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GEOHERMAL R&D PROJECT REPORT FOR
PERIOD APRIL 1, 1977 TO SEPTEMBER 30, 1977

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ABSTRACT

The Idaho Geothermal Research and Development Program was initiated in 1973. The program's mission has been to improve the technology necessary to utilize geothermal fluids of moderate temperature--fluids of about 150°C or 300°F. This report discusses the progress from April to September 1977, during which time an injection well was drilled and the design of a 5000-kW(e) pilot power plant was completed. Manufacturers began fabricating heat exchangers and condensers for the power plant and a cooling tower to dissipate 40 MW of heat was ordered.

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

- The Raft River Rural Electric Cooperative
- The U.S. Geological Survey (Menlo Park, Denver, and Boise Offices)
- The State of Idaho Department of Water Resources
- The Washington Public Power Supply System
- The U.S. Bureau of Land Management, Boise and Burley Offices
- Boise State University

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1.0 SUMMARY

During the six-month period from April to September 1977, the major activities within the Geothermal Program at the Idaho National Engineering Laboratory were as follows:

RRGI-4

A fourth geothermal well was drilled at Raft River to an intermediate depth of 866 m (2840 ft). This well will be used for injection experiments. The well produces 122°C (252°F) water under artesian flow, and drilling was deliberately stopped short of the main 150°C (302°F) producing reservoir. The well is only 610 m (2000 ft) from RRGE-1, which produces from the 1143-m (3750-ft) to 1372-m (4500-ft) depth.

The injection study will examine the interaction among reservoir strata at various depths. The responses of the upper aquifer to injection at RRGI-4 will be monitored in an existing hole 0.8 km (1/2 mile) away, the 396-m (1300-ft) USGS No. 3 slim hole, and in two holes yet to be drilled, a 457-m (1500-ft) hole nearby and a 152-m (500-ft) hole within 0.8 km (1/2 mile).

Heat Exchanger Tests

Heat exchanger fouling and corrosion tests continued with the Raft River 1250 to 1550-ppm fluids, using 6.1-m (20-ft) tubes of various materials. Of chief interest is admiralty brass, which has performed well for six months of testing. It is the material from which the heat exchangers for the 5000-kW(e) pilot plant will be fabricated.

Long-Lead Manufactured Items

Long-lead manufactured items (heat exchangers, condensers, and pumps) were all specified, selected, and ordered for the 5000-kW(e) pilot plant.

60 kW(e) Pilot Plant

Manufacture of a small 60-kW(e) pilot plant turbine generator is nearing completion. Researchers will be able to study an operating binary-cycle geothermal unit before construction begins on the large 5000-kW(e) plant. The 60 kW unit has a single-stage, axial-flow turbine geared to an induction motor/generator and loop circulating pump. The thermodynamic properties of commercial grade isobutane will also be measured with this small unit.

Soil Heat Dissipation Plot

In conjunction with the power-plant work at Raft River, a grid of piping was buried in a one hectare (2-1/2-acre) plot of land. Researchers will study the possibility of using such an underground grid to dissipate a power plant's waste heat without consuming water. The use of water-consumptive wet cooling towers may be restricted in many geothermal areas. The soil heat dissipation method is an alternative cooling method, possibly less expensive than dry cooling towers. The response of various hardy crops (trees, hay, sugarbeets) to the soil heating will be evaluated. Such supplementary benefits may further enhance the attractiveness of soil heat dissipation as a cooling method for power plants.

Fish-Rearing Experiments

Facilities for a fish-rearing experiment using flow-through geothermal water with 1250 to 1550 ppm were built and stocked with tilapia, shrimp, and catfish. This experiment will continue for a full year to study the complete life cycle of the organisms. Last year's three-month experiment indicated faster growth with no toxicity when compared to normal hatchery fish, but was too brief to provide definitive conclusions about a complete rearing cycle.

Boise Pump Testing

Pump testing was conducted on the two new geothermal wells at Boise, Idaho, in order to determine long-term well characteristics and reservoir parameters. These tests have given further confidence to the previous belief of the availability of geothermal water of about 75°C (170°F) all along the Boise Front Fault (northeast edge of the city). The "Beard" well is very productive, with permeability-thickness product factor exceeding 500,000 millidarcy ft. The "BLM" well, 305 m (1000 ft) away and further from the main fault, has only 1/10 this permeability thickness, but is still a useful well. Interactions between these wells and the Warm Springs Avenue Heating System wells were negligible, further implying that extensive development of geothermal wells along the front fault is practical.

2.0 EXPERIMENTS AND TESTING AT RAFT RIVER - J. F. Kunze, L. G. Miller

2.1 Wells

Table I summarizes the uses of the three deep geothermal wells, at Raft River, over the six-month period (April to September 1977).

TABLE I
WELL USE - APRIL 1977 TO SEPTEMBER 1977

<u>Well</u>	<u>Flow Rate</u>	<u>Wellhead Temperature</u>	<u>Uses</u>
RRGE-1	3 to 16 liters/sec (50 to 260 gpm) (continuous use)	135°C (275°F)	Supplied water for corrosion and deposition experiments; cooling-tower-treatment experiment; fluidized-bed and direct-contact heat-exchanger tests; fish-farm, soil-heating, and irrigation experiments, and space heating.
RRGE-2	1 to 30 liters/sec (20 to 500 gpm)	133°C (272°F)	Underwent stepped well-performance tests to evaluate reservoir parameters. Well performed exactly as in the summer of 1975.
RRGE-3	1 to 48 liters/sec 20 to 800 gpm)	144°C (292°F)	Underwent well performance step testing to evaluate reservoir parameters. Down-hole pump installed and further step tests conducted. Compared to predictions from artesian testing, the pump testing indicated the well is better at high production rates than initially expected.
RRGI-4	36 liters/sec	163°C (352°F) (down hole)	In two tests after drilling, accepted injection up to capacity of drilling mud pumps, (32 liters/sec, 540 gpm). Flow tests were conducted to clean out cuttings prior to rig removal. Subsequently, production-flow tested at rates up to 200 gpm.

2.1.1 RRGE-3 Pump Tests

Pump tests were started on RRGE-3 on July 7. The pump used for testing is a REDA 320 ZP tandem-motor submersible at a depth of 236 m (773 ft). This pump is a second-generation pump designed for the flow rates of RRGE-1. After the testing is completed on RRGE-3, this pump will be checked for degradation, etc. It will then be installed in the first well.

A long-term test was started on July 6, at a flow rate of 600 gpm. This test was run for approximately 13 days, while monitoring temperature, pressure, well drawdown, and pump current.

Water samples were taken during all pumping tests, and analyses are being conducted at this time. An on-line pH detector monitored the well output pH throughout most of the test. Some variations were recorded, as seen in Figure 1. Water was discharged into the RRGE-3 reserve pit, a relatively large excavation used during drilling. The water did not get too deep during the two-week test, due to seepage and evaporation. At the request of the Idaho State Water Resource Department, the ground-water level and chemistry were monitored at two locations at opposite directions from the reserve pit, using the domestic well on the southwest and a monitor hole on the northeast. This monitoring will answer the question whether the ground water could be contaminated by the geothermal water seepage over long-term testing. Little evidence has been seen to date. The large volume irrigation pumping during summer months causes the ground-water level to continually drop.

2.1.2 RRGI-4 Drilling

The fourth Raft River geothermal well, RRGI-4, was designed for injection at intermediate depth. This zone was selected for injection so that researchers could study the interaction of that strata with the shallow ground-water aquifer and the deep production zone. If results are as expected, both injection well and pipeline costs will be substantially reduced. The well is located approximately 0.8 m (1/2 mile) south of RRGE-1. This area was chosen because the land was available, the hydrology was better understood, because reservoir engineers suspected major upward leakage from the production zone--allowing them to monitor and study the connections between the reservoirs below RRGE-1 and RRGI-4.

Drillers began work on April 8, drilling with a 38-cm (15-in.) bit and reaming to 66 cm (26 in.). On April 10, 122 m (400 ft) of 51-cm (20-in.), K55, 94-lb surface casing were set and cemented to the surface. A 31-cm (12-1/4-in.) hole was drilled to 582 m (1909 ft), logged and cored, then reamed to 44 cm (17-1/2 in.). At a depth of 577 m (1894 ft) a core was attempted, using the Joides quadracone core-bit system on loan from LASL. During the trip into the hole with the corebarrel, the 30-cm (12-in.) O.D. corebarrel stabilizer became stuck at 438 m (1436 ft). Bit depth was 438 m (1474 ft). Back-off shot service was used to disengage

Fig. 1 Pump tests at RRGE-3

the drill pipe from the coring assembly. The assembly was recovered by using jars and bumper sub to free the stabilizer.

At a depth of 579 m (1901 ft), 34-cm (13-3/8-in.) K55 54.5-lb casing was run and stage cemented. The shoe was drilled out with a 31-cm (12-1/4-in.) bit and drilling proceeded to a depth of 643 m (2110 ft). At this depth, it was necessary to trip out for a new bit. Prior to drilling, the decision had been made to core at selected intervals; this coincided with trips for a new bit. During the trip in with the corebarrel, an obstruction was encountered at 575 m (1887 ft). Milling tools were used, accomplishing only sidetracking around the obstruction. Logging determined the obstruction to be the 34-cm (13-3/8-in.) casing shoe, float collar (one joint up) and two joints of casing which parted and fell 25 m (81 ft). With a fishing spear, an attempt was made to jar the casing loose and let it fall downhole, hopefully creating a more vertical entry through the casing. The casing could not be moved. Attempts to pass the bit and string through the parted casing were made and were successful three times, enabling drilling to proceed to a depth of 860 m (2820 ft). A second core was taken from 860 to 866 m (2820 to 2840 ft).

Predrilling parameters had been set. Maximum total depth would be 1067 m (3500 ft), and the maximum bottom-hole temperature was to be 122°C (250°F).

Temperature logs taken during this period show temperatures of 114°C (237°F) at the top of the parted casing and 122°C (252°F) at 823 m (2700 ft). Artesian flow had reached 250-300 gpm. The decision was made to terminate drilling. Prior to releasing the rig, four joints of 24.4-cm (9-5/8-in.) casing were passed through the parted 34-cm (13-3/8 in.) casing to verify that the well could be deepened and completed as a production well at a later date. Temperature-log data is shown in Figure 2.

Two short injection tests were run, to verify predicted injection capacities of the well, prior to releasing the drill rig. Tests were designed to measure the wellhead pressures required to inject fluids at various rates. The amount of injected fluid was limited to prevent its entering the formations. The first test duration was 4-1/2 hours, utilizing the rig pumps. (See Figure 3 and Table II for Injection test No. 1 Results; see Figure 4 and Table III for Injection Test No. 2 Results.)

The second test was run within 24 hours of the first test. The flow rate was a steady 252 gpm over five hours. The well was cool, as indicated by the initial wellhead pressure of 19 psi. It dropped to 8 psi when the well was shut in at the close of the test.

2.2 Pipelines and Site Facilities

2.2.1 Pipeline from RRGE-3 to RRGE-1 Site

The design of this 2743 m (9000-ft) pipeline was completed, bids let and awarded, and construction started this quarter. This pipeline,

Fig. 2 RRG-4 temperature logs

Fig. 3 First injection test on RRG1-4 - May 3, 1977

TABLE II

RRGI-4 INITIAL INJECTION TEST RESULTS

Time [a]	Wellhead Pressure (psig)[b]	Pump Rate No. 1 [c]	Pump No. 2 Rate [d]	Total Rate (gpm)
0033	32	0	0	0
0034	32	30	30	189
0054	49.5	"	"	"
0055		60	"	378
0056	62	"	"	"
0108	59	"	"	"
0109		60	30	456
0110	65	"	"	"
0119	63	"	"	"
0120		60	60	534
0121	77	"	"	"
0124	78.5	"	"	"
0125		60	0	378
0127	70	"	"	"
0138.5	43.5	"	"	"
0139		30	0	189
0141	43	"	"	"
0148	44	"	"	"
0149		60	0	378
0150	47	"	"	"
0159	54	"	"	"
0159.5		0	0	0
0200	42	0	0	0
0300	32	0	0	0
0310		45	"	283.5
0320	40	"	"	"
0500	55	"	"	"
			Total gallons injected	95,148

[a] Selected intervals.

[b] Shut-in wellhead pressure was 32 psi.

[c] No. 1 pump 6.3 gal/stroke.

[d] No. 2 pump 2.6 gal/stroke.

Pumping rates and wellhead pressure went from 50 psi wellhead pressure at 189 gpm to 78.5 psi at 534 gpm requiring ΔP of 46.5 psi.

The aquifer rapidly returned to normal after being shut-in as indicated by a drop from 42 psi to 37 psi in 5 minutes and normal 32 psi in less than one hour.

Fig. 4 Second injection test on RRG1-4 - May 4, 1977

TABLE III
RRGI-4 SECOND INJECTION TEST RESULTS

(Cold Well)

<u>Time</u>	<u>Wellhead Pressure (psig)</u>	<u>Pump Rate</u>	<u>Total Rate GPM</u>
0055	19 psi	0	0
0100	46	45	252
0130	48	45	"
0200	41	"	"
0230	46	"	"
0300	62	"	"
0330	65	"	"
0400	65	"	"
0430	65	"	"
0500	70	"	"
0530	60	"	"
0600	8	0	0
		Total gallons injected	120,960

The ΔP during this test was 51 psi with a high of 70 psi after four hours then dropped to 60 psi at the end of the test as well cooled off.

when completed in late August, will allow the higher salinity geothermal fluids (by a factor of two over RRGE-1 and RRGE-2) of RRGE-3 to be utilized in the test trailer at the RRGE-1 site. The pipeline has the flexibility to allow:

1. the fluid from RRGE-3 to be discharged into the RRGE-3 reserve pit,
2. the fluid to be delivered to the RRGE-1 site, or
3. fluid from RRGE-1 or RRGE-2 to be transported to RRGE-3 and discharged into the RRGE-3 reserve pit.

The pipeline is sloped from both sites to the middle (near the river), where pipe connections will allow draining of either half or the full pipeline for repair or other requirements. This pipeline is being installed with a minimum of 2.54 cm (1 in.) of polyurethane foam insulation sprayed on after the pipe has been installed in the trench. The pipeline is constructed of 25.4-cm (10-in.) transite pipe buried 76 cm (30 in.) below the ground level. Most above-ground piping and valves are 20 cm (8 in.) spray insulated similar to the buried transite pipe. The use of 2.54-cm (1-in.) thick urethane insulation with pipe buried 76 cm (30 in.) will effectively reduce the heat loss by a factor of at least two--even more for conditions of wet soil. A flow of 1000 gallons/minute through the 25.4-cm (10-in.) transite pipe (4.8×10^5 lb/hr) results in the following:

Heat loss per mile of pipeline = 1.32×10^6 Btu/hr
(equivalent to 48 kW of electricity at 12-1/2% conversion efficiency)

Fluid temperature loss per mile of pipeline = 2.75°F .

2.2.2 Pipeline from RRGE-1 Site to RRG1-4

Design of the pipeline portion of this task is near completion. The A&E work on this pipeline is being done by CH₂M-Hill at Boise, Idaho. Conceptual design of the injection pumping, monitoring, and filtering system is near completion, with reviews being conducted by personnel from East Mesa and the USGS.

This 30-cm (12-in.) polyurethane-foam-insulated line will transfer fluids from the RRGE-1 site to the RRG1-4 site for injection into that intermediate-depth injection well. This work is expected to be completed late in October. Full-scale injection tests can begin upon completion of this system.

The low pump pressures obtained from these short tests are very encouraging. Before full-scale injection begins, the well will be artesian flowed to clean cuttings and debris from the producing formations.

The well was then flow-tested for production under artesian conditions. Because of its intermediate depth and low production temperature (122°C, or 252°F), the artesian pressure is much lower than that of the other three wells. RRG-4 has a pressure of approximately 20 psi when at equilibrium and 50 psi when hot. The transmissivity, or permeability-thickness product of the producing zone (which appears to be between 579 m and 732 m (1900 to 2400 ft) is about the same as that of RRG-2--about 15,000 millidarcy ft.

Table IV describes RRG-4 and provides a chronology of drilling experience.

Tests are being conducted on the outlet water from the tube-and-shell heat exchanger test. Approximately 60,000 gallons of geothermal discharge fluid was diverted through screens to determine the size of particles discharged from the pilot plant heat exchangers. Only a couple of sand grains were caught in the screen. The screen openings are approximately 0.036 cm (0.014 in.) square. Further tests will be conducted on particulates in the geothermal fluid.

2.2.3 Pilot Plant Site Location

An area has been selected southwest of the RRG-1 site for the location of the 5 MW pilot plant. This area has the following advantages over other areas considered:

1. It is near what is considered the center of the resource area. Therefore, pipeline costs will be reduced.
2. This area has two distinct elevations, so that the shop, control building, and cooling tower can be located at a higher elevation than the isobutane systems. This arrangement will produce better cooling-tower performance and ensure safety from isobutane leakage.
3. Large areas of relatively flat land are available adjacent to the facility for the cooling pond, soil cooling and other facilities.
4. Services and facilities located at the RRG-1 site will be close, thus reducing costs.
5. A common fire-control system can serve both areas.
6. The site area and adjacent land are owned and controlled by BLM.

2.2.4 Aquaculture Facility - J. W. Neitzel

The design and construction of the Raft River aquaculture facility was completed. The system consists of a series of indoor

TABLE IV

SUMMARY OF RRG1-4 CHARACTERISTICS AND DRILLING EXPERIENCE

Location:	610 m (2000 ft) S of RRG1-1, in SE 1/4 S 23 T 16S, R 23 E Elevation = 1474 m (4835 ft)
Depth and Casing:	
51-cm (20-in.) surface casing to 34-cm (13-3/8-in.) production casing to	122 m (400 ft) [a] 555 m (1820 ft)
Open hole 24.4 cm (9-5/8 in.) to	866 m (2840 ft)
Production Zone Temperatures :	
579 m (1900 ft)	111°C (232°F) minimum
762 m to 853 m (2500 to 2800 ft)	122°C (252°F) minimum
Drilling Experience:	
Spudded, began drilling	April 8, 1977
Cemented surface casing to 122 m (400 ft)	April 11, 1977
Drilled out of surface casing	April 12, 1977
Reached 582 m (1909 ft)	April 19, 1977
Cemented production casing	April 20 and 21, 1977
Drilled out of production casing	April 22, 1977
[at which time bottom 24 m (80 ft) of casing - two joints - were found to be loose in the hole]	
Reached TD of 866 m (2840 ft)	May 1, 1977

[a] All distances are distance from ground level

fish raceways, outdoor raceways, fish ponds, and a cooling system to cool geothermal water to a temperature of 24 to 30°C (75-85°F). (See Figure 5)

The geothermal supply of 110 gpm will come from the manifold at the main test building near RRGE-1. The hot well water will first be cooled to approximately 93°C (200°F), in a shell-and-tube heat exchanger (which uses the fish-pond discharge as cooling water). This 93°C (200°F) water will then flow to a spray pond where spraying will reduce the temperature to approximately 43°C (110°F). A second spraying into another pond will reduce the temperature to the desired level of approximately 26°C (80°F). If the water in the second spray pond is colder than 24°C (75°F), 2 to 5 gpm of 93°C (200°F) water will be added to the pond discharge to ensure that the water entering the series of raceways is in the correct temperature range.

Before the water enters the building, the flow will be split into two paths--one path for the flow of natural geothermal water, the other with provisions to add chemicals that would be used in a power plant cooling system. Except for the water treatment, each path will be identical. Each of the two flow paths will consist of six parallel fish raceways inside the building, two series of raceways outside, and one fish pond. The treatment chemicals will be removed at the discharge of the fish ponds. The two flow paths will then join and flow through the cooling side of the shell-and-tube heat exchanger, then on to the reserve pit.

The site is located 152 m (500 ft) west of the RRGE-1 site. This location will provide an elevation between the spray ponds and the fish ponds of 5 m (15 ft) to allow gravity flow. Because of this elevation, the spray ponds will act as a reserve water supply, ensuring continuous operation of the facility in the event of a power loss or shut-down of RRGE-1.

Construction of the facility began in July, and it was ready to be stocked with fish at the end of September.

2.2.5 Line Shaft Vertical Turbine Pump - J. W. Neitzel

Initial testing with the submersible REDA Corporation pump, set at 244 m (800 ft), has been encouraging. However, it was deemed wise to conduct tests on shaft-driven pumps (despite their greater expense), so as to evaluate the relative performance and reliability of both types of well pumps.

In March 1977, inquiries were sent to several pump suppliers to determine their qualifications and interest in supplying a vertical-turbine deep-well pump for geothermal service. The pump would be set at a depth of 244 m (800 ft). Power would be supplied to the pump by a surface-mounted electric motor through a vertical stainless-steel shaft. Manufacturing a vertical turbine-type pump for a 150°C (300°F) environment presents some very special problems with regard to expansion

Fig. 5 Aquaculture experiment layout

rates and bearing materials. The 244-m (800-ft) setting even further complicates these problems.

Other design requirements include a flow rate of 800 gpm with a discharge pressure of 150 psi at the surface of the well. Special material requirements were also given, based on test results obtained at the Raft River test-facility. The following materials, for instance, were found to be unacceptable for use in the geothermal fluid because of their susceptibility to corrosion: copper-nickel alloys, aluminum-base alloys, and martensitic stainless steel.

In May 1977, a request for price quotations was sent to the five pump suppliers who showed interest in supplying a geothermal vertical-turbine pump. The companies responding with a quotation were Johnston Pump Company and Peerless Pump Company. The two quotations were reviewed, and Peerless received the award at a low-bid price.

Peerless has been involved with the pumping of geothermal brines from deep wells since 1969. They have pumped brines up to 190°C (375°F) at rates up to 1200 gpm and with pumps set as deep as 213 m (700 ft). Their experience in various projects has given them an overview of the problems of corrosion, erosion, thermal expansion and scaling. With this experience, they are well qualified to supply a deep-well vertical-turbine pump for geothermal service at Raft River.

The Floway Pump Company of Fresno, California, was also contacted as a possible supplier. Floway has supplied pumps and pump components to the Iceland geothermal facilities for the past ten years. With their experience in mind, they were contacted by telephone to determine their interest and to obtain an engineering estimate. It was found that Floway could provide a deep-well vertical-turbine pump to meet the design; however, their deep-well pump would not be capable of supplying the 150 psi wellhead pressure at the 800 gpm flow rate. Their design therefore calls for a booster pump at the surface to bring up the pressure at an additional cost of approximately \$20,000. With the added cost, and with installation problems involved with the second pump, Floway could not compete with the Peerless design and cost.

2.3 Reservoir Engineering - R. C. Stoker

2.3.1 RRGI-4 Coring and Logging

RRGI-4 was drilled and cored during April. Two cores were taken, one at 579 m (1900 ft) and the other from 862 to 865 m (2828 to 2838 ft). Total depth of the injection well is 866 m (2840 ft). The effective water porosity at 579 m (1900 ft) is 24.5%, and the permeability is 60.0 millidarcies. The sample from around 863 m (2833 ft) has an effective water porosity of 28.5% and a permeability of 0.20 millidarcies. See Table V for the latter test results.

Several temperature logs were taken of the well, in addition to compensated neutron/gamma, acoustilog/gamma, densilog/gamma/caliper and

TABLE V

RRGI-4 POROSITY-PERMEABILITY TEST RESULTS

SAMPLE DESIGNATION	WET BULK DENSITY (gm/cc)	DRY BULK DENSITY (gm/cc)	GRAIN DENSITY (gm/cc)	TOTAL POROSITY (%)	EFF. WATER POROSITY (%)	CONFINED WATER PERMEABILITY $\sigma_3 = 2800$ psi
2842.25'	2.28	2.03	2.66	24.0	23.0	280 μ D .28 milli
2844.08'	2.45	2.34	2.69	13.0	13.0	10 μ D .01 milli
2847.5'	2.54	1.93	2.70	28.5	28.5	16 μ D .016 milli
2850.3'	2.31	2.16	2.67	19.0	19.0	80 μ D .08 milli
2852.6'	2.39	2.01	2.70	25.6	23.0	40 μ D .04 milli

dual-induction/spontaneous potential. All applicable logs were digitized for future analysis. These logs were taken from ground level to the 579-m (1900-ft) depth. Logging from 579 m (1900 ft) to total depth of 866 m (2840 ft) ground level has been attempted but has been unsuccessful because of the displaced casing at the 579-m (1900-ft) depth.

All drill cuttings from RRG-4 were examined during drilling, and a good correlation was established between RRG-4 and RRG-1. Cross sections of all four Raft River wells are shown in Figure 6.

2.3.2 RRG-3 Logging

Logging was completed in RRG-3 by running logs in Leg C. A complete set of logs was run, including compensated neutron/gamma, temperature, dual induction/spontaneous potential, acoustilog/gamma/caliper, densilog/gamma/caliper and spectralog. The spectralog indicated unusual amounts of potassium (K-spor) around 1402 m (4600 ft) with some increase in uranium. Another interesting interval occurred in the metamorphosed zone from 1646 to 1676 m (5400 to 5500 ft); logs again showed increased amounts of potassium and uranium. However, the most interesting interval occurred in the Quartz Monzonite below 1768 m (5800 ft). This zone showed an increase in thorium and a particularly large increase in uranium.

2.3.3 RRG-4 Future Injection Tests

In order to properly evaluate future injection testing in the RRG-4 well, baseline data is required for the area around the well. Pressure instrumentation has been established in the USGS No. 3 hole, and more data is being gathered on other surrounding wells. Further long-term injection testing will be conducted in FY-78.

2.3.4 INEL Logging Truck

The logging truck underwent major modifications in order to upgrade the logging capability and efficiency and provide improved all-weather logging ability.

2.4 Environmental Program at Raft River

The environmental report for the Raft River pilot power plant was used in June. The draft report had been offered for review to the following agencies and environmental-interest groups: U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, Idaho Department of Water Resources, Idaho Department of Health and Welfare, Sierra Club, Idaho Conservation League, Wilderness Society, and environmental program contractors within both the Idaho and Washington Offices of the Department of Energy. Personnel from Dames and Moore and from Stafco served as technical advisors for the report. The final report, as well as an assessment of potential geothermal developments (other than those involving DOE) in Raft River was issued in June.

Fig. 6 Cross section of Raft River wells

2.4.1 Species of Concern

The major concern identified by the reviewers of the environmental report was for the preservation of the ferruginous hawk. In light of the concerns that have been expressed in the past by both the BLM and the Fish and Wildlife Service, the Raft River environmental program continues to support the Fish and Wildlife Service monitoring of nesting raptors in the Valley. An aerial survey of the nests between Almo and the northern end of the Valley was conducted in May. Preliminary data from the survey, as well as for past surveys, are summarized in Table VI. Surveys of this type will be taken periodically. The U.S. Fish and Wildlife Service has received funding to expand the study to include research on disturbance-effect patterns. This work began in March 1977.

The Department of Zoology at Brigham Young University was awarded a contract to supplement the initial baseline studies of small mammals, ayians, and insects in the vicinity of the geothermal development. A large grid with nearly 300 traps was established for the small mammal work. As the study progressed, some traps were moved to ten vegetation communities identified in previous work by the University of Utah Research Institute (UURI). Animals at these sites are being sacrificed and examined for reproductive characteristics. The grids were partially sampled again in June and July; the intensive trapping was repeated in August. Plots for the avian study were established on all four sides of the geothermal development area and tied into the vegetation plots. Four major passerine (songbird) species, the Sage Thrasher, Brewer's Sparrow, Sage Sparrow, and Horned Lark, were used as indicator species. Nesting density and species-composition data were used as indices to monitor changes. The ant-aphid system was chosen for an intensive insect study because they are closely responsive to vegetation changes. Selected rate variables were examined and a model of the system was developed. Permanent monitoring stations have been established so that future impact assessments can be related to baseline data. A summary report of the 1977 studies will be available in January 1978. Similar studies will be conducted during 1978.

The first year of the UURI vegetation study was completed. A summary report was issued, and the most relevant data were included in the overall environmental report. Approximately 29,000 ha (72,000 acres) were mapped and 13 major types of vegetative cover were distinguished. The dominant life forms are shrubs, such as greasewood, sagebrush, and saltbush. Nineteen "permanent" plots were established and are being surveyed again this summer.

2.4.2 Particulates

Particulates collected by UURI in the venting plume at RRGE-2 in December 1976 have been analyzed. The particulates did not consist primarily of sodium and chloride ions, as expected from the ion content of the geothermal waters. This result indicates that the liquid droplets containing the geothermal salt were not collected by the filter, and/or other particulates far exceeded these in quantity. Results of the distribution, and the elemental composition of the collected particles are as follows:

TABLE VI

BREEDING DYNAMICS OF FERRUGINOUS HAWKS IN THE STUDY AREA

<u>Year</u>	<u>No. Pairs</u>	<u>Nesting Attempts</u>	<u>Successful Nests</u>	<u>No. Young</u>	<u>No. Fledged</u>	<u>Nesting Success (%)</u>
1972	43	38	31	89	84	85
1973	54	27	23	58	56	81
1974	42	--	18	42	40	--
1975	--*	--	19	48	46	--
1976	--	28	21	57	54	75
1977	35	29	18	51	48	62

* No data

<u>Size (microns)</u>	<u>%/No.</u>	<u>Elements present</u>
< 2	65	Si, Cl, Fe
2-4	18	Si, Fe, K
4-6	10	Si, Ca, K, Fe
6-8	6	Si, Fe, Ca
8-30	6	Si, Cl, K, Ca, Na

Particles in water samples from RRGE-2 and RRGE-3, produced by a particle generator, ranged in size from 1 to less than 0.2 micron. The majority of these particles were cubical, and only chlorine and sodium could be detected with energy-dispersive X-ray analysis. Table VII lists the size range distribution by number and mass. The concentration of these submicron sodium chloride particles was determined to be from 13 to 14 mg per liter of well water.

These small salt particles are similar to those which would be generated by venting the geothermal fluids under normal pressure. Larger particles which would also form will deposit rapidly, but these fine particles will remain suspended for long periods. At relative humidities above 75%, they will form fogs and, together with the ambient submicron sulfate particles, would reduce visibility. Such high humidities rarely occur in the Raft River Valley, except during winter inversion conditions. Also, as the filler particulate samples indicated, the ambient particle concentrations exceed those caused by well testing.

2.4.3 Meteorology

The 1977 summary of meteorological conditions, including ambient and dewpoint temperatures, wind speed and direction, precipitation, and solar radiation, will be completed by NOAA and project personnel in January 1978. A partial record of daily average, maximum, and minimum temperatures for 1977 is shown in Figure 7. A chart of average monthly temperatures and precipitation at the Malta and Strevell stations is shown in Figure 8, (prepared by the University of Utah Research Institute).

2.4.4 Socioeconomic

The socioeconomic study being conducted by the Battelle Human Affairs Research Center in Seattle has been completed. The final report, "Community Impact Assessment of a Diversified Geothermal Energy Project Proposed for the Raft River Valley, Idaho," by J. A. Goodnight, Battelle Human Affairs Research Center, Seattle, has been issued. The report concluded that because of the sparseness of settlement in the immediate area, the development and operation of either a 5 or 10-MW(e) thermal loop/power plant is expected to produce little impact on the local communities. The study also analyzed three levels of non-electric development:

TABLE VII

AVERAGE SUBMICRON PARTICLE CONCENTRATIONS
GENERATED FROM WATER FROM RRGE-2 AND RRGE-3
(number $\times 10^3 \text{ m}^3$)

RRGE-2					
Size Range	No./m ³ $\times 10^3$	%/No.	ug/m ³	cc of H ₂ O used sampled	ug/cc
< 0.2	720,463	26.98	5.35		0.29
0.2-0.4	1,579,254	59.13	93.81		5.11
0.4-0.7	350,871	13.14	128.43		7.06
0.7-1.0	20,197	0.76	27.29		1.50
1.0-2.0	0	0	0		0
	2,670,785		254.88	10.2	14.0 ug/cc of H ₂ O
RRGE-3					
< 0.2	416,578	21.39	3.09		0.12
0.2-0.4	828,066	42.52	49.19		1.86
0.4-0.7	670,573	34.43	245.45		9.30
0.7-1.0	32,370	1.66	43.73		1.66
1.0-2.0	0	0	0		0
	1,947,587		341.46	26.4	13.0 ug/cc of H ₂ O

Fig. 7 Partial 1977 record of daily average, maximum, and minimum temperatures at Raft River

(^aAltitude, ^bAverage precipitation and temperature, ^cLast frost of season, ^dNumber of frost free days, ^eFirst frost of season)

Fig. 8 Average monthly temperature and precipitation, Malta and Strevell

1. Most likely - 2 hectares (4.5 acres) of greenhouseing and one fish farm producing and processing 113,000 kg of warm-water fish annually.
2. Possible - 8 hectares (18 acres) of greenhouseing, one fish farm handling 226,000 kg of fish annually, one 10,000-head feedlot and associated manure processing facility, and 50 MW(e) power plant.
3. Maximum - 24 hectares (53 acres) of greenhouseing, one fish farm with 454,000 kg per year production, one 20,000-head feedlot and associated manure-processing facility, one 50-MW(e) power plant, and one potato-processing plant producing 91,000 kg of hydrated flakes per day.

The study estimated that due to the limited availability of labor in the local area, approximately 60 non-local workers at the "possible" level and over 300 at the "maximum" level of activity would be required. Growth-management actions on the local and county level to minimize the impacts of population influx are detailed in the report.

2.4.5 Water Quality

Water-quality surveys are continuing. A program of weekly sampling of the geothermal wells and monthly sampling of the Raft River and nearby irrigation wells has been established. Routine analyses examine conductivity, pH, chloride, fluoride, silica, and total hardness. Patterns of water chemistry have been plotted for each of the geothermal wells and for shallow and intermediate-depth exploration and irrigation wells in the area. These patterns, shown in Figure 9, will be used as a graphical aid in classifying waters and in tracking the natural or induced interaction of "fresh" water and geothermal fluids.

A 30-m deep monitor well was drilled last spring near the northeast corner of the RRGE-3 reserve pit. A water-level recorder and a sampling pump were installed in the well to determine the effect on the shallow ground water of seepage from the reserve pit, during flow tests on RRGE-3. A series of samples was taken after the water level rose in both the monitor well and in the domestic well at RRGE-3. Analyses showed a slight increase in the total dissolved solids (TDS) in the domestic well (from 716 to 738 milligram/liter), but a corresponding decrease in the sodium content (from 420 to 390 milligram/liter). The total dissolved solids in the pit monitor well decreased from 4060 to 3740 milligram/liter. A corresponding decrease was seen in the other constituents measured. The TDS of the RRGE-3 water averaged 4600 milligram/liter during the test.

In June and September, the Idaho Department of Water Resources conducted water-quality surveys of irrigation wells and the Raft River. With one exception, no changes, other than natural fluctuations, have been seen in any of the wells since August 1975. In a well five miles

Fig. 9 Patterns of Raft River wells' water chemistry

to the northeast of RRGE-2, the total dissolved solids content increased from 2250 milligram/liter in August 1975 to 5300 milligram/liter in June 1977. By September 1977, it had dropped to 3500 milligram/liter. Most of the change in TDS resulted from increases in chloride, sulfate, and calcium. No similar changes were seen in nearby wells, nor could the changes be related to geothermal activity.

3.0 ELECTRIC CONVERSION AND 5-MW PILOT PLANT

3.1 Raft River 5-MW Pilot Plant - R. R. Piscitella

Title I design of the Raft River 5-MW pilot plant was completed in June. This design received a thorough review by ERDA, EG&G, and Washington Public Power Supply System (WPPSS) personnel. All comments were transmitted to Facilities Systems Engineering Corporation (FSEC), the architect-engineering contractor, for inclusion in their Title II design effort.

Long-lead procurement activities were initiated. The boilers, preheaters, condenser, and condensate storage tank were specified and sent to vendors for quotations. A trip was made to the vendor's plants by EG&G engineering, quality, and procurement personnel. Problems in the subcontracts were resolved and the awards were let in July. Figure 10 provides a data sheet on the high-pressure preheater. This is typical of the technical information generated on all heat-exchange components. Technical specifications and procurement action were also initiated on the isobutane feed pumps, geothermal boost pumps, cooling tower, and transformers. Contracts for both the isobutane feed pumps and geothermal boost pumps were awarded in July. Figures 11 and 12 show section-view drawings of the isobutane feed pump and geothermal boost pump.

A test plan for the Raft River 5-MW pilot plant was written by the EG&G Geothermal Program. This document contained detailed information relating to the planned tests, possible operating modes, and the necessary instrumentation. Required instrument accuracies were also defined. This test plan was reviewed by ERDA and transmitted to FSEC for incorporation into the Title II design.

Preliminary operating procedures were written by FSEC and reviewed by EG&G, ERDA, and WPPSS. Their comments were incorporated into the final procedures and into the Title II design.

3.2 60-kW Binary-Cycle Generator

The 60-kW binary cycle Title I design work was completed. The rotating equipment (i.e., turbine, boost pump, feed pump, motor/generator, and gearbox) was specified and awarded to Barber-Nichols Engineering Company in May. Detailed design is well underway and shop fabrication of isobutane components has begun.

This small generating system will utilize a single isobutane boiler, flashing isobutane at 104°C (220°F) and 21.3 atm (301 psig). This will be the input to a single stage, axial flow turbine. Back pressure conditions will initially be 27°C (80°F) and 3.6 atm (41 psig), established by a small, wet, cooling tower condenser circuit. The preheater, boiler, and condenser will be surplus units from decommissioned reactor component test facilities. However, the condenser discharge conditions will eventually be established by a variety of experimental test cooling devices, to determine their effectiveness in reducing the turbine back pressure to levels as low as economically feasible and technically

CUSTOMER	E G & G Idaho		DATE	5/12/77	
			CUST. NO.	K-1108 Add.1	
PLANT LOCATION	Malta, Idaho		PROPOSAL NO.	QE77-9106	
SERVICE OF UNIT	High Pressure Preheater		ITEM NO.	ES-50170	
SIZE 32-528	TYPE	AEL	POSITION	Horizontal	
SURF./UNITS (EFF.)	15059	SHELLS PER UNIT	1	SURF. /SHELL (EFF.)	
NO. OF UNITS	1	SHELL ARRANGEMENT	PARALLEL	SERIES	ENGRS. MB
PERFORMANCE OF ONE UNIT					
		SHELL SIDE		TUBE SIDE	
FLUID CIRCULATED	ISO Butane		GEO Thermal Fluid		
TOTAL FLUID ENTERING	# /HR.	613,000	1,040,000		
VAPOR	# /HR.				
LIQUID	# /HR.	613,000	1,040,000		
STEAM	# /HR.				
NON-CONDENSABLES	# /HR.				
FLUID VAPORIZED OR CONDENSED	# /HR.				
STEAM CONDENSED	# /HR.				
#/CU FT		26.89	59.19		
VISCOSITY	CP.	.081	.24		
MOLECULAR-WEIGHT-VAPORS					
SP. HEAT-BTU/°F		.8	1.0		
TEMPERATURE IN	°F.	178	250		
TEMPERATURE OUT	°F.	238	222.5		
OPERATING PRESSURE	P.S.I.A.	417.2	172.2		
NUMBER OF PASSES	PER SHELL	One	1		
VELOCITY	FT./SEC.		5.5		
PRESSURE DROP	P.S.I.	4.5	ALLOWED	3.5	CALC. 10 ALLOWED 4.8 CALC.
FOULING RESISTANCE REF'D O/SIDE		.00053	.00619		
HEAT EXCHANGED-B.T.U./HR.		28,800,000	M.T.D. (CORRECTED) °F.		24.8
TRANSFER RATE-SERVICE		77.1			
CONSTRUCTION-EACH SHELL					
DESIGN PRESSURE	P.S.I.	650	250		
TEST PRESSURE	P.S.I.	Code	Code		
DESIGN TEMPERATURE	°F.	320	320		
TUBES	B111 INHIB ADM	NO. 708	O. D. 3/4	IN 15	BWG. AVO. WALL
Extended Surface		LENGTH 44'	PITCH 1	XX XX	
SHELL	A516 GR70	NOM. I. D. 32	O. D.		
SHELL COVER (INTEGRAL REMOVABLE)	--	FLTG. HD. COVER	--		
CHANNEL	A516 GR70	CHANNEL COVER	A516 GR70		
TUBE SHEETS-STATIONARY	B171 Alloy 614	FLOATING	--		
BAFFLES-SEGMENTAL	B169 Alloy 614	PITCH 12	% CUT 42(area)	FLOW H. Cut Mod. Seg	
BAFFLE-LONG	--	IMP'T.	Yes		
TYPE JOINTS-SHELL	Welded	TUBES	Confined		
GASKETS-SHELL	--	FLTG. HD. --	CHANNEL 304SS Spiral Wound ASB		
CONNECTIONS-SHELL-IN	10	OUT 12	SERIES	300 RF	
CHANNEL-IN	12	OUT 12	SERIES	300 RF	
CORROSION ALLOWANCE-SHELL SIDE	1/8 on CS	TUBE SIDE	1/2 on CS		
CODE REQUIREMENTS-ASME	1974 Sect. VIII	STAMP (YES) (NXX)	TEMA CLASS R		
WEIGHTS-EACH SHELL AND BUNDLE	BUNDLE ONLY		FULL OF WATER		
REMARKS:-	Insulation clips provided Nitrogen seal				
	2@ 4" inspection ports				
	Shell side expansion joint fitted based on 320°F tube and 130°F shell				
	Note: Exception taken to 3 @ 12" shell outlet nozzles pending explanation by customer.				

FORM S-1

Fig. 10 High-pressure preheater data sheet

Fig. 11 Isobutane feed pump

NO. NAME OF PART

1	PUMP SHAFT	134	BALL BEARING SPACER RING - RADIAL
2	FLEXIBLE COUPLING	135	BALL BEARING - THRUST
7	DEFLECTOR RING	136	BALL BEARING THRUST COLLAR
22	PACKING HOUSING GASKET	165	FLEXIBLE COUPLING KEY
25	IMPELLER KEY	200	IMPELLER WEARING RING
34	IMPELLER	209	BEARING HOUSING
37	CASE	211	BEARING HOUSING COVER - RADIAL
41	BALL BEARING - RADIAL	212	BEARING HOUSING COVER - OUTER - THRUST
42	BEARING HOUSING COVER - INNER - THRUST	215	SHAFT SLEEVE COMPR. NUT - RADIAL
47	BASE	226	CASE WEARING RING
48	STATIONARY OIL BAFFLE	231	BALL BEARING RETAINER
68	PACKING GLAND	238	IMPELLER LOCKNUT - RADIAL
70	PACKING	259	BALL BEARING SPACER RING - THRUST
71	LANTERN RING	260	LOCKNUT & WASHER - THRUST
72	SHAFT SLEEVE	317	SHAFT SLEEVE COMPR. NUT - THRUST
227	PACKING BOX BUSHING	439	SHAFT SLEEVE KEY
87	SHAFT SLEEVE SEAL RING	552	STATIONARY OIL BAFFLE - OUTER - RADIAL
105	PACKING HOUSING - RADIAL	678	IMPELLER LOCKNUT - THRUST
106	PACKING HOUSING - THRUST	1021	PACKING GLAND LINER
127	OILING RING		

Fig. 12 Geothermal boost pump

practical throughout the annual range of weather conditions. Figure 13 is a flow diagram showing condition state points. The turbine will be geared to a 3600-rpm (nominal) AC induction motor/generator. This unit will run under phase conditions as a motor to drive the pumps for loop startup, and will synchronize into the line with phase lease as a generator during operation at full power. Geothermal fluid requirements to the heat exchanger will be about 77/sec (100 gpm).

3.3 Metallurgical and Heat-Exchanger Performance Test Programs G. L. Mines and R. L. Miller

An on-going study of different materials' resistance to fouling led to the selection of metals for constructing the heat exchangers that will be used in the 5-MW pilot plant. Material and heat-exchanger testing continues to provide accurate, long-term data about various materials, and to define optimum operating conditions. The heat-exchanger design appears, at this stage of testing, to be very conservative with regard to both fouling and corrosion considerations.

3.3.1 Heat-Exchanger Testing

The second phase of heat-exchanger tests in the mobile components test trailer began in January 1977. A variety of candidate materials for the pilot-plant heat exchanger are being tested. The first sequence examined carbon-steel and Monel-400 tubes. The previous tests with type-304 stainless-steel and titanium tubes produced little, if any, fouling of heat-exchange surfaces after over 100 days of testing. The more recent tests of carbon-steel and Monel tubes showed some fouling caused by the geothermal fluid. At periodic intervals, the test loop was shut down and the heat exchanger tubes were removed and visually examined. The tube surfaces exposed to the geothermal fluid were scaled, though this scale was primarily a corrosion product rather than a mineral deposition. Based on the analysis of heat-transfer data taken from the tests with the carbon-steel and Monel tubes, the fouling resistance for the heat-exchange surfaces exposed to the geothermal fluid was established at

$$0.00026 \text{ (m}^2 \cdot ^\circ\text{K/W)} \text{ (0.0015 hr} \cdot \text{ft}^2 \cdot ^\circ\text{F/Btu)}$$

This value was based on the data shown in Figures 14 and 15. The squares shown in these figures represent data taken immediately after the outer tube surfaces (exposed to the cooling water) had been wiped clean. Both the carbon-steel and Monel tubes have now been removed from the loop, and the tubes have been sectioned. The tube sections are currently being examined for corrosion processes, and the deposition on the tube surface is being analyzed.

In March 1977, a type-316 stainless-steel tube was placed in the test loop. The data from this tube is very similar to the test data for the 304 stainless steel and titanium tubes, indicating little, if any, heat-transfer fouling. Periodic visual examinations have revealed no deposition on the tube surface exposed to the geothermal fluid.

Fig. 13 Condenser discharge conditions state points flow diagram

Fig. 14 Fouling resistance test No. 2 for carbon steel tube

Fig. 15 Fouling resistance test No. 2 for Monel 400 tubes

3.3.2 Material Selection for Heat Exchangers

Though both titanium and 304 stainless steel performed outstandingly in a test begun in July 1976, neither was finally selected for the preheaters and boilers when the selection was made in April 1977. A less expensive corrosion-resistant material, copper-zinc admiralty brass, was tentatively chosen. Testing began on this material in February, and results were to be available in time to add confidence to this selection. Though 304 stainless steel was nearly as inexpensive, it was decided not to chance the stress-chloride corrosion that would result if residual chloride ions were present when the heat exchangers were exposed to the atmosphere for servicing.

After the selection of admiralty brass for the pilot plant heat exchangers, a tube was fabricated from this material and placed in the test loop. This tube is currently in operation, and after about 200 days of operation, there is little degradation in the heat-exchange performance. A second admiralty-brass tube was inserted into the test loop in July 1977. The fouling rates observed with this tube are similar to those observed in the first tube for the same period of exposure. Periodic examination of the tubes reveals that a corrosion product is forming on the surface exposed to the geothermal fluid, but it is not nearly as extensive as was the case with carbon steel. To date, this deposition has retarded the heat-exchange performance of the admiralty brass tube at an annual rate of about

$$0.00009 \text{ m}^2 \cdot ^\circ\text{K/W} \text{ (} 0.0005 \text{ hr ft}^2 \cdot ^\circ\text{F/Btu)}$$

The heat-exchanger testing thus far has indicated that the fouling of heat exchange surfaces is primarily initiated by corrosion at the surface, and is not caused by a uniform deposition of minerals from the geothermal fluid. Selection of materials resistant to corrosion will provide much lower fouling resistances than selection of materials susceptible to corrosion. At this time, it is not known whether an induction period exists, during which time very little fouling occurs, followed by a period of rapid fouling. This phenomenon has been observed with sea water, though after more than 165 days of testing at Raft River there was no indication of an increased rate of fouling.

Future heat-exchanger testing at Raft River will primarily test admiralty brass under different operating conditions. To date, all testing has been conducted with geothermal fluid from RRGE-1. Future tests will be conducted with fluid from RRGE-3, which appears to have a higher mineral-scaling potential. Tests will also be conducted at various geothermal fluid velocities, to determine their effect on the fouling rates.

3.3.3 Component Testing

During the past reporting period, mechanical component testing was started on the test trailer. The initial phase of testing is being conducted with three different valves: a butterfly valve, a ball valve,

and a trunnion-wafer valve. These valves are being cycled twice a week to simulate operating service conditions. At periodic intervals, the valves will be removed and examined for deterioration of packing, seals, etc.

3.3.4 Corrosion Testing

A technical report, TREE-1176, reporting the results of a series of short-term corrosion-evaluation tests, which used fluids from RRGE-1 will be issued in October 1977. Test data indicated that the following materials are generally unsuitable for use in geothermal plants: aluminum alloys, most copper/nickel-bearing alloys, plain carbon steels, low-alloy steels, and martensitic and austenitic stainless steels. Brasses and bronzes (except nickel-bearing alloys), cast iron and steel in thick sections, Allegheny-Ludlum alloys 6X and 216, two ferritic stainless-steel alloys (Allegheny-Ludlum 29-4 and 29-4-2), Hastelloy G and Inconel 625 nickel-base alloys, haynes 6B cobalt-base alloy, and titanium are all usable with proper precautions.

Tests analyzed materials in both samples from and in component configurations. In the component tests, no severe galvanic or crevice corrosion-related degradation was noted in candidate alloys for pilot-plant heat exchangers. The results of the visual examination are not complete; only those for titanium, AISI 304 stainless steel, and Monel 400 were reported. These materials were substantially free of attack.

A number of current tests are designed to aid in the design and fabrication of the pilot power plant. The most important of these are the water treatment tests for the condenser/cooling tower circuit, the evaluation of materials for erosion and corrosion in a fluidized bed heat exchanger, and the tests of galvanic corrosion.

4.0 ADVANCED HEAT EXCHANGERS

4.1 Liquid Fluidized Bed Heat Exchanger - C. A. Allen, O. Fukuda, E. S. Grimmer, R. E. McAtee (Allied Chemical Corporation)

The scaling of heat-transfer surfaces inhibits the rapid development of binary systems using moderate-temperature geothermal resources that have a high scaling potential. Liquid-fluidized-bed heat exchangers use beds of floating sand to scrub the exchanger-tube surfaces and control the buildup of scale. The objective of this program is to develop liquid-fluidized-bed technology and build demonstration equipment. During the past six months, work proceeded in three areas: 1) a scale-control experiment on the Geothermal Component Test Facility (GCTF) at East Mesa, Imperial Valley, California; 2) flow-distribution experiments at Raft River; and 3) an updated size-cost analysis of vertical and horizontal preheaters.

4.1.1 Scale-Control Experiment

A heat exchanger 20 cm in diameter (a unit that underwent eight months of testing at Raft River) is now operating at the Geothermal Component Test Facility near Holtville, California. The GCTF is operated for ERDA by Lawrence Berkeley Laboratory and the Bureau of Reclamation, and is made available to experimenters who wish to test components for the geothermal power cycle. The objective of this test is to determine the scale-control properties of a liquid-fluidized-bed heat exchanger when used with geothermal fluid that has greater scaling potential than is observed at Raft River. To enhance scaling, flashed and unflashed water are mixed just ahead of the heat-exchanger inlet. Mixing produces an overall temperature drop of up to 35°C (95°F). This temperature drop should promote precipitation of silicon compounds. Flashing the brine releases dissolved CO₂ and promotes calcite deposition. The flow enters the exchangers at 126°C (259°F); it is composed of about 40% flashed brine. A flow diagram for the brine, cooling water and electrical service is shown in Figure 16.

During initial testing, it was determined that several modifications would be needed to operate the test unit with the geothermal brines at East Mesa. A gas separator was required, a larger motor was needed on the mixing pump, and the flow-distribution system required alteration. The gas separator and pump were acquired. The vessel was modified by expanding the plenum size, to decrease brine velocity. A bubble cap distributor plate was added. With these modifications, an extended test was started on May 16, 1977. The pump seals failed, after two weeks of operation, and the experiment was continued until June 21 on unflashed brine. On June 21, following 38 days of operation, the heat exchanger was visually inspected. The outside tube surfaces appeared clean. The inside tube surfaces, which were exposed to cooling water, were badly fouled. This fouling probably accounts for the reduction in heat-transfer coefficients shown in Table VIII.

Fig. 16 Brine, cooling water, and electrical flow diagram

TABLE VIII
HEAT-TRANSFER COEFFICIENT REDUCTION

	<u>Start Up</u>	<u>9 Days</u>	<u>18 Days</u>	<u>25 Days</u>	<u>35 Days</u>
h_o (W/m^2K)	6358	3525	3587	3781	3435
Btu/hr ft^2 $^{\circ}F$	--	--	--	--	--
Deviation (%)	0	48	47	44	49

Following the inspection, the inside of the tubes was cleaned. This will allow computation of inside and outside fouling factors. The equations used to compute h_o consider both fouling resistances when calculating the outside heat-transfer coefficient.

4.1.2 Flow-Distribution Experiments

Providing uniform flow in horizontal vessels is a problem because the cross section through the cylinder changes as the water flows upward through it. To aid in the design of a distribution system, researchers built an experimental unit which allows visual and photographic observation of flow patterns, and which is instrumented to measure pressure drop and heat transfer. The vessel has been instrumented and initial testing has begun at Raft River. The first series of tests is aimed at determining the optimum pressure drop across the distributor, and at measuring heat transfer at different points in the exchanger.

The horizontal, cylindrical vessel is 91 cm (3 ft) in diameter and about 30 cm (1 ft) long. It contains 662 dummy tubes, 6 heat-transfer tubes, and two distributor plates. Both ends of the vessel are covered by transparent Lucite. The heat-transfer tubes are installed so that each tube can be rotated on its axis to determine heat flux around the tube. The temperature difference is measured by thermocouples embedded in the inner and outer tube surfaces. The heat sources are resistance heaters located in the centers of the heat-transfer tubes. All tubes 1.9 cm (0.75 in.) O.D. by 30 cm (12.5 in.) long were mounted on a triangular pitch with a pitch-to-diameter ratio of 1.5.

All experimental apparatus, including instrumentation, have been assembled. Calibration was delayed because of difficulty in adjusting to the low pressure range of 2400 kPa (0.5 psi). Pressure and leak tests of the system are complete for flow rates of up to 13 liter/second (200 gpm). Two demonstration runs with fluidized sand were performed for the public, the Raft River Electrical Coop, and ERDA officials.

4.1.3 Size-Cost Analysis

The size and cost of a fluidized-bed preheater for the Raft River pilot power plant was recalculated for a stainless-steel tube bundle. At the same time, the costs of vertical, horizontal, and conventional tube-and-shell heat exchangers were compared. Table IX summarizes the size and cost of these units.

The size and cost of a fluidized-bed heat exchanger with a tube bundle of admiralty brass was calculated and compared to the conventional unit; a material as soft as brass cannot be used in a fluidized-bed exchanger, however. It is apparent from Table IX that fluidized-bed heat exchangers can compete with conventional heat exchangers. It appears that vertical exchangers have a slight cost advantage over horizontal exchangers. However, these calculations are all based on cross-flow heat-transfer coefficients. This advantage could disappear when parallel-flow coefficients become available.

A 60-kW(e) pilot-plant preheater is being designed for installation at Raft River. This pilot-plant preheater will contain three vertical stages and three horizontal stages. When it becomes operational, a direct comparison will be possible between the horizontal and vertical fluidized-bed heat exchangers.

4.2 Direct-Contact Heat Exchangers - R. F. Boehm, H. R. Jacobs (University of Utah)

Work on direct-contact heat exchangers continues at the Raft River Geothermal Site, at Salt Lake City, and in Glasgow, Scotland. During the period ending September 30, 1977, the Raft River boiler-test loop was tested with both pentane and R-113. Researchers installed a baffle-plate, liquid-liquid preheater on the field test assembly, and conducted studies of working fluid losses. In Salt Lake City, work progressed on the basic boiling mechanisms of fluids lighter than water, and on additions to the system computer program (including an economic analysis subroutine). Work in Glasgow included development of analytical techniques for correlating data from direct-contact condensers and volume boiler models. A first draft of the two-year project overview was issued the end of May and summarized in a presentation to ERDA headquarters staff. Two technical papers were presented at the Geothermal Resources Council Annual Meeting, May 1977, two papers were presented at the National Heat Transfer Conference in August 1977, and two were accepted for next year's International Heat Transfer Conference.

4.2.1 Boiler and Preheater Testing

After assembling the new high-pressure boiler system at the Raft River site, engineers began tests using R-113. Performance agreed well with tests using the original system. Prior fluid-loss and heat-transfer data satisfied the predictions made with computer program DIRGED; the program could be used to design a full-scale spray-type boiler using

TABLE IX

SIZE AND COST OF LIQUID FLUIDIZED BED AND CONVENTIONAL
TUBE-AND-SHELL HEAT EXCHANGERS

Type	No. of Passes	No. of Stages	Heat Transfer Area (m ²)	Tube Material	Diameter (m)	Length per Stage (m)	Total Cost (\$)
Horizontal FB	2	6	777	Type 316	2.7	~1.8	203,000
Horizontal FB	1	6	788	Type 316	1.5	~3.6	191,000
Vertical FB	2	6	769	Type 316	1.8	~1.8	187,000
Vertical FB	2	6	621	Admiralty Brass	1.8	1.5	103,000
Horizontal Conventional	2	1	~1519	Admiralty Brass	--	--	~200,000

R-113. Fluid losses could be minimized by flashing or gas-sparging the spent brine. (The latter system has been shown to be effective in the laboratory and needs to be tested on a larger scale.)

Pentane tests began in early May. Several leaks were detected in the test unit, which was located near the northwest corner of the RRGE-1 reserve pit, downwind of other experimental installations and electrical facilities. All problems concerning pentane were soon eliminated, and a test program was designed. Long-term testing for carryunder and heat transfer began in mid-June, using vessel pressures of 414 kPa (60 psig), 552 kPa (80 psig), and 690 kPa (100 psig). Tests determined working-fluid losses, temperature profiles, water condensation rates, and other factors. The R-113 data-reduction system worked well with the pentane data, and the heat transfer curves thus derived were similar to previous R-113 curves. The pentane curves do, however, show greater differences for various boiler pressures than did those for R-113.

A direct-contact preheater was also installed on the field test loop in early June. Although planners had decided to install a rotating-disk preheater, problems in obtaining seals for the shaft required the use of a disk-and-doughnut baffle preheater. With this preheater, the configuration of baffles can be varied, or the baffles can be totally removed. When the baffles are removed, the tower can be operated as a simple spray tower. A single-system, direct comparison may thus be made between a baffled and unbaffled tower. The preheater was operated in each configuration at Raft River in July. The field test assembly was then moved to East Mesa, California, for brines that are likely to foul standard tube-in-shell heat exchangers. Figure 17 shows the East Mesa components. The preheater operated smoothly, demonstrating heat transfer efficiency with both baffle configurations, about the same amount of fluid was lost and water was condensed from the vapor as at Raft River. It was occasionally necessary to vent non-combustibles from the system, however.

4.2.2 Direct-Contact Condensers

Three basic types of direct-contact condenser show promise for use with a binary geothermal power plant. These are the barometric condenser, the packed-bed condenser, and the bubble condenser. Although some experimental data have been reported in the literature for work with vapors other than steam, there is little quantitative information that could be used for accurate designs. It was therefore decided to initiate work on all three types of condensers.

In a packed-bed condenser cold water flows downward through a bed of particles at the same time that the hot vapor rises through the bed. Mr. Kevin Thomas began work on the concept in May at the University of Utah. A condenser, 15.24 cm (6 in.) in diameter and 139 cm (4 ft) high, was constructed during June. Testing commenced in July, using three different packing materials: interlox saddle and Al_2O_3 spheres of two different diameters. A simplified theoretical model, which should help in interpreting the experimental results, is also being developed. The working-fluid vapor is injected into a column of water.

Fig. 17 Direct contact heat exchanger and preheater loop for pentane. Conditions shown denote East Mesa operation.

In a collapsing-bubble condenser, the concept had previously been investigated by Sideman and co-workers at Technion. The analytical models that they developed, however, overlooked consideration of the condensate in predicting bubble collapse. With the assistance of Ph.D. student, H. Fannir, H. R. Jacobs developed a theoretical model at the University of Strathclyde. This model gives excellent agreement with experimental data published in the literature. Mr. Fannir is currently experimenting with pentane condensing systems for single and multiple bubbles. This type of condenser should alleviate problems with non-condensibles more readily than should barometric condensers.

In a barometric condenser the working-fluid vapor is sprayed with water or cooled vapor. Work has been aimed at developing a model to predict heat-transfer rates for dispersed sprays. No such model has been available that can be applied to the economics of equipment which condenses organic vapors.

4.2.3 Systems Analysis

An economic analysis subroutine has been defined and is in the process of being added to subroutine DIRGEO. The subroutine will be compatible with those developed by other research groups, and should yield similar costs for similar systems.

Preheater subroutines have been defined for direct-contact, counter-flow devices. Preheater sizing subroutines which follow the work of Jacobs will be included. This subroutine will be updated as additional design data become available.

4.2.4 Working Fluid Loss Considerations

Pentane losses appear to be less than half those predicted by equilibrium solubility considerations. For a typical test run of 6-3/4 hours, at a system pressure of 414 kPa (60 psig), losses of between 5 and 15 ppm. The equilibrium solubility calculations would indicate losses of 45 ppm for salt-free water. The actual losses are more typical of brine with dissolved-solid concentrations of 25,000 ppm. As the Raft River brine has a concentration of only about 2000 ppm, the results look very promising; we can expect less than equilibrium solubility losses with the direct-contact system operating on a geothermal well.

Studies of gas sparging and flash-expansion recovery techniques continue. Both techniques show promise for recovering most of the working fluid from spent brine; however, further work needs to be accomplished before the economics of recovery systems can be evaluated.

5.0 LOW TEMPERATURE RESERVOIR ENGINEERING - R. C. Stoker

The low-temperature reservoir-engineering effort is primarily concerned with two areas in Idaho: Boise and Sugar City/Rexburg. In addition to these areas, evaluations of geothermal potential have been conducted at Idaho Falls, Pocatello, Butte City, Terrace Lake, and in the Salt Lake City area (Farmington and Sandy).

The Boise area can support further development of geothermal energy for space heating. The two Warm Springs Heating District wells have been in use since 1893, providing space heating for 200 to 400 homes along Warm Springs Avenue. As a result of the INEL reservoir-engineering effort, the major geological structural controls on this resource have been determined.

The Sugar City area also has the potential for developing geothermal energy. This area exhibits above-normal heat gradients and contains a few wells that discharge warm water. The warmest well, drilled in the town of Newdale to a depth of 117 m (385 ft), produces water at 36°C (97°F). The water must be cooled before it can be used for domestic purposes.

5.1 Boise Geothermal Area

Since 1976, when two successful exploratory wells were drilled in Boise, considerable interest has been expressed in developing the area further. The previous semi-annual report (October 1976 through March 1977) contains detailed information about the two wells. The structural controls and the hydrology influencing the hot-water supply are now generally understood, and further well development is feasible.

Before further development begins, however, details about the reservoir must be obtained. This information is required to determine well spacing, well design, well productivity, well interaction, and expected resource lifetime. Reservoir testing began in August, using the two exploratory wells (BEH-1 and BHW-1) for pumping and monitoring. The tests will be conducted in steps at various pumping rates, and a long-term test will be run at lower free-flow conditions (approximately 150 gpm).

5.2 Seasonal Geothermal Reservoir Head Variations in Boise - J. F. Kunze

In all geothermal development, possible environmental effects are of prime concern. Every effort is made to ensure the stability and purity of nearby aquifers. Because a number of Boise homes depend on existing geothermal wells, the integrity of the Boise resource is particularly important. Soon after the new exploratory wells were drilled, researchers designed tests to check for interaction among the different wells.

This kind of test is difficult to design and interpret. Possible interference effects are hard to distinguish from natural seasonal variations. In addition, experimenters began to have problems with the instrumentation as the spring run-off began. Preliminary results indicate, however, that the new wells interfere very little, if at all, with the Warm Springs wells.

The idea was to monitor the BEH-1 well (the BLM well) to see if it responded to seasonal variations in pumping from the Warm Springs wells. Researchers reasoned that if changes in the reservoir level at BEH-1 did not correlate with the changing demand at the older wells, new drilling and testing could continue without fear of affecting the Warm Springs heating resource. The BEH-1 well was allowed to reach equilibrium before the test began. The second experimental well, the "Beard well," was not flow-tested during the experiment.

During the entire winter, until mid-May of 1977, the artesian pressure of the BEH-1 well was monitored with a sensitive quartz transducer mounted at the wellhead. Figure 18 graphs the changes in pressure. The most important natural variation is normally the spring run-off that recharges the reservoir. Precipitation was only 30% of normal, however, for the period beginning in October.

If there were communication between the old and the new wells, artificial effects would also have varied with the season as heating water was withdrawn. The flow from the older geothermal wells was not accurately measured during this season. The outdoor temperature should give a reasonably accurate indication of the changes in well output, however, because essentially all of the flow went to heat private residences. Minimum flows are approximately 32 liters/sec (500 gpm), and maximum flows amount to about 113 liters/sec (1800 gpm) when both wells are operating during the coldest days.

Density changes in the well's water column (due to changes in temperatures) would cause a third, less substantial, variation. If the well's temperature had reached equilibrium with the underground environment, it should not vary even as much as 3°F during a season. Such a change would cause only a 0.002 Pa (0.33 psi) variation over the 300 m (1000 ft) between the producing zones and the wellhead.

Figure 18 shows that the reservoir pressure response does not correlate with the demands of the Warm Springs Avenue geothermal wells. Nor can it be accounted for by density changes in the well water column. The decline observed in November, December, and January may be somewhat normal, as freezing temperatures caused a decline in the run-off from precipitation. Drought may have exaggerated the effect during the winter of 1976 and 1977. The reservoir showed an increase in pressure as spring run-off began. Interference from the Warm Springs Avenue wells accounted for a difference in pressure of less than 0.003 Pa (0.5 psi).

Fig. 18 Boise exploratory hole No. 1 (BLM)

5.3 Sugar City Evaluation - R. C. Stoker

The Sugar City Evaluation is a jointly funded study by the Economic Development Administration (EDA) and ERDA. All data gathering involving well temperature profiles, well-water chemistry, and geothermometry was completed during the reporting period. Data evaluation and a summary report are being published as TREE-1249, Geothermal Potential of the Sugar City, Idaho Area. Figures 19 and 20 show approximate isotherm plots based on well temperature logs and on geochemical temperature indicators, respectively. These clearly show a thermal anomaly in the Newdale area NE of Sugar City, and some indication of a thermal anomaly south of Sugar City. The latter appears close enough that pipeline costs from the area to serve Sugar City's 240 homes and businesses would not be unreasonable.

The U.S. Geological Survey is currently planning further geophysical surveys in the area during July. Magnetism, gravity, and deep resistivity will be surveyed.

5.4 Geothermal Potential Evaluation of Other Areas

As part of the national non-electric program, the geothermal potential of several other areas was also evaluated. Currently available geological information was examined.

Farmington and Sandy, Utah are close to the major Wasatch Fault zone, which is associated with several thermal springs in Utah. The fault zone runs the entire length of the state and appears to provide an upward conduit for hot water, especially in the northern part of the state.

Idaho Falls and Pocatello, Idaho, are located on the eastern margin of the Snake River Plain. Warm wells and a few warm springs are located in the foothills to the east of both areas. These areas are similar to the Sugar City/Rexburg area; it is evident that warm water can be located along certain fault conduits.

Butte City, Idaho, lies in the northwest corner of the eastern Snake River Plain. A city-owned well encountered warm water when it was drilled in the late fifties. Since the water was to be used for domestic purposes, however, the lower warm portion of the well was filled in and production was taken from the upper cold-water aquifer. Because the city lies out on the plain and the area lacks outcrops, little geological information is available.

Terrace Lakes, Idaho (approximately 50 miles north of Boise, in the Garden Valley area) is situated in an area that has considerable potential for geothermal space heating. The area has three hot springs, ranging at their outlet from 57° to 74°C (135° to 166°F). One well encountered water of 54°C (130°F) at only 23 m (75 ft). Water from another well has a temperature of 60°C (140°F) at approximately 24 m (80 ft). One house is already completely heated by water from the

Fig. 19 Isotemperature plots of well water temperatures at 4200 ft elevation (approximately the 700 ft depth from the Snake River Plain surface in the region)

Fig. 20 Isotemperature plots derived from the SiO_2 chemical analysis of well waters, and applying a chemical/enthalpy mixing model with no steam escape assumed

74°C (166°F) spring. The hot water in the area occurs along a north-south trending fault. Another fault occurs slightly east of the hot water-bearing fault, and it appears to be a structural control for the geothermal fluid.

6.0 NON-ELECTRIC APPLICATIONS - W. D. Gertsch

6.1 Beneficial Uses and Direct-Heat-Use Experiments (Raft River)

6.1.1 Soil Warming and Heat Dissipation Experiments - N. E. Stanley

Warming a plot of soil with condenser cooling water is an attractive idea for several reasons. The growth rate and yield of selected plants are increased appreciably by warming the soils in the root zone. Soil warming can hasten and prolong the growing season, increase seed germination, and provide limited frost protection near the soil surface. Increased crop yields may thereby help offset the investment in the power-plant cooling system.

Soil warming is part of an integrated system for low-level heat utilization. If sufficient land is available, soil warming may be a feasible alternative to conventional cooling towers for geothermal power plants in the arid West. This cooling system may have distinct advantages in terms of environmental protection, water and energy conservation, and anti-fouling chemical usage in the closed-loop condenser system.

A three-year experiment designed to investigate the beneficial effects of soil warming by heating crops with simulated condenser discharge has been initiated at Raft River.

A soil-warming and heat-dissipation system has been installed on a 1.2-ha (2.6-acre) plot of land. The plot consists of three crop areas, to measure field-crop response, to check tree-biomass production, and to grow unheated control crops. On the field-crop response plot, the geothermal fluid temperature will be controlled by mixing hot geothermal water with cold water to simulate the temperature of condenser discharge (38°C or 100°F). The water will flow through a manifold piping arrangement consisting of 38-m (1-1/2-in.) diameter PVC pipes buried 0.61 m (2 ft) below the surface and spaced 1.53 m (5 ft) apart.

The geothermal fluid temperature in the tree biomass production plot will be adjusted to obtain data on optimal and detrimental soil temperatures for a variety of tree species. The fluid will flow through two double-line loops buried 0.61 m (2 ft) below the surface and spaced 1 m (3-1/4 ft) apart. A pictorial layout of the experiment is shown in Figure 21. Fluid cooling, soil temperature, and soil moisture will be monitored, and the plant response will be analyzed. Data produced from the soil-warming experiment will be used to determine the heat transmissibility of the silt-loam soil typical of the Raft River geothermal area, as well as the effects of moisture, sand, cover type, and ambient changes on transmissibility and its relationship to heat dissipation.

A subsurface irrigation system, with sand envelopes around the buried pipe, was also installed on portions of the soil-warming system. This arrangement will provide additional heat-dissipation information necessary for the design of a power-plant cooling system.

Fig. 21 Soil warming facility layout

6.1.2 Agriculture - R. C. Schmitt

The second year (Phase II) of the Raft River geothermal irrigation experiment was initiated, and mid-season sampling was completed. This year's expanded experiment comprises the following crops and acreages: (See Figure 22)

- 8 ha (20 acres) barley
- 2 ha (5 acres) alfalfa, oats, and grasses
- 3 ha (7 acres) alfalfa and barley
- 4 ha (10 acres) alfalfa

About half of each plot is watered with geothermal fluid from RRGE-2 (approximately 1200 mg/liter). Control crops sprinkled with conventional irrigation water are grown on the second half of each tract.

6.1.3 Aquaculture - N. E. Stanley

Researchers initiated Phase II of the aquaculture studies, utilizing geothermal water for the culture of three aquatic food species (channel catfish, tilapia, and shrimp) for a "grow-out" cycle at commercial and massive stocking densities. The objective is to determine residues of fluoride and heavy metals, and the effects of geothermal water on the growth rate, health, and edibility of each species.

A layout of this experiment is shown in Figure 23. Plans are being formulated to introduce into the experiment a power-plant effluent environment, including chemical additives being considered for use in reducing heat-exchanger fouling in the Raft River power plant.

6.1.4 Space Conditioning - J. G. Keller and L. E. Donovan

The geothermal heating systems of several trailers and out-buildings completed the first winter season of operation at Raft River. Water from RRGE-1 transferred heat through a heat exchanger to a glycol-water solution for use in conventional, horizontal-unit heaters. The secondary closed loop maintained an average of from 77 to 88°C (171 to 190°F) under heating load. Savings from this geothermally supplied heating system will average 110 barrels of oil per year.

An ARKLA 3-ton lithium-bromide air conditioner has been ordered. It will cool the main office trailer and provide data about such units' operational characteristics. Installation is scheduled for early spring 1978.

6.2 Industry Interactions - W. D. Gertsch

It continues to be a goal of the INEL Geothermal Non-Electric Program to stimulate and encourage industrial participation in the use of moderate-temperature resources. This goal is being pursued along three complementary avenues. The program is:

Fig. 22 Irrigation experiment plots

Fig. 23 Aquaculture experiment layout

1. Developing a joint industry-government test program at the Raft River site to explore the potential of using the geothermal resource in various industrial applications. This objective includes certain hardware R&D on absorption refrigeration units, low-temperature heat exchangers, industrial driers, and heat pumps;
2. Soliciting interest in establishing small-scale industrial demonstration operations in the Raft River Valley;
3. Providing appropriate assistance to potential industrial developers at other geographic locations in the Northwest and northern mountain states.

During this reporting period, expressions of interest have been made for setting up a joint experiment at Raft River which would involve the development and application of a gas-fluidized bed drying system to process a food industry waste sludge. The resulting product would be a very high protein pelletized food suited for animal and fish consumption.

6.3 Management Assistance Program - S. W. Metzger

Since September 1976, INEL has coordinated and monitored the technical and administrative activities associated with nine Non-Electric Engineering and Economic Study contracts executed under PRDA DGE-76-1. During the reporting period, INEL's Phase II PRDA Management-assistance responsibilities were satisfied in connection with the Memorandum of Understanding between DGE and IDO. This Memorandum of Understanding governs INEL's PRDA contract involvement. The Phase-II responsibilities focused on progress reviews, which were conducted in Idaho Falls. Monthly and quarterly reports were monitored and critiqued during the period. In addition, the special considerations, requests, and problems of PRDA contractors were coordinated and resolved as required. Selected INEL and PRDA Contract personnel participated in an international meeting on the "Economics of Non-Electric Applications of Geothermal Energy." With respect to the impending PRDA contractor symposium, INEL's responsibilities to the symposium's planning committee were discharged during the reporting period.

6.4 Technical Assistance Activities - L. E. Donovan

During this reporting period, the Geothermal Program provided technical assistance to individuals in several locations. The activities are summarized below.

6.4.1 White Sulphur Springs, Montana

White Sulphur Springs is a community of approximately 1200 people. Near the center of town are several hot springs that used to be free flowing. One hot spring is now used to heat 12 motel units, an

indoor hot spa, and an outdoor swimming pool. The First National Bank of White Sulphur Springs has purchased land directly across the street from the motel, for the construction of a new banking facility which they propose to heat geothermally. As a result of INEL's technical-assistance program, the First National Bank received a grant from the Montana Department of Natural Resources and Conservation for drilling and constructing a geothermal heating system in 1977. Occasional consultation continues as plans are implemented.

6.4.2 Sun Ranch, Cameron, Montana

The 12 000-ha (30 000-acre) ranch near Cameron, Montana, has three free-flowing hot springs, the hottest at 60°C (140°F). Preliminary planning work suggested that if either the flow rate or temperature were increased, the resource could support a 0.4-ha (1-acre) greenhouse. Alternate utilization programs were outlined for consideration.

6.4.3 Greenhousing, Pocatello, Idaho

Materials concerning the use of low-temperature (<40°C or <104°F) resources for greenhousing were supplied to a developer who would like to use a 42°C (108°F) well near Pocatello, Idaho. Resources between 32° and 49°C (87° and 120°F) have as yet seen little use, because they've been too cool for direct uses and too warm for heat-pump applications. The results of experimental work which might span this temperature gap were transmitted to the developer.

6.4.4 Manti, Utah

The South Sanpete School District in Manti, Utah, has a 23°C (73°F) spring located within 2000 m (1-1/2 miles) of a proposed new school-district building. A preliminary analysis compared the economics of using the spring water and a heat pump with the economics of building a normal coal-fired water-heating system. The air-conditioning potential as well as the heating potential of the heat-pump system compared favorably with other alternatives. The school district was advised to continue the investigation.

6.4.5 Garden Valley, Idaho

Terrace Lake, Inc., a recreational ranch at Garden Valley, Idaho, plans to develop a 240-ha (593-acre) tract of land. They will include a nine-hole golf course (with plans for 18 holes) and space for 100 individual condominiums. The expected value of land and improvements, without dwellings, should exceed \$1,000,000. A key to the quality of development is proposed geothermal heating, and a Garden Valley Geothermal Company has been formed.

In addition to the proposed condominiums, 25 existing units will probably want to be part of proposed heating system. One of the principals of Garden Valley Geothermal Company near Terrace Lake already heats his home with local geothermal water, as do others in the immediate area.

These space-heating applications use geothermal springs or shallow wells with temperatures in the range of 50 to 65°C (122 to 149°F).

The geothermal developer plans to submit a DGE-PRDA proposal to determine appropriate well locations, design a distribution system, and investigate a self-powered circulation system. At the request of the developer, assistance was provided in estimating the requirements and expenses of a number of tasks associated with the proposed development.

6.4.6 Idaho Falls, Idaho

A meeting was held with a residential developer regarding possible geothermal resources near the Idaho Falls Golf and Country Club. Some preliminary guidance was offered for evaluating the local resource.

6.4.7 Helena, Montana

Engineering assistance was provided to a Helena, Montana residential developer for providing geothermal space heat and hot water to a single family residence. Guidance was given as to the extent that the geothermal resource could be developed.

6.4.8 Deer Lodge, Montana

A meeting was held with personnel of the Warm Springs State Hospital near Deer Lodge, Montana. The possibility exists of developing an 80°C (178°F) resource (surface spring temperature) for supplying the facility's 22 M Btu/hr heat load.

6.5 Case Studies - I. A. Engen

Three case studies are now being made:

6.5.1 Native American Tribal Lands

A U.S. map with overlays illustrating both known hot springs or well locations and the tribal lands developed during the last quarter has been transmitted to area offices of the Bureau of Indian Affairs. A computerized matching of hydrothermal resources and Indian lands was provided to DGE.

6.5.2 Federal Building Conversion Study

Work is continuing, primarily on a fill-in basis to level work loads, compiling federal building data. When these data are complete, the compilation will be processed with the resource data computed for the Indian lands study. A map of known hot springs and well locations, together with federal building locations has been prepared. Indexing of building locations (with defense installations identified separately) is being accomplished.

6.5.3 Heat Pump Study

Work is continuing on a heat-pump data base. For each case, data will be included concerning adaptability for geothermal use, temperature span of the useful supply source, and materials of construction. Staff members attended a Westinghouse conference devoted to the new "Templifier" heat pump units, which operate with temperature sources of from 32° to 71°C (90° to 160°F). A heat pump primer report has been issued to assist in the understanding of heat pumps in commercial and residential space and process heat applications.

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