.8 pCi/L—essentially within drinking water standards.

The Elko Heat Company is now completing the final design and evaluating their disposal options.

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

Flow tests showed that the well would produce 5.68 to 6.31 L/s (90 to 100 gpm). This was inadequate for both space and domestic water heating loads. Therefore, a system is being designed to use the 71.1°C resource to heat 4.73 L/s (75 gpm) of domestic water from 12.8 to 60.0°C. The design was reviewed by EG&G Idaho and DOE-ID, and comments were returned to the prime contractor on September 25. The name of the prime contractor has been changed from MERDI to MultiTech, Inc., by the formation of a subsidiary company.

Pagosa Springs, Colorado. The geothermal resource in Pagosa Springs has been in limited use since the early 1900's. 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. Many of the town's public and private buildings will be heated by the geothermal project.

The reservoir capacity appears adequate for the peak 63.09 L/s (1000 gpm) district heating system. The distribution system was designed to handle twice this capacity.

Corrosion tests of material coupons were performed with an apparatus and procedures furnished by EG&G Idaho. Construction bids were opened, evaluated, and approved and contracts were awarded in the period from April 30 through June 22. Distribution pipelines and insulation were installed and acceptance pressure-testing in progress by September 30. Sixty nine prospective users had signed preliminary use agreements. The construction attracted significant media interest, particularly from Denver.

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 project would retrofit the minimum security section of the prison for domestic water and space heating. 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 there is some concern about interference between the two projects with a limited resource.

CH₂M Hill was placed under contract and completed the preliminary system design and the study of geothermal fluid disposal alternatives. An application for the disposal of geothermal water into the Jordan River was prepared and submitted. The Utah Water Pollution Control Committee met on September 25 and generally favored the application, but they may wait for the results of the planned 30-day flow test of well USP/TH-1 before ruling on it. EG&G Idaho is supplying a 25-hp pump and downhole pressure and temperature instrumentation for the flow test.

Madison County, Idaho. The Madison County Geothermal Project planned to demonstrate a low-temperature geothermal resource for food processing and district space heating.

In the previous report period, the well MCG-1 was drilled to 1199 m (3933 ft), but the water temperature never exceeded 21.7°C. A 3.8 L/s (60 gpm) downward flow ran from 731 to 853 m (2400 to 2800 ft) where the hole had sluffed in and bridged across after drilling. It was postulated that warm lower zones may be masked by the cold downward flow, particularly since the lower 143 m (470 ft) had never been logged.

During this report period, the hole was reopened to total depth, deepened about 3 m

(10 ft), and a 5-1/2-in.-diameter liner hung from 658 to 1070 m (2160 to 3510 ft). The water temperature increased to 22.8°C during airlift flow tests, but cool water was still entering the well bore at the liner hanger. A seal assembly was set over the hanger joint, but it did not stop the cold water entry. The seal assembly was removed. It will be refurbished and reinstalled.

Utah Roses, Sandy, Utah. The Utah Roses greenhouse complex is located in the town of Sandy, which is approximately 17 km south of Salt Lake City, Utah. The complex consists of 23,500 m² (6 acres) of greenhouses that produce cut roses for the national floral market. A production well drilled to a depth of 1525 m (5009 ft) produces water at a pumped flow rate of 12.6 L/s (200 gpm) and a temperature of 50°C with a drawdown of about 366 m (1200 ft).

The geothermal water will be piped to 55 unit heaters located in the greenhouse to produce 3,387,930 Btu/h. The system will provide 100% of the heat load down to an outside temperature of 4.4°C. The spent geothermal water will be discharged to the Jordan River via the Aaranall Ditch.

During the reporting period, the NPDES permit for discharge into the Jordan River was issued, all major system components were purchased, and installation was begun. System startup is expected in November.

Boise, Idaho. The objective of the Boise City/Boise Warm Springs Water District (BWSWD) 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 fourth Boise City well was completed, resulting in an estimated combined artesian flow from all city wells of 157.7 L/s (2500 gpm). Well temperatures are typically just under 76.7°C. To supplement two existing wells, the BWSWD-3 well was completed but production was inadequate. A BWSWD-4 well is being considered.

The BWSWD pipeline design was completed, and bids for construction were opened September 30. Design of the Boise City distribution system was started. Users for 208.2 L/s (3300 gpm) of the City's resource have been

identified. Of this amount, 77.35 L/s (1220 gpm) have committed to join the system, and it is considered highly probable that the balance will join. After the EPA declined consideration, a state discharge permit was approved which authorized discharge into the Boise River in the vicinity of Veteran's Park. A second permit is pending that would allow discharge further upstream, i.e., above the Americana Bridge. If granted, this will result in a large cost saving since the discharge point would be much closer to the user area.

PRDA Projects

Engineering, Marketing, and Economic Study of a 4.5-Million-Gallon Geothermal Fuel Alcohol Plant for the Vale Geopark Site. Renewable Energy, Inc. (REI), formerly Technology International, Inc., is conducting a feasibility study and generating a preliminary design for a fuel alcohol plant. Data from a 457-m (1500-ft) production well will be used in the study.

Four thermal gradient holes were drilled to total depths from 39.6 to 86.9 m (130 to 285 ft), and water samples were taken. The resource analysis, environmental analysis, and plant design proceeded. Computer models of a market and economics analysis and of a plant operating model were partially completed. The first quarterly report was issued.

Drilling of the production well, part of REI's cost share for the project, has been delayed and may delay completion of the study.

Resource, Engineering, and Economic Study for Direct Heat Applications of Geothermal Energy at the Salida (Colorado) Geothermal Project. Chaffee Geothermal, Ltd., is studying the direct heat application of the Poncha Springs-Salida Geothermal Prospect to the industrial process heat requirements of CoZinCo, Inc., and to other prospective energy users in Salida.

During the reporting period, a retrofit design for process and space heat at CoZinCo, Inc., was completed, and the information on the resource was assembled. Preparation of the draft final report is in process.

Commercial Production of Ethanol in the San Luis Valley, Colorado. Westec Services and

McCulloch Geothermal Corp., are investigating the feasibility of using geothermal energy in the San Luis Valley, Colorado, to provide all or part of the total energy requirements of a 75- to 190-million L/yr (20- to 50-million gpy) ethanol production plant.

A proposal to generate a computer code to study the sensitivity of ethanol production to feedstocks and resource parameters was not accepted due to a lack of available funding. At the end of the reporting period, the draft final report was 98% complete. The period of performance was extended from September to November 30, 1981.

Resource, Engineering, and Economic Study for the Great Western Malting Co. Geothermal Project. Trans Energy Systems, Inc., is determining if drilling wells and constructing a heat recovery system to use geothermal energy in processing barley malt is justified.

During the reporting period, the resource definition was completed, allowing the preliminary design of an air preheat system to proceed. The environmental and institutional portions of the project were completed.

Research and Development of Information on Geothermal Direct Heat Application Projects. ICF, Inc., is conducting a study of the more mature PON projects to compile, evaluate, and analyze the data for selected issues; identify and, if possible, circumvent barriers to development; and report on the project.

Data were gathered on selected projects. A report on the economic analysis of five projects was issued. The five projects were: Diamond Ring Ranch, South Dakota; Klamath Falls YMCA, Oregon; Pagosa Springs, Colorado; Philip School, South Dakota; and St. Mary's Hospital, South Dakota. Each project was found to have been capable of standing on its own economic merits if investor confidence had been sufficient to gain financing through normal channels.

These results were presented at a State Commercialization Teams meeting on September 9 and 10; to the PON Semiannual meeting in Boise, Idaho on September 24 and 25; and in a paper accepted for the Geothermal Resources Council Annual Meeting.

PON/PRDA Support

PON Semiannual Review. DOE-ID and EG&G Idaho hosted the PON semiannual review meeting at Boise, Idaho on September 24 and 25. Presentations were made for 19 projects, including those administered by DOE/SAN and DOE/NV, and a 150 page summary report was distributed. The group toured the Mott House and Boise Warm Springs Water District pump house historic structures and witnessed an artesian flow test of the Boise City No. 2 well.

GRC Special Session. The special session on the DOE-sponsored Direct Heat Application Projects was held on Wednesday, October 25 at the GRC Annual Meeting in Houston, Texas. Dr. James C. Bresee, Acting Director, DOE/DGHT, gave the opening Program Overview. The session was divided into two parts of six presentations each: (a) Systems Design and Operation, and (b) Nontechnical Considerations. PON projects presented were: City of Klamath Falls, Boise, Susanville, Pagosa Springs, Moana, Reno, and T-H-S Hospital. A status report on all active PON projects was available, and a handout was distributed describing PON and general direct-use information sources.

M-X/RES GEOTHERMAL APPLICATIONS DEVELOPMENT

(T. W. Lawford and M. K. Shane)

The M-X/RES project has been terminated following the administration decision to base the missile in existing silos rather than the original relocatable basing mode in southern Nevada and Utah. DOD funding projected to supplement the DOE funding did not materialize, requiring revisions to schedules and a reduction in the scope of work.

The principal accomplishment for the reporting period was a draft report on advanced binary power plants and hybrid fossil/geothermal plants. The report discusses variations in plant performance and component sizes over a resource temperature range of 182 to 232°C. Also covered are topics such as the optimum hydrocarbon mixture as a working fluid for an advanced binary cycle, the sizing of an advanced binary power plant for three possible resource temperatures, and the possible advantages of using a combined fossil fuel-geothermal (hybrid) power plant for M-X/RES applications.

The results of the study indicate that, to the extent the resource can now be characterized, advanced binary plants operating with 90% isobutane and 10% hexane in a supercritical Rankine cycle give a performance as much as 30% higher than those in previous studies. Also, the hybrid concepts appear to be potentially competitive, and they warrant additional study.

Equipment for a possible 204°C reservoir temperature was sized for a 20-MW(e) power plant for the purpose of generating "order-of-magnitude" costs for power plants in the temperature range and size that will be required at the operating base locations. Figure 6 illustrates a possible configuration for this concept.

Also, additional work was completed in the area of geothermal space conditioning systems and equipment that could be used at an operating base like Milford, Utah. A computer code that simulates the entire production, distribution, and waste disposal process for geothermal district heating systems was put on line and debugged. Cost surfaces were developed as functions of possible resource characteristics, and a simplified method was developed to obtain cost estimates for a given district space conditioning system. District heating system data required as input are: heat load, well cost and flow rate, reservoir temperature, distribution system area and building density, and transmission pipeline length.

INEL-S-33 448

Figure 6. M-X binary power plant—20 MW module.

REFERENCES

1. T. L. Thurow, J. F. Sullivan, *INEL Geothermal Environmental Program, 1979 Annual Report*, EGG-2028, April 1980.
2. L. S. Cahn, T. L. Thurow, J. A. Martinez, *INEL Geothermal Environmental Program, 1980 Annual Report*, EGG-2113, April 1981.
3. S. G. Spencer and D. M. Callun, *An Analysis of the Response of the Raft River Monitor Wells to the 1979 Injection Tests*, EGG-2057, September 1980.
4. P. Skiba, D. Goldman, S. Spencer, L. Hull, *The Raft River Geothermal Project Groundwater Monitoring Program Progress Report*, EGG-2119, July 1981.
5. J. T. Parker and C. J. Smith (eds.), *Semiannual Progress Report for the Idaho Geothermal Program, October 1, 1980 to March 31, 1981*, EGG-2110, September 1981.

APPENDIX A

PUBLICATIONS OF THE IDAHO GEOTHERMAL PROGRAM

APPENDIX A

PUBLICATIONS OF THE IDAHO GEOTHERMAL PROGRAM

Table A-1 lists reports published 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

CASE STUDIES OF LOW-TO-MODERATE TEMPERATURE HYDROTHERMAL ENERGY DEVELOPMENT

EG&G IDAHO, INC., IDAHO FALLS (USA); LAWRENCE BERKELEY LAB., CA (USA)

1981

IDG-10008

SEMIANNUAL PROGRESS REPORT FOR THE IDAHO GEOTHERMAL PROGRAM OCTOBER 1, 1980 TO MARCH 31, 1981

PARKER, J.T.; SMITH, C.J.

1981

EGG-2118

RAFT RIVER GEOTHERMAL PROJECT GROUNDWATER MONITORING PROGRAM PROGRESS REPORT

SKIBA, P.; GOLDMAN, D.; SPENCER, S.; HULL, L.

1981

EGG-2119

CORROSION TESTING OF CARBON STEEL IN HEATED GEOTHERMAL BRINE

SUCIU, D.F.; WIFOFF, P.M.

1981

EGG-GTH-5474

RAFT RIVER GEOTHERMAL FACILITY

WHITBECK, J.F.

1981

EGG-M-03281

CONDENSING CURVES FOR A NUMBER OF MIXED-HYDROCARBON WORKING FLUIDS

DEWITT, O.J.

1981

EGG-GTH-5456

INEL GEOTHERMAL ENVIRONMENTAL PROGRAM 1980 ANNUAL REPORT

CAHILL, L.S.; THURON, T.L.; MARTINEZ, J.R.

1981

EGG-2113

PULSATING-FLOW MEASUREMENT WITH AN ORIFICE FLANGE

BOSSARI, L.M.

1981

EGG-1183-1797

Table A-1. (continued)

TECHNICAL ASSISTANCE AND INFORMATION DISSEMINATION EFFORTS AT THE ILLINOIS NATIONAL ENGINEERING LABORATORY, OCTOBER 1, 1979--SEPTEMBER 3, 1979

TOTH, M. J.; ENGEN, I. R.; HELTZER, F. L.

1980

EGG-GTH--5367

HYDROTHERMAL ENERGY DEVELOPMENT PROJECTS

DIBELLO, E. G.

1981

CONF-810515--7

ANALYSES OF MIXED-HYDROCARBON BINARY THERMODYNAMIC CYCLES FOR MODERATE-TEMPERATURE GEOTHERMAL RESOURCES

DEMUETH, O. J.

1981

EGG-PG-P--86-041

PROTOTYPE GEOTHERMAL POWER PLANT SUMMARY OF OPERATION FOR AUTOMATIC-RUN TEST PHASE

HINES, G. L.

1981

EGG--2678

SEMIANNUAL PROGRESS REPORT FOR THE ILLINOIS GEOTHERMAL PROGRAM, APRIL 1 TO SEPTEMBER 30, 1980

ZHRIG, R. R.

1981

EGG--2677

GEOTHERMAL WETLANDS: AN ANNOTATED BIBLIOGRAPHY OF PERTINENT LITERATURE

STANLEY, H. E.; THORON, T. L.; RUSSELL, B. F.; SULLIVAN, J. F.

1986

EGG--2629

COMPLETION AND TESTING REPORT: INEL GEOTHERMAL EXPLORATORY WELL ONE (INEL-1)

PRESTWICH, S. H.; BOWMAN, J. R.

1980

IID--10095

ANALYSIS OF THE RESPONSE OF THE RAFT RIVER MONITOR WELLS TO THE 1979 INJECTION TESTS

SPENCER, S. G.; CALLAN, D. H.

1980

EGG--2657

MODERATE TEMPERATURE GEOTHERMAL: A DIRECT SOURCE OF PROCESS ENERGY

STIGER, R. R.

1980

CONF-801014--1

REMOVAL OF SILICA FROM RAFT RIVER GEOTHERMAL WATER

SUCHT, D. F.; MILLER, R. L.

1980

EGG-FH--5176

Table A-1. (continued)

OPERATIONAL UPSET TRANSIENTS IN A DUAL BOILING BINARY CYCLE GEOTHERMAL POWER PLANT
WIGGINS, D. J.; BLIER, C. J.

1988

CONF-880920--9

RAFT RIVER 5-MW(e) GEOTHERMAL PILOT PLANT PROJECT
RASMUSSEN, T. L.; WHITBECK, J. F.

1988

CONF-880920--8

SNW RAFT RIVER FACILITY EXPERIENCE

WHITBECK, J. F.

1988

CONF-880681--1

SEMIANNUAL PROGRESS REPORT FOR THE IDAHO GEOTHERMAL PROGRAM, OCTOBER 1, 1979-MARCH 31, 1988

THRIG, R. R.; (ED)

1988

EGG-2834

GEOTHERMAL DEVELOPMENT IN SOUTHWEST IDAHO: THE SOCIOECONOMIC DATA BASE

SPENCER, S. G.; RUSSELL, B. F.; (EDS)

1979

EGG-GTH-5007

PROGRESS IN DIRECT HEAT APPLICATIONS PROJECTS

CHILDS, F. W.; JONES, K. W.; NELSON, L. B.; STRAWN, J. R.; TUCKER, M. K.

1988

CONF-880920--15

RESULTS OF ACID TREATMENTS IN HYDROTHERMAL DIRECT HEAT EXPERIMENT WELLS

STRAWN, J. R.

1988

CONF-880920--16

NUMERICAL SIMULATION OF THE IMPACT OF FLUID INJECTION IN THE RAFT RIVER GEOTHERMAL AREA

SPENCER, S. G.; GOLDMAN, D.

1988

CONF-880920--17

BEHAVIOR OF TEMPERATURE AND CONCENTRATION OF SHALLOW GROUNDWATER IN THE RAFT RIVER GEOTHERMAL AREA

TANG, D. H.; GOLDMAN, D.; MARTINEZ, J. R.; LANTZ, R. B.

1988

CONF-880557--3

HEAT PUMPS IN LOW TEMPERATURE APPLICATIONS

KELLER, J. G.

1988

CONF-880886--7

Table A-1. (continued)

LOW-TEMPERATURE HYDROTHERMAL RESOURCE EVALUATION

GOLDMAN, D.

1988

CONF-880629--2

RAFT RIVER 5-MW(e) GEOTHERMAL PILOT PLANT

STIGER, R. R.

1988

CONF-880806--8

RADIUM AND URANIUM DETERMINATION ON SAMPLES OF UTAH ROSES GEOTHERMAL WATER

WILLIS, C. P.

1988

EGG-PHYS-5169

FLUIDIZED-BED POTATO WASTE DRYING EXPERIMENT AT THE RAFT RIVER GEOTHERMAL TEST SITE

COLE, L. T.; SCHMITT, R. L.

1988

EGG-2836

DESIGN AND OFF-DESIGN OPERATION OF A DUAL-BOILING BINARY GEOTHERMAL POWER PLANT

BLETH, C. J. JR.

1988

CONF-880725--9

HYDROTHERMAL ENERGY: A SOURCE OF ENERGY FOR ALCOHOL PRODUCTION

STIGER, R. R.

1988

CONF-880626--1

INEL GEOTHERMAL ENVIRONMENTAL PROGRAM, 1979 ANNUAL REPORT

THURMAN, T. L.; SULLIVAN, J. F.

1988

EGG-2828

GEOTHERMAL DIRECT APPLICATIONS HARDWARE SYSTEMS DEVELOPMENT AND TESTING, 1979 SUMMARY REPORT

KELLER, J. G.

1988

EGG-2813

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

IMKIG, R. R.

1988

EGG-2818

SHORT-TERM PILOT COOLING TOWER TESTS

SUCIU, D. F.; MILLER, R. L.

1988

EGG-FM-5887

Table A-1. (continued)

GEOTHERMAL DIRECT USE PROJECTS

DIBELLO, E. G.

1988

CONF-880218-1

GEOTHERMAL DEVELOPMENT IN SOUTHWEST IDAHO: THE SOCIOECONOMIC DATA BASE

SPENCER, S. G.; RUSSELL, B. F.

1979

EGG-GTH-5008

GEOTHERMAL RESOURCE EXPLORATION IN BOISE, IDAHO

NELSON, L. B.; NIEMI, M. L.; STOKER, R. C.

1988

EGG-2811

IDAHO GEOTHERMAL DEVELOPMENT PROJECTS. ANNUAL REPORT FOR 1976

IDAHO NATIONAL ENGINEERING LAB., IDAHO FALLS (USA)

1976

IDG-1548-12

EFFECTS OF IRRIGATION ON CROPS AND SOILS WITH RAFT RIVER GEOTHERMAL WATER

STANLEY, M. E.; SCHMITT, R. C.

1988

EGG-2805

PERFORMANCE AND OPERABILITY STUDY OF THE RAFT RIVER 5 MW(e) PILOT GEOTHERMAL POWER PLANT STEADY STATE BEHAVIOR

BLIGH, C. J.

1979

EGG-PK-G--79-617

GEOCHEMICAL MODELING OF THE RAFT RIVER GEOTHERMAL FIELD

OVERTON, M. L.; CHANEY, R. E.; MCATEE, R. E.; GRAHAM, D. L.

1979

EGG-2804

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

BURDGE, L. F.; SCHULTZ, R. J.; STIGER, R. R.

1979

TREE-1359

BRUNEAU KNOWN GEOTHERMAL RESOURCE AREA: AN ENVIRONMENTAL ANALYSIS

SPENCER, S. G.; RUSSELL, B. F.; (EDS)

1979

EGG-GTH-5004

MOUNTAIN HOME KNOWN GEOTHERMAL RESOURCE AREA: AN ENVIRONMENTAL ANALYSIS

SPENCER, S. G.; RUSSELL, B. F.; (EDS)

1979

EGG-GTH-5005

Table A-1. (continued)

CASTLE CREEK KNOWN GEOTHERMAL RESOURCE AREA: AN ENVIRONMENTAL ANALYSIS

SPENCER, S.G.; RUSSELL, B.F.; (EDS)

1979

EGG-GTH-5003

CRANE CREEK KNOWN GEOTHERMAL RESOURCE AREA: AN ENVIRONMENTAL ANALYSIS

SPENCER, S.G.; RUSSELL, B.F.; (EDS)

1979

EGG-GTH-5002

VULCAN HOT SPRINGS KNOWN GEOTHERMAL RESOURCE AREA: AN ENVIRONMENTAL ANALYSIS

SPENCER, S.G.; RUSSELL, B.F.; (EDS)

1979

EGG-GTH-5001

DIRECT APPLICATIONS OF GEOTHERMAL ENERGY MARKET PENETRATION ANALYSES AND INFRASTRUCTURE REQUIREMENTS

LUNTS, B.C.; HANNY, J.R.

1979

CONF-790906-32

EVALUATION OF TESTING AND RESERVOIR PARAMETERS IN GEOTHERMAL WELLS AT RAFT RIVER AND BUTSE, IDAHO

ALLMAN, D.W.; GOLDMAN, D.; NIEMI, W.L.

1979

CONF-791020-1

POTENTIAL USE OF GEOTHERMAL RESOURCES IN THE SNAKE RIVER BASIN: AN ENVIRONMENTAL OVERVIEW, VOLUME II, ANNOTATED BIBLIOGRAPHY

SPENCER, S.G.; RUSSELL, B.F.; SULLIVAN, J.F.; (EDS)

1979

EGG-2000(VOL 2)

POTENTIAL USE OF GEOTHERMAL RESOURCES IN THE SNAKE RIVER BASIN: AN ENVIRONMENTAL OVERVIEW, VOLUME I.

SPENCER, S.G.; RUSSELL, B.F.; SULLIVAN, J.F.; (EDS)

1979

EGG-2000(VOL 1)

RAFT RIVER GEOTHERMAL AQUACULTURE EXPERIMENT, PHASE II.

CAMPBELL, D.K.; ROSE, F.L.; KENT, J.C.; WATSON, L.R.; SULLIVAN, J.F.

1979

TREE-1370

HEAT PUMPS: PRIMER FOR USE WITH LOW TEMPERATURE GEOTHERMAL RESOURCES

KELLER, J.G.

1977

IDO-1570-T17

POTENTIAL FOR UTILIZING GEOTHERMAL RESOURCES FOR THE CULTURE OF FRESHWATER FISH

SULLIVAN, J.F.; BELERAI, H.H.

1979

CONF-790906-24

Table A-1. (continued)

SNAKE RIVER BASIN ENVIRONMENTAL PROGRAM

SPENDER, S.G.; SULLIVAN, J.F.

1979

CONF-790906--25

INJECTION AT RAFT RIVER: AN ENVIRONMENTAL CONCERN

SPENDER, S.G.

1979

CONF-790905--26

TODAY'S GEOTHERMAL POWER ECONOMICS AND RISK

LAMFORD, T.M.

1979

CONF-790803--44

CHEMICAL LOGGING: A GEOTHERMAL TECHNIQUE

MCATEE, R.F.; ALLEN, C.A.

1979

CONF-790906--21

GEOCHEMICAL MODELING AT RAFT RIVER

ALLEN, C.A.; CHANEY, R.E.; MCATEE, R.E.

1979

CONF-790906--22

ANALYSIS OF BINARY THERMODYNAMIC CYCLES FOR A MODERATELY LOW-TEMPERATURE GEOTHERMAL RESOURCE

DEBUTH, D.J.

1979

TRER-1365

CHEMISTRY AND MATERIALS IN GEOTHERMAL SYSTEMS

MILLER, R.L.

1979

CONF-790508--1

COMPLETION REPORT: RAFT RIVER GEOTHERMAL PRODUCTION WELL FIVE (RRGP-5)

MILLER, L.G.; PRESTWICH, S.M.

1979

IDO-10082

COMPLETION REPORT: RAFT RIVER GEOTHERMAL PRODUCTION WELL FOUR (RRGP-4)

MILLER, L.G.; PRESTWICH, S.M.

1979

IDO-10081

CORROSION OF COPPER-ZINC AND COPPER-NICKEL ALLOYS IN A GEOTHERMAL BRINE

MILLER, R.L.

1978

CONF-790219--5

Table A-1. (continued)

HEAT PUMPS COUPLED TO GEOTHERMAL RESOURCES CAN PROVIDE ECONOMICAL PROCESS HEAT

NEILL D. T.; SCHMITT, R. C.

1979

CONF-790446--1

COMPLETION REPORT: KRAFT RIVER GEOTHERMAL INJECTION WELL SEVEN (KRG1-7)

HILLER, L. G.; PRESTWICH, S. H.

1979

IDO-10064

COMPLETION REPORT: KRAFT RIVER GEOTHERMAL INJECTION WELL SIX (KRG1-6)

HILLER, L. G.; PRESTWICH, S. H.

1979

IDO-10063

OVERVIEW OF GEOTHERMAL ENERGY IN THE UNITED STATES

SCHULTZ, R. J.; DIBELLO, E. G.

1979

CONF-790530--1

1978 ANNUAL REPORT, INEL GEOTHERMAL ENVIRONMENTAL PROGRAM

SPENCER, S. G.; SULLIVAN, J. F.; STANLEY, N. E.

1979

TRER-1340

CHEMICAL LOGGING OF GEOTHERMAL WELLS

MCHTEE, R. E.; ALLEN, C. R.; LEWIS, L. C.

1979

CONF-790415--17

GEOTHERMAL ENERGY MARKET POTENTIAL IN INDUSTRIAL PROCESSING

SCHULTZ, R. J.; HANNY, J. A.; KNUTH, M. H.

1978

CONF-781183--1

CORROSION OF COPPER BASE ALLOYS IN A GEOTHERMAL BRINE. SPE PAPER NO. 7881

MILLER, R. L.

1979

CONF-790100--2

MEASUREMENT AND CONTROL TECHNIQUES IN GEOTHERMAL POWER PLANTS

WHITBECK, J. F.; DART, R. H.; HILLER, J. D.; BREMER, D. R.

1979

TRER-1342

SEMIANNUAL PROGRESS REPORT FOR THE IDAHO GEOTHERMAL PROGRAM. APRIL 1--SEPTEMBER 30, 1978

BLAKE, G. L., (ED.)

1978

TRER-1295

Table A-1. (continued)

SEMIANNUAL PROGRESS REPORT FOR THE IDAHO GEOTHERMAL PROGRAM, OCTOBER 1, 1977-MARCH 31, 1978
IDAHO NATIONAL ENGINEERING LAB., IDAHO FALLS (USA)

1978

TREE-1278

RAFT RIVER SAN GEOTHERMAL PILOT PLANT

WHITBECK, J.F.; PISCITELLA, R.R.

1978

CONF-788641-1

TRANSIENT MODELING AND SIMULATION OF THE GEOTHERMAL ELECTRIC PLANT

HILLER, J.D.

1977

TREE-1116 NUCLEAR TECHNOLOGY DIVISION ANNUAL REPORT FOR PERIOD ENDING SEPTEMBER 30, 1976 PP. 527-529

AGRICULTURE, GREENHOUSE, WETLAND AND OTHER BENEFICIAL USES OF GEOTHERMAL FLUIDS AND HEAT

SCHMITT, R.C.

1981

CONF-810471-1

RESIDENTIAL SPACE HEATING COST: GEOTHERMAL VS CONVENTIONAL SYSTEMS

ENGEL, I.A.

1978

TREE-1182

GEOTHERMAL R AND D PROJECT REPORT FOR APRIL 1, 1977-SEPTEMBER 30, 1977

KINZE, J.F.; (ED)

1978

TREE-1256

HEATING AND COOLING THE RAFT RIVER GEOTHERMAL TRANSITE PIPE LINE

SHAFFER, C.J.

1977

TID-28244

RESULTS OF SHORT-TERM CORROSION EVALUATION TESTS AT RAFT RIVER

HILLER, R.L.

1977

TREE-1176

FLOATING POWER OPTIMIZATION STUDIES FOR THE COOLING SYSTEM OF A GEOTHERMAL POWER PLANT

SHAFFER, C.J.

1977

TREE-1164

TECHNICAL DIVISION QUARTERLY PROGRESS REPORT, APRIL 1-JUNE 30, 1977

SLANSKY, C.M.; DICKEY, B.R.; MUSGRAVE, B.C.; ROHDE, K.L.

1977

TCP-1123

Table A-1. (continued)

GEO THERMAL R AND D PROJECT REPORT. OCTOBER 1, 1976-MARCH 31, 1977

KUNZE, J.F.; (ED)

1977

TREE-1134

TECHNICAL DIVISION QUARTERLY PROGRESS REPORT. JANUARY 1-MARCH 31, 1977

SLANSKY, C.H. (ED)

1977

ICP-1117

ASBESTOS-CEMENT PIPELINE EXPERIENCE AT THE RAFT RIVER GEO THERMAL PROJECT

MILLER, L.G.; KUNZE, J.F.; SANDERS, R.D.

1977

TREE-1114

TECHNICAL DIVISION QUARTERLY PROGRESS REPORT. OCTOBER 1-DECEMBER 31, 1976

SLANSKY, L.H. (ED)

1977

ICP-1111

POTENTIAL FOR UTILIZING GEO THERMAL ENERGY FOR SPACE HEATING IN RE-CONSTRUCTED SUGAR CITY, IDAHO

KUNZE, J.F.; LUTHOUSE, J.H.; STOKER, R.C.

1977

TREE-1016

TWO-DIMENSIONAL SIMULATION OF THE RAFT RIVER GEO THERMAL RESERVOIR AND WELLS

KETTENACKER, M.C.

1977

TREE-1085

DETERMINATION OF THE 5MW GROSS NOMINAL DESIGN CASE BINARY CYCLE FOR POWER GENERATION AT RAFT RIVER, IDAHO

INGVARSSON, I.J.; HROSEN, M.W.; (EDS)

1976

TREE-1029

BENEFICIAL USES OF GEO THERMAL ENERGY DESCRIPTION AND PRELIMINARY RESULTS FOR PHASE 1 OF THE RAFT RIVER IRRIGATION EXPERIMENT

SCHMITT, R.C.; SPENCER, S.G.

1977

TREE-1046

GEO THERMAL R AND D PROJECT REPORT FOR PERIOD JULY 1, 1976 TO SEPTEMBER 30, 1976

KUNZE, J.F.; (ED)

1976

TREE-1030

GEO THERMAL SHELL AND TUBE HEAT EXCHANGER AUGMENTATION

NEILL, D.T.

1976

TREE-1023

Table A-1. (continued)

GEOTHERMAL R AND D PROJECT REPORT FOR PERIOD APRIL 1, 1976 TO JUNE 30, 1976
KUNZE, J.F.; (ED)
1976
TRER--1006

CORROSION ENGINEERING ON THE UTILIZATION OF THE RAFT RIVER GEOTHERMAL RESOURCES
HILLER, R.L.
1976
ANCR--1342

GEOTHERMAL R AND D PROJECT REPORT, JANUARY 1, 1976--MARCH 31, 1976
IDAHO NATIONAL ENGINEERING LAB., IDAHO FALLS (USA)
1976
ANCR--1319

PLAN FOR DEVELOPING MODERATE TEMPERATURE/LOW SALINITY GEOTHERMAL RESOURCES
KUNZE, J.F.; WHITBECK, J.F.
1976
ANCR--1318

TEST REACTOR OPERATION SUPPORT
HEATH, R.L.; HENSCHOLD, J.W.; SMITH, G.L.
1976
ANCR--1255 NUCLEAR TECHNOLOGY DIVISION ANNUAL PROGRESS REPORT FOR PERIOD ENDING JUNE 30, 1975 PP. 275-294

DESIGN CONCEPT FOR FLASH STEAM SYSTEMS FOR USE WITH MEDIUM TEMPERATURE GEOTHERMAL WATER
WHITBECK, J.F.
1975
ANCR--1210

CONCEPTUAL STUDY FOR TOTAL UTILIZATION OF AN INTERMEDIATE TEMPERATURE GEOTHERMAL RESOURCE
SWINK, D.G.; SCHULTZ, R.J.
1976
ANCR--1260

GEOTHERMAL R AND D PROJECT REPORT FOR OCTOBER 1, 1975--DECEMBER 30, 1975
IDAHO NATIONAL ENGINEERING LAB., IDAHO FALLS (USA)
1976
ANCR--1285

GEOTHERMAL STEAM PLANT MODELING AND POWER TRADEOFF STUDIES
SHAFFER, C.J.
1976
ANCR--1295

GEOTHERMAL R AND D PROJECT REPORT, JULY 1, 1975--SEPTEMBER 30, 1975
IDAHO NATIONAL ENGINEERING LAB., IDAHO FALLS (USA)
1975
ANCR--1281

Table A-1. (continued)

SPACE HEATING SYSTEMS IN THE NORTHWEST: ENERGY USAGE AND COST ANALYSIS

KELLER, J.G.; KUNZE, J.F.

1976

ANCR-1276

CONCEPTUAL DESIGN AND COST EVALUATION OF ORGANIC RANKINE CYCLE ELECTRIC GENERATING PLANT POWERED BY MEDIUM TEMPERATURE GEOTHERMAL WATER

DART, R.H.; NEILL, D.T.; WHITBECK, J.F.

1975

ANCR-1226

ANALYSIS OF THE BINARY CYCLE FOR GEOTHERMAL POWER GENERATION

HAUSEN, W.W.; INGVARSSON, T.J.

1975

ANCR-1245

DRILLING PLAN BOISE SLIM (2-3/8 IN. DIAMETER) HOLES DEMONSTRATION SPACE HEATING PROJECT, OCTOBER 1975

STONER, R.G.

1975

ANCR-1261

GEOTHERMAL R AND D PROJECT REPORT FOR PERIOD APRIL 1, 1975-JUNE 30, 1975

KUNZE, J.F.

1975

ANCR-1247

FY 1974 PROGRAM PLAN FOR GEOTHERMAL PROJECT

BERGNET NUCLEAR CO., IDAHO FALLS, IDAHO (USA)

1974

ANCR-1139

GEOLOGICAL ASPECTS OF AN ASSESSMENT OF THE NATIONAL POTENTIAL FOR NON-ELECTRICAL UTILIZATION OF GEOTHERMAL RESOURCES

HOLLENBAUGH, K.H.; NICHOLS, C.R.

1975

ANCR-1218

NON-ELECTRIC UTILIZATION PROJECT: BOISE, IDAHO

KUNZE, J.F.; RICHARDSON, A.S.; HOLLENBAUGH, K.H.; NICHOLS, C.R.; HINK, L.L.

1975

CONF-750625-15

MODERATE TEMPERATURE UTILIZATION PROJECT IN THE RAFT RIVER VALLEY

KUNZE, J.F.; MILLER, L.G.; WHITBECK, J.F.

1975

CONF-750625-14

GEOTHERMAL SPACE HEATING OF A GEOTHERMAL DRILLING RIG

KELLER, J.G.; MILLER, L.G.; MINES, G.L.; RICHARDSON, A.S.

1975

ANCR-1241

Table A-1. (continued)

REVIEW AND TENTATIVE SELECTION OF A WORKING FLUID FOR USE WITH A MEDIUM TEMPERATURE (300-450° F) GEOTHERMAL RESOURCE

WHITEBECK, J. F.

1975

ANCR-1224

NATIONAL PROGRAM DEFINITION STUDY FOR THE NON-ELECTRICAL UTILIZATION OF GEOTHERMAL ENERGY

KUNZE, J. F.; RICHARDSON, A. S.

1975

ANCR-1214

GEOTHERMAL R AND D PROJECT REPORT FOR PERIOD 1 JANUARY 1975--31 MARCH 1975

KUNZE, J. F.

1975

ANCR-1222

FISH CULTURE UTILIZATION OF GEOTHERMAL ENERGY

ROBERTS, P. A.

1975

ANCR-1228

COOLING METHOD STUDY FOR THE PROPOSED RAFT RIVER POWER PLANT

NETTZEL, J. W.

1975

ANCR-1263

GEOTHERMAL SPACE HEATING PROJECT INVOLVING IDAHO STATE OWNED BUILDINGS IN BOISE, IDAHO

KUNZE, J. F.; RICHARDSON, A. S.; NICHOLS, C. R.; HINK, L. L.

1975

ANCR-1231

CHOOSING MATERIAL FOR THE RAFT RIVER GEOTHERMAL PLANT

REITHANN, G. A.; SCHUTZ, H. W.

1975

ANCR-1285

PRELIMINARY THERMAL ANALYSIS OF BINARY CYCLE FOR GEOTHERMAL PILOT PLANT

HANSEN, W. W.; INGVARSSON, I. J.

1975

ANCR-1191

GEOTHERMAL R AND D PROJECT REPORT FOR PERIOD OCTOBER 1, 1974 TO DECEMBER 31, 1974

AREDET NUCLEAR CO., IDAHO FALLS, IDAHO (USN)

1975

ANCR-1288

ENVIRONMENTAL REPORT: DEEP GEOTHERMAL TEST WELLS IN THE RAFT RIVER VALLEY

SPENCER, S. G.

1975

ANCR-1284

Table A-1. (continued)

GEOTHERMAL R AND D PROJECT REPORT FOR PERIOD JULY 16, 1974--SEPTEMBER 30, 1974
AEROJET NUCLEAR CO., IDAHO FALLS, IDAHO (USA)

1974

ANCR-1190

IDAHO GEOTHERMAL R AND D PROJECT REPORT FOR PERIOD MARCH 16, 1974 TO JULY 15, 1974

KUNZE, J.F.; MILLER, L.G.; WHITBECK, J.F.; LEWIS, B.D.; MARTIN, L.F.; RICHARDSON, R.S.; SHAFFER, C.J.

1974

ANCR-1175

LOW TEMPERATURE DEMONSTRATION GEOTHERMAL POWER PLANT IN THE RAFT RIVER VALLEY

KUNZE, J.F.; MILLER, L.G.; NEILL, D.T.; NICHOLS, C.R.

1974

ANCR-1138

CONCEPTUAL DESIGN OF A GEOTHERMAL DEMONSTRATION PLANT FOR THE RAFT RIVER BASIN

KUNZE, J.F.; MILLER, L.G.; NEILL, D.T.

1973

ANCR-1129 NUCLEAR TECHNOLOGY DIVISION ANNUAL PROGRESS REPORT FOR PERIOD ENDING JUNE 30, 1973

GEOTHERMAL POTENTIAL OF THE SNAKE RIVER PLAIN AREA

KUNZE, J.F.; BRUNGER, R.H.

1973

ANCR-1129 NUCLEAR TECHNOLOGY DIVISION ANNUAL PROGRESS REPORT FOR PERIOD ENDING JUNE 30, 1973 PP. 385-389

IDAHO GEOTHERMAL R AND D PROJECT REPORT FOR PERIOD DECEMBER 16, 1973 TO MARCH 15, 1974

KUNZE, J.F.; MILLER, L.G.

1974

ANCR-1153

NUCLEAR TECHNOLOGY DIVISION ANNUAL PROGRESS REPORT FOR PERIOD ENDING JUNE 30, 1973

AEROJET NUCLEAR CO., IDAHO FALLS, IDAHO (USA)

1973

ANCR-1129

FY 1974 PROGRAMS PLAN FOR GEOTHERMAL PROJECT

AEROJET NUCLEAR CO., IDAHO FALLS, IDAHO (USA)

1974

ANCR-1139

THERPP: A THERMODYNAMIC PROPERTIES PROGRAM

DEEDS, R.S.

1979

TREE-1081 (REV)

THERPP: A THERMODYNAMIC PROPERTIES PROGRAM

DEEDS, R.S.

1977

TREE-1081

Table A-1. (continued)

HEXCOR: A HEAT EXCHANGER COST AND DESIGN OPTIMIZATION ROUTINE

TURNER, S.E.; MADSEN, M.M.

1977

TRG-1112

RAFT RIVER GEOSCIENCE CASE STUDY

DOLENC, M.R.; HULL, L.C.; HIZELL, S.A.; RUSSELL, B.F.; SKIBER, P.A.; STRAWN, J.A.; TULLIS, J.A.

1981

EGG-2125 (VOL. 1)

RAFT RIVER GEOSCIENCE CASE STUDY--APPENDICES

DOLENC, M.R.; HULL, L.C.; HIZELL, S.A.; RUSSELL, B.F.; SKIBER, P.A.; STRAWN, J.A.; TULLIS, J.A.

1981

EGG-2125 (VOL. 2)

GEOTHERMAL SOURCE POTENTIAL AND UTILIZATION FOR METHANE GENERATION AND ALCOHOL PRODUCTION

AUSTIN, J.C.

1981

EGG-2137

GEOTHERMAL SOURCE POTENTIAL AND UTILIZATION FOR ALCOHOL PRODUCTION

AUSTIN, J.C.

1981

EGG-2138

POTENTIAL GEOTHERMAL ENERGY APPLICATIONS FOR IDAHO ELKS REHABILITATION HOSPITAL

AUSTIN, J.C.

1981

EGG-2139