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**GEOHERMAL R&D PROJECT REPORT FOR PERIOD
JULY 1, 1976 TO SEPTEMBER 30, 1976**

December 1976

EG&G Idaho, Inc.

IDAHO NATIONAL ENGINEERING LABORATORY

IDAHO OPERATIONS OFFICE UNDER CONTRACT EY-76-C-07-1570

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SEPTEMBER 30, 1976

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IDAHO NATIONAL ENGINEERING LABORATORY

Idaho Falls, Idaho 83401

Edited by

J. F. Kunze

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ABSTRACT

Progress in the third quarter of 1976 is reported for the geothermal energy projects conducted by or under the direction of the Idaho National Engineering Laboratory of the Energy Research and Development Administration. These projects include the Raft River geothermal development within reservoir and surface testing programs; the Boise Space Heating Project; the design and analysis of power conversion concepts for generating electricity from moderate temperature (approximately 150°C or 300°F) resources; advanced heat exchanger research and testing; and studies relating to a variety of direct uses of geothermal heat energy.

ACKNOWLEDGEMENTS

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 Coop.
The U.S. Geological Survey (Menlo Park, Denver, and Boise Offices)
The State of Idaho Department of Water Resources
Reynolds Electric and Engineering Company and the Nevada Operations
Office of ERDA
The Northwest Public Power Association and Public Power Council
The U.S. Bureau of Land Management, Boise and Burley Offices
Boise State University
Idaho Bureau of Mines and Geology
Lawrence Berkeley Laboratory's Geothermal Energy Division

SUMMARY

The Idaho National Engineering Laboratory (INEL) is operated by the Energy Research and Development Administration to help provide the engineering research needed to bring new energy schemes into the nation's economy. The location of the laboratory, near Idaho Falls, Idaho, is on the Snake River Plain, a geologically active rift zone with geologically recent volcanic activity, and an abundance of ground water. The area is thus a natural location for the occurrence of hydrothermal energy at relatively shallow depths, as indicated by the numerous hot springs along the borders of the plain and in the intersecting valleys. The relatively recent age of the near surface geological changes and the characteristic volcanism instead of old sediments implies that a continuum of temperatures of hot water will be present, and their salinities should be relatively low compared to the resources in older sediments. This trend has been confirmed from hot spring measurements, indicating the presence of numerous reservoirs (or aquifers) at low to moderate temperatures (below 150°C or 300°F). Such temperatures are currently not attractive economically to compete in the electric power production market, nor have such resources found much use in direct heat applications in this nation.

The INEL has, therefore, aimed its program at developing techniques, through engineering and research, to make it possible to harness such resources more economically, thus allowing this form of geothermal energy to compete effectively with other forms of energy. The principal site chosen for the experiments and testing work is in the Raft River Valley, an adjunct to the Snake River Plain. Principal reasons for the choice were the average geothermal characteristics of the valley (water no hotter than 150°C appears to lie at depths of 1 to 2 km), plus the desired industrial involvement of the local utility (Raft River Rural Electric Cooperative) and the entire association of 110 public and municipally owned utilities of the Northwest (Northwest Public Power Association). The State of Idaho offered its full cooperation, both in the research phases as well as the regulatory aspects. It was through the latter association that the beginnings of a space heating demonstration effort involving lukewarm water of approximately 75°C (167°F) developed. ERDA has conducted the conceptual design and exploration work on a demonstration project which would be completed by the State on State-owned buildings at Boise, Idaho.

The following summarizes work conducted in the third calendar quarter of 1976 (summer).

1. The routine operation of a metallurgical test was initiated "round-the-clock" on geothermal well water. On test are 20 ft long heat exchanger tubes experiencing heat transfer, and various coupon metallurgical samples (no heat exchange) of a wide variety of possible candidate materials for the thermal loop components.

2. "Pilot plant" conceptual and preliminary designs were submitted to a number of architectural engineering firms. From these, Facilities Systems Engineering Corp. was selected to perform the final design for a 40 MW(thermal) heat transfer loop, with considerable flexibility that would include generating add-on adaptability equivalent to nominally 5 MW.
3. Well No. 2, 6500 ft deep, that had been used to dispose of 8 million gallons of geothermal fluid, was subject to a 6 week recovery test, to determine if its previous production capability could be restored. During the test, 7 million gallons was flowed out. The temperature returned to within 13° F of original production zone temperature, and flow rate to within 30% of September 1975 values. The results agree with theory for recovery time.
4. An experimental 12 acre agricultural plot experienced a full growing season on a variety of typical area crops, half of these irrigated with 2000 ppm geothermal water, half with river water (500 ppm). No observable difference was measured in mineral uptake between these two categories of irrigation.
5. An experimental, temporary set of fish raceways was set up to measure fish growth response and mineral uptake on Tilapia, shrimp, catfish, and perch, from direct flow through geothermal water of nominally 2000 ppm, cooled to nominally 77° F. The lack of disease carrying organisms in the geothermal water resulted in a very significant reduction in anticipated, normal mortality rates.

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I. EXPERIMENTS AND TESTING AT RAFT RIVER

L. G. Miller, Manager, Field Operations

1. WELLS

1.1 RRGE-1

This well, the first of the deep geothermal wells, supplied a steady flow of fluids for surface test equipment, with on-line operation exceeding 90% during the quarter.

The REDA submersible pump examination and modifications were completed. This pump had seen service during the winter, at pumping rates of 800 to 1900 gallons per minute. Pump is being returned for further testing. Examination indicated the mechanical and electrical pump components were in very good condition. A small amount of water had entered the lower motor housing, presumably through the joint between the tandem motors. Some of the changes made were use of higher temperature motor oil, higher temperature babbitt on the motor, the protector thrust bearing pads, and change-out of the protector shaft bushings from Ni-resist to bronze.

The second pump was ordered with the above changes and designed to match the characteristics of RRGE-1 as to flow, drawdown, and horsepower derating. This pump will be installed in RRGE-1 when reinjection facilities are available for the extra flow of water.

Well flow during the quarter was under artesian pressure only, supplying the corrosion test trailer with 180 to 300 gpm continuously except for short interruptions due to piping problems and pressure probe recovery.

1.2 RRGE-2

This was the second of the deep wells drilled, to 6500 ft. Several short reinjection tests were run to check out the transfer pump, pipeline and reinjection pump system. Then several short flow tests were run to obtain temperature profiles as the reinjected water came back out of formation. The 8 million gallon previously reinjected over the past eight months had indeed cooled the well from its original temperature.

Beginning in August, a continuous 43 day flow recovery test was run. Flow was maintained at specified levels. Temperature and surface pressure were routinely measured. Total flow from the well during the 43 day test was over 7 million gallons. Total flow from the well since deepening it was slightly greater than the amount of cool water previously reinjected. At the conclusion of the 43 day recovery effort, fluid temperatures from the producing zone were still below original temperatures by approximately 10 degrees. Further details of the testing and temperature recovery are covered under the Reservoir Engineering, Section 2 that follows.

1.3 RRGE-3

This well has been allowed to remain quiescent since its 10 day flow test immediately after completion of the drilling in June. Beginning in August, the surface pressure was continuously monitored with an accuracy of ± 0.01 psi. The effects of flowing both RRGE-1 and RRGE-2 on this third well 7,000 to 9,000 ft away were thus measured, since the liquid column in the well had reached essential equilibrium.

The well site design was prepared for a gravel working surface, and the erection of security fencing.

1.4 Site Facilities and Pipelines

The transite pipelines from RRGE-1 to RRGE-2 has been in operation over a year with intermittent flows of hot, warm, and cool water. The pipeline has operated without problems during the periods of steady state operation. However, it is extremely sensitive to minor shocks (two such breaks have occurred) and ratcheting effects at the transite to steel coupling at each end has caused those to separate from each other several times. A design change corrected the latter problem.

Despite the sensitivity to thermal shock, the use of buried transite pipe appears to be a significant cost savings approach compared to the conventional welded steel pipelines. Both materials and labor cost savings amounted to approximately 40% on the 4,000 ft line from RRGE-1 to RRGE-3 wells will also be of transite, but buried only to about half the depth (2-1/2 ft) that the first line was buried. It is planned to use about a 1-inch layer of high resistance insulation around the pipe. The combination should achieve both a further cost savings as well as assuring negligible heat loss. Since the output of a power plant operating from 290°F water is decreased approximately 1% for each °F reduction in temperature, it is hoped to keep line losses to less than 3°F over 8,000 ft. The insulation effects of "dirt" can vary by an order of magnitude, depending on the solids composition and the moisture content. A thin layer of an insulation with $k \approx 0.02$ Btu/hr F° ft should accomplish this goal. The shallower burying of the pipe is estimated to save \$5/ft installation cost, while the insulation cost (10 in. diameter pipe) is estimated to add about \$1/linear foot.

2. RESERVOIR ENGINEERING

R. C. Stoker, D. Goldman, S. J. Prestwich

2.1 Instrumentation for Reservoir Testing

The reservoir testing program during this quarter was designed for non-interference with the continuous metallurgical testing at the RRGE-1 site. Useful reservoir evaluation data was obtained as follows:

- 1) The RRGE-3 well was monitored at the surface, under static shut-in conditions, during most of the summer while both RRGE-1 and RRGE-2 were flowed, the former all summer, the latter for half the summer.
- 2) RRGE-2 was flowed in attempts to restore it to its former condition after its use as a reinjection well during the previous winter. Recovery was nearly complete.

Two types of instruments are presently being used for obtaining reservoir pressure data. One consists of surface pressure instrumentation, the other is a downhole pressure instrumentation system.

2.1.1 Surface Pressure Instrumentation This system consists of a Paroscientific Digiquartz Pressure Transducer, Model 2200-A, 0-200 psia. The transducer is connected to an artesian wellhead via tubing to observe wellhead pressure whose frequency of oscillation varies with pressure induced stress. The transducer is coupled with a Paroscientific Digiquartz pressure frequency measuring unit, translating the frequency to a pressure readout (LED type). Relative pressure readout is accurate to within 0.01 psi. A Hewlett Packard 5150A Thermal Printer is used in the system to read the pressure data.

2.1.2 Downhole Pressure Instrumentation The system consists of a Hewlett Packard Quartz Pressure Probe and a RAWCO Temperature Probe which are lowered into the well by an armored coaxial cable to the desired depth.

The pressure data is recorded at the surface by Gearhart-Owen instrumentation which incorporates a Digital-Analog converter, digital recorder printer, scanner, digital-analog signal processor, counter and strip chart recorder. The system is capable of detecting and recording pressure changes of 0.01 psi to as small as 0.001 psi, depending on the stability of the electronics and noise in the cabling system. The equipment previously used was first generation equipment in which correction factors for temperature and pressure must be entered to calibrate the system. A second generation system will be used in the future in which the corrections are made automatically.

2.2 Pressure Probe Retrieval From RRGE-1

On Monday, June 21, while retrieving a quartz crystal downhole pressure probe from RRGE-1, the cable jammed near the top of its travel. The jam occurred within the stripper and was interpreted as the top of the travel. Subsequently, the cable was accidentally sheared by the master gate valve. On Monday,

June 28, it was confirmed, by use of a viewing light pipe inserted in the side ports of the well head, that the instrument was still hanging inside the well head, with the cable caught in the closed gate of the valve.

Some of the more straightforward methods of retrieval were reviewed and rejected because of uncertainties and/or safety reasons. The wellhead pressure was a nominal 150 psi. There also existed a requirement for flow from this well to support other previously scheduled experiments. Thus, it was determined to delay any retrieval attempt until later when a properly designed retrieval system could be fabricated.

The system selected for the retrieval effort consisted of a boom assembly/retrieval tool designed to operate through one of two side entry 3-inch lines located below the 12-inch master valve. The boom assembly was designed to lower the retrieval tool down to the 800 foot level when a special flapper valve was located. The retrieval tool was designed to engage the stinger pipe and lift it out of the flapper valve. The flapper valve is located on the lower end of the permanently installed packer (see Figure 1). Once the flapper valve was closed, access to the well could be accomplished under no flow/no pressure conditions. See Figure 2 for boom assembly/retrieval tool details and Figure 3 for retrieval tool engaged in the stinger pipe.

The \$13,000 probe was successfully recovered on September 28 using the above described retrieval system.

2.3 Reservoir and Well Testing

The summer attempts to restore RRGE-2 to full production began with a short constant discharge test from July 16-20, 1976. The discharge rate was 150 gallons per minute (gpm) and the discharge temperature stabilized at 266°F (130°C). The hot wellhead pressure of about 24 psi did not show any significant decline. A downhole temperature survey showed a maximum temperature of 290°F (144°C) at the bottom of the hole.

A 43 day flow test was run on well RRGE-2 from August 12 to September 24, 1976 for the main purpose of recovering to post drilling downhole temperatures. The first nine days of flow were held at a constant discharge rate of nominally 150 gpm. During the remaining 34 days, the discharge rate was increased to 300 gpm for a 3 hour period every 27 hours. The total discharge of water during the 43 days was slightly greater than 7 million gallons.

Prior to, during, and after the flow of RRGE-2, well pressures were monitored at RRGE-3 (See Figures 4 and 5). Note that during this same period of monitoring, well RRGE-1 was also flowing from 150 to 350 gpm. The 0.16 psi rise on August 20, 1976 is as yet unexplained. The daily bi-model fluctuations can be attributed to earth tides. A downward decline before the start of flow at RRGE-2 to after the termination of flow at RRGE-2 was approximately 1.3 psi. The pressure rise beginning September 3 is probably due to termination of flow at RRGE-2 and/or RRGE-1. A more analytical analysis of pressure changes would require tighter controls on flow rates.

Fig. 1 Flapper valve on retrieval tool

Fig. 2 Boom assembly/retrieval tool (Scale 1/8)

Fig. 3 Retrieval tool engaged in stinger

Fig. 4 Pressure response in well RRGE-3

Fig. 5 Pressure response in well RRGE-3

The chemical analysis of RRGE-3 shows it to be significantly different in composition from the other two wells. About twice the amount of dissolved solids are contained in RRGE-3, 4600 ppm, compared to 2000 ppm for the other two wells. (See Table I) The implication is that the reservoir conditions are substantially different in the region of RRGE-3.

2.4 RRGE-2 Temperature Recovery

A temperature survey was taken after reaching the original completion depth of 5988 ft under flow conditions. A maximum temperature of 297°F (147°C) was recorded at approximately 5950 ft.

The well was then subjected to a period of monitoring and testing from July through November 1975. Starting the first part of December, reinjection started in the well culminating March 3, 1976, with reactivation of drilling to deepen the well an additional 500 ft. During the period of major reinjection (December-March), a total of 8 million plus gallons were reinjected. Temperature surveys taken during the drilling just prior to TD and just after reaching TD showed a significant cooling of the well. However, a five day recovery monitoring flowing of the well for recovery showed indicated recovery and an average temperature increase of 15°F (8°C) between 5000-6000 ft, to a nominal 255°F, still well short of the original temperature. Only 2.5 million gallons was flowed from the hole during this period. (For further detail see pages 8 and 9 of ANCR-1319.)

The well was then shut in for four months during which another increase occurred of an additional 15°F (8°C). The well was then continuously flowed for approximately 43 days, beginning August 12. On August 28, an attempt to log the temperature failed due to equipment difficulties at a depth of 5000 ft. The temperature recorded at that depth was 282°F. This was still 13°F cooler than the recorded temperature at 5,000 ft on July 27, 1975, at the time of original completion before any reinjection.

Again, a single point temperature measurement was obtained on September 28 at 5000 ft, still 83°F, five days after the completion of a 43 day continuous flow test. During that flowing period, 7 million gallons were flowed from the well.

The well was essentially shut-in after September 23, except for a steady bleed of about 10 gallons to prevent wellhead freezing and provide a minor amount of hot water for the fish experiments. On November 23, a complete logging run was made, and the temperature at 5000 ft had dropped to 276°F. Figure 6 shows the various temperature surveys taken on the well. Figure 7 shows the flow history since the conclusion of the re-injection experiments in March 1976.

The apparent strange behavior of the well recovery to production status is actually an indication of both the porosity in the permeable formation and the fraction of the open hole vertical stratigraphy that is permeable. The injection of 8 million gallons of 100°F water cooled the formation surrounding the well by 50 to 70°F (depending on porosity). For the entire formation to again return to nearly 300°F (its original temperature) will

TABLE I

WATER ANALYSIS

(Average of Composition of Wells in Raft River Area)

	<u>Geothermal Production Wells</u>		<u>Intermediate Hot Wells</u>	<u>Irrigation Wells</u>	<u>Raft River</u>
	<u>1 & 2</u>	<u>3</u>			
Temperature	295 ⁰ F	298 ⁰ F	200 ⁰ F	70 ⁰ +	Seasonal Variance
TDS	2,000	4,592	2,600	550 - 2,120	507
Conductivity	2,700	9,870	4,555	1,720 - 3,600	
Cl ⁻	816	1,626	1,435	738 (210-1,267)*	117
Si	52	69	94	35	19
Fe	m	---	<0.02	m	m
Mg	.23	.6	.25	48	59
K	39	95	26	13	7.5
Ca	29	200	88	191 (53-320)*	76
SO ₄	54	34	64	35	46
HCO ₃	30 to m	51	41	174	159-m
SiO ₂	---	---	87	---	---
Organic	0	0	0	<10/100 ml	318/100 ml

* Stewart's well is hi TDS value

Fig. 6 Various Temperature Surveys from RRGE-2

RRGE #2 RECOVERY AFTER REINJECTION

Fig. 7 Flow history of RRGE-2 since conclusion of the re-injection experiments in March 1976

require the passing through the formation of much more than 8 million gallons of water. During this recovery flow, if the flow is stopped for many days or weeks, the producing formation temperature will try to equilibrate with the intermediate non-producing strata. Once the flow is restarted, a recorded temperature change in the producing strata will reflect this equilibration, in this case as a reduction in temperature.

3. ENVIRONMENTAL PROGRAM

S. G. Spencer, W. W. Hickman

The major effort by INEL personnel during the summer centered on the chemical monitoring of the experimental agricultural plots. Three water samples were taken each time the crops were irrigated, two of which were analyzed by different labs and the third which was put into storage for future reference. Several hundred samples of the crops (roots, stems, and fruit), as well as soil, were taken for neutron activation analysis. Special experimental procedures will be used for the very short-lived activation elements, such as fluorine. Additional crops samples were collected for yield, chemical (via wet chemistry and atomic absorption) and feed value analyses.

Related studies on non-geothermal waters are being conducted by Utah State University, characterizing fluoride effect on livestock in the Raft River and Bruneau areas where fluoride in normal stock waters can be high. Significant uptake of fluoride in feed crops irrigated with such high fluoride geothermal water could compound the problem in the food chain.

The environmental monitoring building was set up just northeast (downwind) of RRGE-2 and the meteorological tower transferred to a location adjacent to it. NOAA is currently installing the telemetry system and modifying the air quality, seismic, and meteorological equipment that will attach to this system. The University of Utah Research Institute, which is operating Hi-Vol and nuclepore particulate samples at the Raft River Coop. and at Mrs. Crank's, will install a trailer at the monitoring site to periodically monitor NO_x , sulfates, and other pollutants of interest. In addition, they are setting up an automatic camera to characterize visibility and stability conditions in the upper Raft River valley. Plans have been made to perform particulate identification studies in the plumes from the geothermal areas. Artificial laboratory generation of particulates may also be used to extrapolate from field data.

The Idaho Department of Water Resources continued their water quality sampling program, taking sets of samples from irrigation wells and the Raft River near the end of the irrigation season. Because of the difficulties encountered in sampling irrigation wells, they have suggested drilling up to 20 slim-hole monitoring wells at various depths upstream and downstream of the geothermal wells. This would alleviate many of the problems and uncertainties associated with sampling irrigation wells.

The biological studies being performed by Idaho State University, University of Idaho, University of Utah Research Institute, and Dr. Speth are continuing. Initial data compilation will be completed this fall and final reports issued by the first of next year. A plan is being developed to tie together all the segments of the ecosystem in the Raft River into a working model based on these data.

Design was completed for the storage boxes which will house the batteries and electronics for three telemetered microseismic stations to be located in the vicinity of Raft River. These will be installed and the system set up in November, 1976. Arrangements have been made to have all university participants concerned with the environmental program and report writing to meet in Idaho Falls on November 12.

The second re-check on level markers for possible subsidence (or any level change) over a 4-1/2 square mile area was completed in September. The measurements are good to second order (± 0.01 ft), and showed no change since the initial establishment of the baseline in June, 1975.

The chemical content of the waters from various sources is routinely monitored. Typical results are shown in Table I and II. Note the much higher chemical content of RRGE-3 compared to RRGE-1 and RRGE-2 (these had nearly identical chemical content). Table II gives the trace element concentrations measured in several types of vegetation in the area. The samples were gathered in the fall of 1975 and analyzed by neutron activation.

The Raft River environmental program was reviewed in a meeting at LLL, attended by ERDA-Washington, ERDA-San Francisco, USGS, USFWS, LLL, and INEL personnel. Comparisons were made to the Imperial Valley Environmental Project being coordinated by LLL. Provisions were made for information transfer between the two programs.

TABLE II

DATA ON WATER COLLECTED FROM 12 WELLS AND 4 RIVER STATIONS IN THE RAFT RIVER VALLEY

ON AUGUST 25 and 26, 1976

ALL CONCENTRATIONS ARE REPORTED IN mg/l UNLESS OTHERWISE STATED

Location	Orthophosphate - P	Ammonia - N	Nitrate - N	Bicarbonate	Chloride	Fluoride	Sulphate	Calcium	Magnesium	Sodium	Potassium	Silicate	Boron	Lithium	Iron	Arsenic µg/l	Mercury µg/l	Temperature °C	Specific Conductance µmhos at 25° C	pH	Bacteria per 100 ml		
																					Total Coliform	Fecal Coliform	Focal Streptococcus
15S 24E 27daa1	.01	.00	1.22	171.41	222.94	.32	91.2	114.8	25.06	66.01	5.87	51.9	.13	.03	.11	4	.1	14.2	1140	7.6	13	0	12
15S 25E 33ccd1	.02	.00	.60	256.2	391.92	.15	153.6	180.4	22.67	144.9	6.26	40.7	.16	.03	.20	3	.1	11.5	1350	7.8	0	0	0
15S 26E 23abd	.00	.08	1.0	124.44	1255.88	5.23	94.03	100.0	5.25	795.80	19.94	65.6	.27	1.97	<0.1	4	.6	29.9	4700	7.9	0	0	5
15S 26E 23ddd	.00	.08	.55	131.76	1165.82	4.42	57.6	93.8	6.22	653.2	17.99	70.7	.19	1.65	<0.1	5	.4	42.2	4350	7.8	0	0	2
15S 26E 24bad1	.00	.00	.67	194.59	678.76	2.11	61.44	105.0	12.69	369.15	12.90	50.9	.18	.81	<0.1	4	2.4	27.2	2550	7.6	0	0	0
15S 26E 24bcb1	.00	.00	1.16	212.28	690.66	2.33	57.6	112.6	16.10	318.55	10.56	51.6	.16	.64	<0.1	4	<0.1	16.0	2400	8.0	6	0	14
15S 26E 24dcc	.00	.00	.60	157.99	651.78	2.52	50.88	97.0	15.49	341.55	13.29	63.0	.15	.31	<0.1	6	.2	31.3	2510	7.9	0	0	1
15S 26E 27dcc	.00	.12	.39	245.22	320.92	2.40	60.48	59.6	12.57	219.65	9.33	51.6	.08	.36	<0.1	3	.4	15.0	1450	8.1	0	0	0
15S 27E 6abc	.02	.00	.28	257.42	464.34	1.50	67.2	125.0	17.32	220.8	9.78	50.0	.15	.43	.12	6	.2	11.0	1560	7.8	31	0	29
15S 27E 7dbc	.02	.00	1.44	263.75	316.66	.70	59.12	135.60	22.33	145.36	9.01	44.8	.15	.20	.15	5	.9	9.3	1550	7.7	18	10	94
15S 27E 18bcc	.00	.00	.27	133.47	353.58	.46	32.16	99.6	23.91	119.0	11.04	66.9	.11	.19	.13	3	.5	21.8	1340	8.0	0	0	1
15S 27E 18cac1	.02	.00	2.50	275.33	687.28	.63	75.36	201.0	34.65	262.2	10.56	44.8	.12	.53	.25	4	.2	13.5	2750	7.88	48	25	3
Raft River Locations																							
SE NW NW Sec 11																							
16S 25E	.01	.00	.01	273.89	200.58	.04	88.80	93.60	26.47	113.62	7.82	41.6	.15	.04	<0.1	5	.7	17.2	1160	8.2	250	214	290
NW SE SE Sec 32																							
15S 26E	.01	.00	.02	264.74	212.29	.98	76.80	109.40	25.13	94.07	8.21	43.2	.15	.06	<0.1	6	.7	19.2	1160	8.2	560	470	410
SW SE SE Sec 23																							
15S 26E	.00	.00	.02	239.73	216.55	.96	75.36	103.80	24.77	92.92	8.60	45.1	.15	.06	<0.1	7	1.0	19.0	1160	8.3	8800	340	600
NW SW SE Sec 7																							
15S 27E	.00	.00	.02	207.40	215.13	.94	77.76	96.80	27.21	90.62	8.99	40.7	.15	.06	<0.1	5	.5	19.5	1150	8.25	8400	60	2200

4. SHALLOW GROUND WATER USE CONSIDERATIONS

Available shallow water resource data for the Raft River geothermal area was re-examined. Current data from NOAA, Idaho Department of Water Resources, and USGS* suggest that the quantities of water necessary for once-through cooling of a major geothermal electric power plant are not available without the expectation of slowly raising the temperature of the near surface water table. Once through cooling has thus been temporarily rejected as a useful generic study when applied to the Raft River Valley. This is not to say that once through cooling and reinjection back into the ground might not be applicable in other areas (such as the Snake River Plain), or that it might eventually be employed for the test loop of 40 MW(th) size being designed for the Raft River Geothermal Site.

Briefly, the situation appears as follows, for a 50 MW(e) geothermal power plant of 13% efficiency.

Rejected heat = 333 MW(th)

If use once through cooling, for a ΔT rise of
20°F requires 113,000 gpm or 185,000 acre ft/year

	<u>Raft River Valley</u>	<u>Southern Part of Raft River Valley**</u>
Total Annual Precipitation	1,280,000 acre-ft	400,000 acre-ft
Estimated evapotranspiration	1,140,000 acre-ft	360,000 acre-ft
Estimated run-off	140,000 acre-ft	40,000 acre-ft

The 50 MW(e) size of a plant is considered a minimum size for attractive long range investment purposes. Obviously, run-off, a portion of which may recharge the aquifer, is insufficient to remove the power plant heat by underground flow. However, if a large reservoir of cold water exists near the surface, its "cold" (negative heat) might be mined, just as one might mine the heat in a geothermal reservoir. Toward the latter consideration, the capacity of this near surface reservoir in the southern portion of the Raft River Valley might be approximately:

12 million acre-ft (assume porosity of 0.2 and a 300 ft thick aquifer)

This reservoir could cool the power plant for nominally 65 years before it would approach a 20°F rise in temperature (assuming no heat loss).

* Idaho Department of Water Resources Bulletin, No. 19, August 1970
Further local information useful in reaching these tentative conclusions was supplied by W. D. Nichols, USGS, Sacramento

** The lower third of the valley, within 10 miles of the present geothermal development site.

Thus, mining of the negative heat from an extensive near surface aquifer is a viable possibility. But before further serious consideration is given to this alternative, the actual size of that aquifer needs to be determined with greater accuracy. The aquifer does not receive sufficient flow through from the run-off annually to significantly remove the heat of a 50 MW(e) geothermal power plant from the reservoir where it would be deposited by this cooling method.

5. DIRECT, BENEFICIAL USES AT RAFT RIVER

R. C. Schmitt

5.1 Agriculture

Progress for the irrigation experiment during this reporting period included:

1. Completion of the 1976 growing season (Phase 1 of the experiment) for all crops under investigation.
2. Sampling of crops for activation analysis, chemical analyses and yield evaluation.
3. Final samples of soil and waters.
4. Removal of crops and preparation of plans for follow-on.

Phase 1 of the agriculture experiment is complete except for compilation of data, analyses, and reporting. Analysis of samples continues with a final report scheduled for December 31, 1976. Disposal of crops await the results of analyses. Tentative results indicate no obvious detrimental effects on growth and no additional mineral uptake on these first year crops as a result of irrigation practices with geothermal water.

5.2 Aquaculture

Progress in the aquaculture experiment consisted of the following:

1. Setting up of the experiment began in early summer, and involved installing raceways, instruments, geothermal water source plumbing and the necessary controls. Included in the latter was a special cooling pond approximately 30 ft by 30 ft in area, with five spray nozzles flowing at a rate of 150 gallons per minute (total) to create evaporation cooling.
2. Establishing Tilapia, Channel Catfish, and Yellow Perch in the geothermal water environment.
3. The accumulation of data on fish behavior, growth rate, tolerance, mortality rates, and etc.

The experiment is expected to continue beyond the reporting period with giant prawns (macrobrachia) to be added to the fish population. Residue behavior in the fish flesh of the contaminants in geothermal water (heavy metals, fluorides, etc.) are part of the information being sought, as well as measurements of the rate of growth.

II. ELECTRIC CONVERSION AND PILOT/THERMAL LOOP

J. F. Whitbeck, Manager, Geothermal Electric

The emphasis of the program to generate electricity from moderate temperature water is on those experiments which will test the performance and reliability of new concepts. Whether electricity can be generated from 300°F water is not the question (it can). What is of major concern is the development of new techniques to increase the efficiency of the conversion cycle and reduce the costs of the installation components so that these temperatures of geothermal waters can compete with the other forms of generating electricity. Present evaluation indicates that standard techniques long advocated and/or demonstrated for converting geothermal energy to electricity from 300°F geothermal water are nominally competitive with oil-fired generating plants, and therefore nearly 50% higher in cost than coal or nuclear. The Raft River program will concentrate on reducing this difference but; 1) increasing the efficiency primarily through the more effective use of the cold climate of the mountainous regions in reducing the condenser temperatures, and 2) by developing more reliable and hopefully less expensive heat exchangers and condensers to use on these geothermal systems of low salinity (<5000 ppm).

1. RAFT RIVER THERMAL LOOP FACILITY DESIGN

R. R. Piscitella

The thermal loop, phase 1, to be built will have a heat transfer capacity of 40 MW(th) and a nominal electric output capacity of 5 MW(e) gross, depending on the efficiency of the cycle.

A review and evaluation of potential Architect Engineering firms for the design of the thermal loop was completed by ERDA and Facility Systems Engineering Corporation of Los Angeles was selected to perform this work. The initial management plan for thermal loop was completed and submitted to ERDA. Additional work on revision 1 of the System Specification and Description for the Raft River Thermal Loop Facility was conducted. This consisted of incorporating conceptual fill, drain and operating procedures, and further defining the vent, drain and flare system. The work on the system definition will be completed in mid October and will result in completing the specification of the "reference" thermal loop system. This "reference system" will then be modified during the detailed design to provide the flexibility required by the thermal loop test plan and incorporate new concepts.

2. GEOHERMAL SYSTEMS ANALYSIS

W. W. Madsen

The analysis effort involves studies related to the design of the Raft River thermal loop, the application of various binary cycles to different temperature resources, with emphasis on the moderate temperature resource evaluation of test data and evaluation of new concepts. The following significant items were completed during the reporting period.

1. The report of the isobutane working fluid optimization studies has been reviewed, revised, and prepared for publication. It has studied the various parameters within the secondary cycle to best mate that cycle to the particular geothermal water conditions and the cooling circuit conditions. Isobutane is the preferred candidate for conditions near those of Raft River, 300°F input, 50 to 90°F condenser conditions.
2. Further optimization studies were made of binary power cycles that could be used in extracting energy from a range of geothermal fluids from low (200°F) to high (400°F) in temperature, using a variety of working fluids. The computer program GEOSYS was used to simulate the power plant operation. Three additional working fluids were considered: Genetron 31/114 (an azeotrope), propane, and pentane. The studies were performed in the same manner as the isobutane studies, optimizing with respect to the number of boilers, boiler temperatures, and amount of superheat. The results of these studies show that different working fluids are maximum effectiveness over various bands of geothermal fluid temperatures. The thermodynamically most effective case is that which produces the greatest net power per pound of geothermal fluid circulated. Figure 8 illustrates the optimum fluid use for each geothermal fluid temperature band. A complete technical report is being prepared on the results of this work.
3. The computer program GEOSYS was modified to compute film coefficients for the heat exchangers (single or multiple pass counterflow) and to use enthalpies instead of specific heats for all heat balance calculations. However, all of the parametric studies that were performed on the previous version of GEOSYS were documented in the report for consistency.
4. A program was written to evaluate the thermodynamic properties of various light hydrocarbons using the Starling-Benedict-Webb-Rubin equation of state.* Programs were written which

* K. E. Starling, "Fluid Thermodynamic Properties for Light Petroleum Systems," Gulf Publishing Company, Houston, Texas, 1973

Fig. 8 Working fluid optimum cycles vs geothermal fluid temperature

generate either pressure-temperature grids or pressure-enthalpy grids. An option is also available which will punch cards for use in the GEOSYS table look-up.

5. Three Bureau of Mines computer programs entitled, "Computer Usage for Evaluation of Design Parameters and Cost of Heat Exchangers," were combined to yield one program with four options. The program is useful when applied to heat exchangers with no change in phase. It can be flagged to consider tube side pumping costs, shell side pumping costs, or pumping costs of both fluids as prime parameters; the fourth flag tells the computer to do all the above, thus simplifying comparisons.
6. The computer program RRHXDR was written to evaluate the specific experimental data from the Raft River heat exchanger loop. Inputs to the programs consist of the pertinent temperatures and flow rates from the heat exchanger instrumentation. Outputs include information such as Reynolds numbers, velocities, heat transfer coefficients, and fouling resistances. At this point, only preliminary data has been revised and therefore, no firm results are available.
7. The Geothermal Electric Transient model, shown schematically in Figure 9, was completed and the Time and Frequency (TAF) digital computer simulation was coded and debugged. Initial results have been generated using each of the three code capabilities:
 - a. Direct steady-state solution
 - b. Frequency response
 - c. Transient response

A contract is in the process of being let for the development of the hybrid computer program (using combined digital and analog computers). Although developed primarily for the Raft River system, the hybrid model should be generally useful to anyone concerned with transients of similar binary systems.

Fig. 9 Geothermal-electric transient model - September 1976

Fig. 9

TRANSIENT MODEL LEGEND

Quantities

S Valve Position
W Flow Rate

Subscripts

WLP	working, low preheater
WLBI	working, low boiler inlet
WHBI	working, high boiler inlet
WLBE	working, low boiler exit
WHBE	working, high boiler exit
WLT	working, low turbine
WHT	working, high turbine
WCI	working, condenser inlet
B	brine
BBP	brine, boost pump
BBY	brine, bypass
C	coolant
CP1	coolant, pump 1
CP2	coolant, pump 2
EV	evaporation
M	makeup
A	air

Node Numbering

1-35	isobutane
41-49	coolant
52-66	brine
71-72	air

3. TESTING RELATED TO PILOT PLANT FACILITY

R. L. Miller, G. L. Mines

Corrosion coupons were installed in two 3-inch lines connected directly to RRGE-1. This test, which was instituted prior to startup of the test trailer unit, was for preliminary screening of materials. This preliminary test has been completed after approximately 70 days of exposure to variable conditions and results are being evaluated. The test was then shifted to the test trailer unit under more controlled conditions. Primary corrosion tests in the 4-inch loops on the test trailer were started in August. This test sequence is scheduled for approximately 100 day exposure with partial coupon removal and installation on a scheduled reference of one month changes, with the main test spanning three months (100 days). This test is a planned interval test as defined by National Association of Corrosion Engineers (NACE) Standard, TM-01-69 (1972 Revision).

Heat exchanger fouling tests were started in mid September. No change in overall heat transfer coefficient was noted at the end of this report period, however, it is anticipated that several weeks will be required before discernable change can be seen.

III. ADVANCED HEAT EXCHANGERS

The development of better performance and more economical heat exchangers is considered of prime significance to both the electric and the non-electric applications of geothermal energy. Operating from a 150°C reservoir; a binary, organic working fluid electric power plant has tube-in-shell heat exchangers representing approximately 1/2 of the total cost of the above-ground equipment (heat exchangers plus condensers). Improvements in the heat exchange mechanism can thus have a very significant effect on the cost of electricity from such a plant.

In the case of non-electric applications, many geothermal fluids have too high a solids content to be conveniently used. The economical transfer of their thermal energy to a clean fluid is thus essential to the national finding extensive non-electric geothermal uses.

Three approaches are being pursued at the Idaho National Engineering Laboratory:

1. Determination of the extent of fouling in standard tube-in-shell heat exchangers for the type of water that exists in Raft River and development of effective and inexpensive methods of periodically removing the scale.
2. Fluidized bed heat exchangers which tests have shown will definitely eliminate the scaling problem. The question of cost, because of its larger physical size compared to conventional heat exchangers, has yet to be resolved by design variations and tests to determine the performance of these design variations.
3. Direct contact heat exchangers which show the potential of eliminating the tubes in the heat exchanger and the condenser. The principal question concerns the small intermixing of fluids, and the effect of this mixing on turbine performance (metallurgically) and on operating costs.

1. DIRECT CONTACT HEAT EXCHANGER DEVELOPMENT

R. F. Boehm, H. R. Jacobs, Department of
Mechanical and Industrial Engineering,
University of Utah

1.1 Large Boiler Experiments

Large boiler experiments continued in the lab at the University of Utah. The boiler facility was moved to Salt Lake City during the spring while the wells and test site were being readied for routine operation. Attention shifted from the determination of heat transfer correlations, which were discussed in earlier reports, to special concern for developing

correlations for carryunder and exit temperature variation as a function of the operating parameters. These are of particular concern for design considerations, equipment sizing information, and general operational limitations. Hence, operation has been concentrated to define these conditions.

One way of representing safe operating conditions is shown in Figure 10 for the surface boiler and Figure 11 for the volume boiler. These curves are, to an extent, beneficial for both definition of the exit temperature and indicating limits for carryunder. The latter has generally been found to be mass flow ratios less than approximately 2.0 for both types of boilers. The exit temperature can be predicted with a moderate degree of accuracy from a best fit of the points shown.

The fact that all the data fall in a moderately well defined band for a wide range of mass flow ratios and subcoolings is encouraging. Several important unknowns exist, however. When these results are compared to earlier small-scale boiler tests at the University, poor agreement is found. This agreement is poorer for the volume boiler than for the surface boiler. While some of this discrepancy may have been due to some problems in the earlier tests (see discussions in Section 1.2), there are several controlled variables that are different between the large and small scale tests. For example, in the "surface boiler" tests, R-113 droplet size and velocity, system pressure and contact time were quite different between the two classes of experiments. In tests on the large boiler at the University, the effects of these variables are being assessed. This work will be continued at Raft River during the next quarter, as a great deal more latitude in testing conditions will be available. It is hoped that lower mass flow ratios will be demonstrated and that a better correlation, encompassing all pertinent variables, will be developed.

Another point concerning the temperature prediction needs to be emphasized. While it does appear that the exit temperature from the boiler is readily predicted from either Figure 8 or Figure 9, in fact such is not the case. The saturation temperature still remains an unknown. However, we assume that the work we are now pursuing will allow us to predict all variables a priori.

Part of the work yet to be performed is the evaluation of another fluid whose properties are quite different from those of R-113. To accomplish this, we are now designing a loop which will utilize pentane. The basic configuration of the loop will be similar to that of the previous system using R-113, with some changes in the methods used for the monitoring and control of fluids, necessitated by the potential explosive nature of an air/pentane mixture. These changes include the substitution of sonic sensors in the place of the electrically conducting type used in the Freon system for the control of level, flow meter calibration and water separation functions, and the addition of a brine booster pump which may be needed to overcome the pressure differential between the well and the heat exchanger when operating at higher temperatures. All electrical equipment in the direct vicinity of the installation will be either "explosion proof"

Fig. 10 The outlet temperature variation of a surface boiler, shown as a function of mass flow ratio. A variety of subcooling values for the inlet R-113 stream is included.

Fig. 11 The outlet temperature variation of a volume boiler, shown as a function of mass flow ratio. A variety of subcooling values for the inlet R-113 stream is shown.

or "intrinsically safe," and the components themselves will be mounted on a flatbed trailer located at least 60 ft away from the control center. Other modifications will include the use of pneumatics to operate process and control valves and to monitor pressure in the system, and a second coil in the condenser to handle any excess pentane vapor which may inadvertently escape from the main vessel through the safety relief valve with the condensed liquid being routed back to the reservoir. The system will also be equipped with two gas analyzers, one to detect any possible leaks from the system itself and the other to help in determining the point of carryunder by continuously monitoring the percentage of pentane in the spent brine.

The flow diagram shown as Figure 12 reflects the maximum possible temperatures, pressures, and flows envisaged when operating the system on the east Mesa 6-1 well. The conditions of temperature and pressure encountered at Raft River are anticipated to be less than these, though available flows are considerably greater.

At the end of the present quarter, almost all components have been ordered, and many are already in-house. Due to the specialized nature of some of the equipment being purchased, delivery times are quite long. Target date to have construction of the loop completed is December 1, 1976.

1.2 Small Boiler Experiments

Small scale boiler tests are being pursued to gain more insight into a variety of questions. The volume boiler originally used by Blair has been extensively revised. The larger diameter glass tube has been installed, the injection manifold has been reconstructed of a low thermal conductivity plastic, and additional instrumentation has been installed. In addition, necessary modifications had been made to the complete loop in an earlier quarter to accomplish testing with pentane.

The apparatus has now been essentially debugged. More problem in defining the carryunder point has been experienced using pentane, compared to the earlier work with R-113.

1.3 Turbine Studies

The turbine studies described briefly in the last quarterly report have now been completed.* Results of these studies are of value for assessing performance and cost of turbines in direct contact boiler power plants. While it is generally true that the fluid which may be optimum from turbine considerations may not be optimum from overall plant considerations, due to such factors as working fluid loss through solubility and pumping costs, it is of value to examine the turbine in detail.

Figure 13 indicates the mass flow ratio for the special case of a mixture of saturated water vapor and saturated working fluid entering the turbine for six working fluids. If the total pressure is lower than the sum of the two saturation pressures, the working fluid will be superheated and the mass flow ratio will be different than those shown. Note, that

* R. W. Bliss, "Analysis of Binary Vapor Turbines," Master of Science Thesis, University of Utah, December 1976

Fig. 12 Test loop schematic design for use with pentane at East Mesa and Raft River.

Fig. 13 Ratio of mass flows in the turbine, based on theoretical vapor pressure ratios for computing the carryover of water.

supercritical propane is shown as a band of states. This results from an optimized situation whereby the energy density* for the turbine is maximized.

The relative amount of water vapor in the flow increases with decreasing boiling point fluids. Hence, propane with a high vapor pressure has a much lower relative water flow than pentane with a lower vapor pressure. In general, the relative flow increases in all regions except near the critical point of the working fluid. If the energy density entering the turbine is maximized in the vicinity of the critical point, the working fluid would be superheated, rather than saturated, for this special case only.

Fluids suitable for higher pressure operation give higher energy density of turbine work as can be seen from Figure 14. This variable correlates inversely (approximately) with cost of the turbine as is shown in Figure 15.

We then determined the variation of turbine diameter and speed with the turbine inlet temperature and the condenser temperature, assuming operation at the maximum efficiency point (90 percent). This was performed for all six of the fluids noted in Figure 13. One example of these results is shown in Figure 16, which represents data for pentane operating at 10 MW. A summary of results for pentane operating at various powers and inlet conditions is shown in Figure 17. Another summary of all data for a turbine inlet temperature of 130°C and a condenser temperature of 30°C is shown in Table III.** In all cases discussed above, a single turbine stage was assumed with an adiabatic efficiency of 0.9. Attempts at an analysis of a multistage turbine were inconclusive. However, for the power levels and fluids considered here, it is felt that only a single stage is necessary.

1.4 Solubility Determinations

At the time of the last report, work had been completed on the determination of the solubility in water of refrigerant 113 and of pentane, for various salt concentrations from 0 to 25 weight percent, and temperatures varying from 25 to 100°C. Work has now been completed for refrigerant 114 and isobutane for the same range of parameters. While all results are given in a recently completed Master of Science thesis,** some of the pertinent details will be highlighted here.

Solubility values for R-113 are shown in Figure 18. Note that the units on the ordinate of the graph represent the solubility normalized by the working fluid partial pressure. Fair agreement with previously reported

* Defined as the enthalpy drop across the turbine divided by the specific volume of the mixture exiting the turbine.

** Also given in that table are numbers taken from ANCR-1224 by J. F. Whitbeck. Although J. F. Whitbeck's numbers are for a single fluid traversing the turbine, general agreement with the present analysis is shown.

*** George W. Hellstrom, "The Solubility of Selected Secondary Fluids for Use in Direct Contact Geothermal Power Cycles," Master of Science Thesis, University of Utah, December 1976.

Fig. 14 Comparison of the turbine energy density of the six working fluids.

Fig. 15 Comparison of cost of the turbine for the six working fluids. Turbine net power is 10 megawatts.

Fig. 16 Single stage turbine optimum diameter and rotation rate for pentane. The net turbine power is 10 megawatts.

Fig. 17 Single stage turbine optimum diameter and rotation rate for pentane for different turbine powers.

TABLE III

MOLECULAR WEIGHT AND TURBINE SIZING

(The inlet temperature is 130°C and the condenser temperature is 30°C.)

<u>Fluid</u>	<u>Inlet Pressure</u>	<u>Molecular Weight</u>	<u>Normalized Energy Density</u>	<u>Binary Relative Turbine Size (This Report)</u>	<u>INEL Relative Turbine Size*</u>
Propane	66.9 bars	44	1.00	.092	.07
Isobutane	36.2	58	.48	.181	.14
N-butane	28.9	58	.3788	.210	.18
Freon 114	27.4	171	.337	.397	.34
Pentane	13.7	72	.147	.489	---
Freon 113	11.1	187	.109	1.000	1.00

* From report ANCR-1224, Review and Tentative Selection of a Working Fluid, J. F. Whitbeck, May 1975

Fig. 18 Solubility of R-114 in aqueous and saline solutions

data for the 0 percent salt data from other laboratories is shown. The decreasing solubility with increasing salt concentration is demonstrated.

Similar results for isobutane are shown in Figure 19. Results for R-113 and pentane in the same format were given in the last quarterly report.

A comparison for pentane, R-113, R-114, and isobutane for 2.5 percent salt is shown in Figure 20. Other concentrations of salt indicated similar trends with changes only in the absolute magnitudes.

The most important factor involves relative cost,* and a typical curve for this is shown in Figure 21. In this figure costs are based relative to the most expensive fluid which is R-114. These costs are a result of the relative costs per unit of mass of each fluid, as well as the variation in solubility. Both an outlet geothermal temperature and condenser temperature are indicated. It is assumed that, after the heat exchange processes, the spent brine is saturated with working fluid at some "outlet temperature." It is then assumed to be flashed to the pressure corresponding to the condenser temperature, and the working fluid thus liberated is reclaimed. Clearly the plain hydrocarbons exhibit lower relative costs than either of the fluorinated hydrocarbons. This is an important result. If hydrocarbons also demonstrate higher heat transfer and overall thermodynamic performance (see discussion elsewhere in the report), then they are clearly more desirable for application in the direct contact power cycle.

1.5 Thermodynamic Analysis

The development of the first generation of the basic computer code to analyze plant performance (introduced in TREE-1008) has now been completed.** This code calculates virtually all plant parameters, including pressures, temperatures, flow rates, gross and netpowers, amount of working fluid reinjected, etc. Included in the program are subroutines to determine thermodynamic properties of fluorocarbons, hydrocarbons, and water. Various components in the cycle (e.g., pumps, condenser, turbine, and preheater) are also handled in subroutine forms which are called by a driver program.

Although the total package is a very powerful tool for analyzing binary thermodynamic cycles, (both direct contact and "conventional" binary), it temporarily has some pertinent limitations. First and foremost for our purposes, it does not have a full and accurate predication of the boiler performance. This problem was described in some detail in the earlier section entitled "Large Boiler Tests" of this report. Currently, the brine temperature drop in the boiler is input as an independent variable. While operation of a plant can be such that any reasonable temperature drop can be achieved, in reality other variables in the control of the plant will limit this. Carryunder of the working fluid in direct contact cycle is one example.

* While absolute costs are of interest, they can readily change with several economic factors. Relative costs will change primarily with changes in basic technology since all fluids considered here have a hydrocarbon base.

** D. H. Riemer, "Numerical Evaluation of Geothermal Power Systems Utilizing Binary Cycles," Master of Science Thesis, University of Utah, December 1976

Fig. 19 Solubility of isobutane in aqueous and saline solutions

Fig. 20 Relative solubility for 2.5% NaCl solutions in several working fluids

Fig. 21 Fluid cost normalized to the cost of R-114 for a separator temperature of 30°C and an outlet geothermal temperature of 90°C

Another current shortcoming is that the pressures at which the parallel-flow direct contact preheaters operate are not chosen by an optimizing technique. Rather they are chosen in a fixed manner for all cycles.

Detailed parametric runs using this program will be included in the next quarterly report.

2. LIQUID FLUIDIZED BED HEAT EXCHANGER

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Liquid fluidized bed heat exchangers are designed to prevent scale accumulation on heat transfer surfaces. In a geothermal binary system, the secondary fluid flows through the tube side of the exchanger and the brine through the shell side. The tubes are surrounded by a bed of particles and when the brine passes through the bed at sufficient velocity, the particles are fluidized (floated). The agitation of these particles enhances the heat transfer effectiveness within the shell side of the heat exchanger, in fact makes it nearly isothermal. Furthermore, the agitation gently scrubs the tube surfaces, keeping them clean, and the sand particles act as deposition centers for precipitates. Previous experiments have demonstrated scale control in both synthetic and actual geothermal fluids on a laboratory bench test scale.

2.1 8-inch Horizontal Unit

A fluidized bed is essential isothermal because of its high internal heat transfer coefficient. Therefore, several stages of beds are required for most applications. Structurally it is simpler if these are arranged in a horizontal instead of a vertical array. To demonstrate both the horizontal concept and scale control in real brines, an 8-inch horizontal unit was constructed. The major long term scale-control experiment using this unit is scheduled to be conducted at the East Mesa Site in Imperial Valley, California when the ERDA Geothermal Component Test Facility is ready for operation. The unit is currently undergoing preliminary testing and upgrading at the Raft River Geothermal Site. The unit consists of a cylinder with its axis horizontal, and with the geothermal fluid entering the distributor plate from the curved bottom of the vessel.

During the summer quarter, the unit was assembled and installed on the test loop trailer located at RRGE-1. A picture of this unit is shown in Figure 22. The shell is 8 in. Schedule 40 carbon steel pipe 18 in. long and flanged at both ends. The tube bundle consists of 49 3/8 in. diameter by 15-1/2 in. carbon steel tubes, each mounted on a triangular 3/4 in. pitch. The tube bundle assembly has a floating head, single pass, design. The distributor plate which supports the bed is a perforated stainless steel plate with 0.033 in. diameter holes spaced on a 0.075 in. triangular pitch. The bed consists of silica sand screened closely to 1 mm. The secondary fluid is treated water from the test loop trailer. The unit is instrumented to measure flow rates, temperatures, pressure, and differential pressure across the bed. Sealing of the floating head was a problem. The best system was found to be an ethylene-propylene O-ring sealed to the tube sheet with a thin coat of RTV.

The most serious problem to date has been trying to achieve even flow distribution across the bed. Several distributor plate arrangements have been tried. The next series of plates to be tried will create a

Fig. 22 8-inch Horizontal Unit

higher pressure drop across the distributor since increasing the pressure drop with previous tests improved the flow distribution. Part of the program plan calls for optimizing distributor plate design, and these experiments will receive higher priority in the future. In addition, experiments to reduce the pitch/diameter ratio of the tubes will be conducted, aimed at reducing the pressure vessel size to a minimum while still allowing the fluidizing action to function effectively.

2.2 East Mesa Benchscale Test

Benchscale atmospheric pressure experiments were performed at the Bureau of Reclamation test site in Imperial Valley, California. This preliminary experiment was designed to identify any problems unique to that resource which would affect operation of a liquid fluidized bed.

Experimental apparatus consisted of a vertical glass vessel 16 in. high x 5 in. diameter with a single perforated plate distributor with 0.033 in. holes on a 0.075 in. triangular pitch. The heat transfer was three concentric 1/4 in. tubing coils. The brine from well 6-1 was flashed before it was passed through the vessel. Cooling water was supplied from the desalting pilot plant. Frequent interruptions in the brine and cooling water supply prevented a continuous experiment at constant operating conditions. After one month of operation, the experiment was terminated.

Several unique effects and problems were encountered due to the higher solid content, which was 25,000 ppm. For the first time, deposition on the particles was observed. Chemical analysis indicated the coating to be mostly calcite with a few percent iron sulfide or iron oxide. The scale which deposited on the tubes above the bed had greater adhesion than what has been previously seen in calcite and silica scale experiments. This may be due to the presence of the iron compounds. Scale buildup on the bottom of the distributor plate reduced flow after one day of operation. Five steel balls approximately 0.15 in. in diameter were installed in the plenum area to impinge on the bottom of the distributor and keep it free of scale.

When the pressurized system is installed, the bed material may have to be periodically replaced due to scale accumulation. This is not expected to be a significant problem since under pressurized conditions calcite will not deposit and the rate of the deposit of iron compounds is low. Scale accumulation on the bottom of the distributor plate lead to a modification in the design of the distributor plate and plenum region.

2.3 Program

Development of a liquid fluidized bed heat exchanger for geothermal applications is close to schedule, but some program modifications have been required. Benchscale experiments designed to increase the geothermal flow rate by increasing particle size and density have been reduced in scope and shifted to the 8 in. vessel in Raft River. Three items interacted to make this desirable.

1. Strike induced delays in setting up the experiments in the INEL laboratory.

2. Recent publication of the results of a pertinent piece of related work proved most helpful. A paper by Richardson, Romai, and Shaliiri on "Heat Transfer from Immersed Surfaces in Liquid Fluidized Beds" in the Journal of Chemical Engineering Science reduced the scope of the experiment to verification of their work.
3. Construction delays on the ERDA test facility at East Mesa made the 8 in. vessel immediately available for preliminary experiments at Raft River.

A preliminary economic analysis is in progress to determine approximate size and costs of a 5 MW low pressure preheater. These estimates will be compared with those for a conventional tube and shell unit.

Experiments at Raft River and East Mesa have demonstrated the necessity for an experimental task to develop a distributor plate which will provide uniform flow distribution and will not be susceptible to scaling on the bottom side. This task was scheduled in the draft program plan for FY-78, but the need for the information has advanced its priority. Resources originally planned for benchscale work on increasing flow velocity will be applied instead to develop a distribution system.

IV. LOW TEMPERATURE RESERVOIR ENGINEERING

R. C. Stoker

The low temperature geothermal reservoir engineering effort is currently concerned with two areas in Idaho; Boise and Sugar City, that are likely candidates for early use of geothermal energy for space heating. Unlike Raft River, these areas represent sub-boiling resources, at a relatively shallow depth (500 to 2000 ft), hopefully.

1. BOISE EXPLORATORY WELLS AND HOLES

Five exploratory wells have been drilled in the northeast section of Boise, Idaho. Drilling was accomplished to help define the characteristics and extent of the geothermal resource in that area. Three cored slim (2-7/8 in. diameter) holes (BSH Numbers 1, 2, and 3) and two large diameter test wells (BEH-1 and BHW-1) have been completed in the area. The slim holes were completed in the first quarter of 1976. The test wells were completed in this quarter as described below. (See Figure 23 for the location of the five wells and structural linears in the area.)

1.1 Boise Hot Water-1 (BHW-1)

BHW-1 (a common designation has been "Beard" well) was originally drilled to a depth of 967 ft in the upper portion of the Boise Front Fault Zone. The well "sanded in" (plugged up) during flow testing in the early part of April. The Beard Brothers drilling rig was moved back on site early in the reporting period to clean the well out and drill deeper into the fault zone. The sand fill was tagged at 284 ft and finally cleaned out down to total depth (967 ft). Logging of the hole was initiated but more caving occurred and it was impossible to get any tool past 382 ft. The well was again cleaned out to total depth. The zones between 400-500 ft and 700-750 ft were identified as caving areas.

The well was bailed out and airlifted from 168 ft at 390 gpm to clean it out. It eventually flowed at 194 gpm under artesian free flowing clean conditions. A pump test was planned at rates up to 600 gpm but a pump could not be found locally that would go in the 8-in. surface casing to 180 ft.

A cellar was installed by emplacing a steel cylinder 6 ft high and 6.4 ft in diameter, coated with an asphalt paint, around the wellhead. Wood planks (3 in. x 12 in.) were placed across the top and the cellar was backfilled. This method will winterize the wellhead.

A decomposable drilling mud (Quiktrol), composed mainly of yeast and lime, was used to stabilize the hole while casing was run and set. The 4-1/2 in. O.D. casing consisted of 100 ft of screen from 823 to 923 ft, and slotted casing set from 965 ft to total depth (1283 ft). (See Figure 24 for well cross section.)

BSH = Boise slimhole
 BEH = Boise exploratory hole
 BHW = Boise hot water

Fig. 23 Map of linears for the Freestone-Cottonwood Canyon area

Boise Deep Wells
Well and Lithology Cross Sections

Fig. 24 Boise deep wells

The wellhead system was modified in late September, by installing an 8-inch master valve on the 8-inch casing flange. This operation necessitated killing the well for hardware changeout. The method selected involved the replacement of fresh geothermal water in the upper section of the hole with heavier salt water to overcome the 11 to 14 psi (cold to hot) shutin head. Salt (1000 lbs) was mixed with 900 gallons of water and the solution pumped into the well. A total of 750 gallons of solution was pumped into the well, theoretically displacing geothermal water down to the 535 ft level. As this solution heated up, the water level was maintained about 4 ft below the flange seat level by occasionally adding more salt solution.

After the changeout was completed, a total of about 1650 gallons of salt solution and geothermal fluid was pumped and flowed back out of the well and removed to a dump disposal area. The well returned to near normal shutin pressure after the salt solution was removed.

1.2 Boise Exploratory Hole-1 (BEH-1)

BEH-1 was drilled on the same location as the slim hole BSH-2 (BLM compound). It reached a total depth of 1222 ft, with 7-inch O.D. casing set to 610 ft. Because of the heavy drilling mud left in the hole, it was not initially a free flowing or pressurized well. The drilling mud level was measured at 30 ft below ground level through the spring and early summer.

Due to the caving problem experienced in BHW-1, it was determined that slotted casing should be installed to total depth in this well before flowing it. Consequently, the Beard Brothers drilling rig was moved over the hole after completing the work on BHW-1. The 3-1/2 inch O.D. casing was run and set without difficulty and the cleanout operation (bailing) was initiated. The well began to flow by itself during the bailing operation. At that time, leakage (approximately 50 gpm) was noted between the casing flange and 8-inch master valve as well as from around the 2-inch flow line block valve. The gasket was replaced on the master valve and all connections tightened which eliminated the leakage. A cellar was also constructed around the wellhead for winterization. The cellar consisted of a steel cylinder 5 ft high and 6.4 ft in diameter, coated with an asphalt paint, around the wellhead. Wood planks (3 in. x 12 in.) were placed across the top and the cellar annulus backfilled. Cold shutin pressure stabilized at 10.5 psig, virtually identical to the pressure recorded in BHW-1. (See Figure 24 for well cross section.)

1.3 Well Drilling Summary

The Boise Drilling Summary is shown in Table IV and consolidates the pertinent information about each well.

The temperature profiles of BEH-1 and BHW-1 reveal that the gradient in both wells are approximately the same at depth. Moreover, the production surface temperatures (165-170°F) are adequate to support the space heating project proposed for the Boise area. This temperature range is the same as for the two Warm Springs Avenue heating system wells over a mile away, wells that have been supplying home heating for 84 years.

TABLE IV
BOISE DRILLING SUMMARY AS OF SEPTEMBER 1976

<u>Hole or Well</u>	<u>Location*</u>	<u>Total Depth (feet)</u>	<u>Maximum Temperature</u>	<u>Casing Depth (feet)</u>
BSH-1	Freestone Canyon	250	82°F	150
BSH-2	BLM Compound	650	132°F	550
BSH-3	Foothills East	550	94°F	130
BEH-1	BLM Compound	1222	>164°F at 1050 ft	1222
BHW-1** (Demo well)	Freestone Canyon	1283	172°F at 875 ft	1283

* The locations of these exploratory holes and demonstration wells are shown in Figure 23.

** This well developed 194 gpm artesian flow on August 4, 1976, during free flow tests. Outlet temperature reached 167°F after flowing for 12 hours.

1.4 Boise Area Geology

The early geologic mapping in the area and the location of warm wells indicated that the Boise Front Fault was a major structural control influencing the geothermal resource. An analysis of the limited hydrologic study, geophysical study, remote sensing imagery study and the knowledge gained from drilling BSH-1, BSH-2, BEH-1, and BHW-1 has resulted in a modification of the original concept. The Boise Front Fault apparently is not as important a structural control as are the intersecting linears (of fault zones) that occur in the immediate area of investigation, although the Front Fault carries the hot water fed by the linears. These linears generally trend NE-SW and are visible all along the foothills to the north of Boise. However, several linears cut across the general trend and appear to have a major influence in the area around both the Warm Springs Penitentiary wells and this area of investigation. It would appear that the heated water moves along certain linears from the northeast and spread out along the Front Fault where the linears intersect it. The Front Fault is not completely impervious and allows leakage of the geothermal waters through it and subsequently out into the valley proper where it mixes with the cool water of the fresh water aquifer thus diluting the geothermal resource temperature in the valley. This flow system is also short-circuited or interrupted when the NE-SW linears are intersected by NW-SE trending linears before they reach the Boise Front Fault. This situation makes the selection of production drill sites only slightly more complex. *

2. SUGAR CITY EVALUATION

A report** has been prepared that is a preliminary overview of the potential application for geothermal energy space-heating uses in Sugar City, Idaho. The opinions and recommendations presented in the report are based on a cursory study prompted by the urgency for the rebuilding and recovery efforts of Sugar City, a town recently devastated by the Teton Dam collapse. This report was first prepared for the Sugar City Council and Madison County Commissioners in August 1976.

Further well temperature and geochemistry evaluation may be conducted in the near future. This work hopefully will lead to a better estimate of where and at what depth warm water is likely to be found in the Sugar City area. The problem is one of finding water warm enough to be useful (hotter than 120°F) at a cost consistent with the heating needs of the town of 800 people, now and in the not too distant future.

* Editor's Note: The reader should be aware that the above theory is the one most generally believed by geothermal geologists studying the Boise area. However, hard facts to support this theory, especially pertaining to the origin of the waters, are at this time lacking. Further reservoir engineering work will include the search for reflected boundaries, attempts to determine if highly directional motion of the fluid occurs into the wells, and isotope studies on the geothermal waters may find positive answers to assess this theory. Also interaction between these wells and the Warm Springs wells will be investigated during this coming heating season.

** "The Potential for Utilizing Geothermal Energy for Space Heating in Re-Constructed Sugar City, TREE-1016, EG&G Idaho, Inc.

V. NON-ELECTRIC APPLICATIONS

R. J. Schultz
Manager, Geothermal Non-Electric

To date, the limited non-electrical uses of geothermal energy have centered around space heating whereas a potentially large application could be in industrial processes. This potentially large application may actually be the most profitable application of the geothermal resource although a combination of power production plus process heat application may prove more desirable. Geothermal water in the temperature range found at Raft River (approximately 300°F); i.e., the intermediate temperature range which is typically the more common temperature range of geothermal resource found in the U.S., appears usable in process applications and power productions, or usable as a demonstration of a combined electrical, non-electrical utilization.

A successful demonstration of the process application of geothermal energy for a combined system utilizing this typical resource could stimulate widespread development of similar resources in other areas of the U.S. and contribute significantly to creating new energy choices for the future. This goal is a substantial part of the national plan for energy independence in the years ahead.

Geothermal energy projects for producing electricity from liquid dominated systems are generally predicated on using the geothermal water only for a partial extraction of its heat content not its total fluid content. Generally, the fluid is to be returned to the geothermal reservoir via reinjection. If this fluid is used in non-electric applications generally more heat can be extracted from the water before reinjection of the water. Most plans call for physical separation of the geothermal water and process fluid. Beneficial uses of the total fluid such as agriculture, irrigation, aquaculture, washing and purifying operations is not contemplated because of concerns over possible environmental effects either from the dissolved solids, heavy metals, or fluorides in the geothermal waters or from maintaining satisfactory fluid level in the geothermal reservoir.

However, as geothermal energy usage advances, large quantities of these waters may become available either in the form of discharge from power plant operations or from resources too low in temperature for power conversion. Beneficial uses of these geothermal fluids may be extremely valuable to reduce the costs of drilling re-injection wells, and the costs of re-injection pumping, to provide a source of water for agriculture in water starved areas, or to reduce the costs of geothermal energy by a total energy extraction concept. Furthermore, it is argued that geothermal energy development cannot long proceed without fully understanding the potential detrimental environmental effects that might result with geothermal water contamination of soils, plants, or animals.

The studies of surface beneficial use of this relative pure waters was initiated this summer in the Raft River Valley, for both agriculture

and aquaculture. This work is discussed in Section I.5., and should, if the applications are successful, be of relative importance generically, since the water contained 2000 ppm and appeared to be generally originating from young volcanics, not limestone reservoirs. The water from the Boise wells is much purer, having only 300 ppm, but is substantially cooler (170°F vs 300°F in Raft River).

Recognizing the need for a scientific evaluation of the full range of uses for the geothermal energy resource, the Idaho National Engineering Laboratory is conducting a coordinated program to stimulate the non-electric uses and to provide information and data to help solve technical problems that might exist and to improve the economics for the non-electrical utilization of geothermal energy.*

The work covered under the National Non-Electric Program Management and Assistance Program includes all management, planning, and stimulation activities undertaken by the INEL non-electric project function. Tasks included in this project are: (a) provide management and program planning assistance to ERDA, (b) provide technical assistance to potential users including certain case studies, and (c) information dissemination.

These activity areas are designed with the overall goal of educating and stimulating the public and private sectors of the United States to utilize the low-to-moderate temperature hydrothermal resource in various processes and applications. A program of planning, management assistance and field technology transfer is required to stimulate the in-situ use of this resource. Case studies are required to develop potential uses and to ensure proper generic and specific utilization practices.

The non-electric geothermal energy "user" is a very diffuse and encompassing sector. The users vary from individual space heating uses to large industrial complexes. Dissemination of information to such a varied group becomes difficult at best. Many techniques are and will need to be utilized to disseminate technical, legal, institutional, economic and resource data and information to potential user groups or individuals throughout the United States.

1. NON-ELECTRIC ENGINEERING AND ECONOMIC STUDY MANAGEMENT ASSISTANCE PROGRAM (N-EE&ES)

The N-EE&ES Program being conducted by ERDA-DGE represents an inducement to stimulate a broad techno-economic base of public and private sector involvement in the applications of geothermal energy. INEL will be monitoring and providing program evaluation for nine of DGE's designated N-EE&ES contracts. The effort to date has been contractual support to ERDA-ID and the development of a management information system (MIS) which will be applied by each of the nine INEL monitored contractors.

* A prior evaluation of the probably potential and an outline of a national program is ANCR-1214, "National Program Definition Study for the Non-Electrical Utilization of Geothermal Energy," June 1975, Idaho National Engineering Laboratory.

2. TECHNICAL ASSISTANCE ACTIVITIES

Assistance during this reporting period was primarily concerned with five geographical locations. A brief summary of these activities by location follow:

2.1 White Sulphur Springs, Montana

White Sulphur Springs is a community of approximately 1200 people with what used to be several free flowing hot springs near the center of town. One hot spring is used for space heating 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 this motel for the construction of a new banking facility which they hope to heat geothermally. Land adjoining the motel has a small hospital complex which is in an expansion program. The A&E firm under contract is designing a hot water heating system that can be converted easily to geothermal at a later date.

Discussions were held with the bank president, the local motel owner, and a representative of the hospital engineering consulting firm, it became apparent that the type of assistance most needed is in the resource assessment area. Some advice was given along these lines, at least, where to go to obtain available information. The possibility of a city wide geothermal system was discussed and information provided by the Economic Development Administration concerning financial assistance was supplied. Assistance in utilization concepts will be continued once an action plan is formulated by the community.

2.2 St. Mary's Hospital, Pierre, South Dakota

This is a large hospital complex with a central boiler facility supplying heat via steam and hot water circulating systems. The boilers are fired with No. 6 fuel oil and heating bills have been typically \$60,000 to \$70,000 per year. Oil and gas exploration plus deep irrigation well drilling around Pierre have produced reliable subsurface geologic information that indicates a source of warm water (approximately 150°F) likely within the first 2000 ft of depth on or near the hospital grounds.

The hospital board of directors has authorized funding for an engineering consulting firm to look into alternate energy concepts with geothermal one of those alternates. An energy conversion program is foreign to the hospital administration staff, therefore, the type of assistance requested and provided this quarter has been in the form of program management guidelines. Actual conversion concepts will be addressed during the first quarter of FY-77.

2.3 Pagosa Springs, Colorado

Colorado School District No. 50 has a hot water well on the Pagosa Springs school grounds. This well has been used in the past to provide a portion of the buildings heating needs, however, with less than satisfactory results.

A review of heating system configurations and operating parameters at the school, started this quarter, is almost complete. Conceptual engineering designs for converting the school's heating requirements to geothermal are in progress. These designs will be based on refurbishing the existing well or drilling a new one to obtain a better quality heat source.

2.4 Sugar City, Idaho

This town of approximately 800 people was directly in the path of the disastrous flood caused by the collapse of the Teton Dam. Subsequently, the entire town was essentially destroyed. Along with rebuilding efforts, it seemed reasonable and timely to pursue a more efficient and energy conserving arrangement for providing space heating needs of the community. Warm wells within seven miles of the town also provided impetus for the possible use of geothermal.

A study was done to determine the feasibility and economic viability of a district heating system to serve the total community. Different alternates included distribution of geothermal water of various temperatures for direct use or heat pump application and a district hot water heating system concept, fuel fired, with locally available less scarce fuels (woodwaste and coal).

2.5 Timberline Lodge, Oregon

Timberline Lodge is a U.S. Forest Service owned ski facility located at an elevation of 6000 ft on Mt. Hood. This 11,235 ft mountain is considered an active volcano with the last known eruption having occurred within the last 2000 years. The lodge is a large wood and natural stone structure built during the 1930's and in itself a national historical monument.

Presently, heat is supplied by a fired boiler, two pipe, low pressure steam system. A recent convention facility addition to the lodge uses a forced air distribution system with hot water perimeter heat but the original lodge uses cast iron radiators and small natural convectors for individual guest rooms. The heating season is practically year round and fuel consumption has been averaging 3800 barrels of No. 6 fuel per year. This represents a fuel cost of about \$56,000 per year.

The Forest Service is now in the design phase for a new day lodge which when completed along with a planned motel complex will increase the fuel consumption to 7500 barrels per year (approximately \$126,000 per year).

The geology of the area is most favorable to the location of hot water near the lodge even though there are no wells on the mountain at that elevation. A 500 ft test hole drilled near the lodge this summer by the State of Oregon was most favorable.

Work is being accomplished with the Forest Service on heating system conversion concepts even though more concrete designs will have to await actual confirmation of the resource. The new day lodge design will include a hot water heating system for ease of later conversion.

2.6 Information Dissemination Activity

The dissemination of information to potential geothermal users and other types of industrial participants is essential to increase the sphere of geothermal energy utilization. Both mass communications and individual, one-on-one discourse is required to make the public and private sectors more knowledgeable in the potential applicability of geothermal energy.

The information dissemination activities undertaken during this quarter were presentations to technical and non-technical groups, release of mass median news articles, exhibits at public meetings and transmittal of technical documents and brochures to interested parties upon request.

Information was transmitted to 41 individuals, private companies and institutions at their request. The documentation transmitted included approximately 145 technical reports, paper reprints and brochures.

Four groups were provided with exhibit type material for set up and presentation. These groups were the Lake County California County Fair; the Teachers Institute, and the Western Meeting of Professional Engineers, both in Boise, Idaho; and Energy Seminar, Akron, Ohio. A relatively permanent exhibit has been installed in the new Intermountain Science Experience Center in Idaho Falls, Idaho.

2.7 Case Studies

During the transition quarter, several studies/surveys were initiated. The primary purpose of these centered upon: 1) information dissemination; 2) extension of geothermal stimulation data for sequential technical assistance and program development and; 3) facilitating on-going INEL RD&D projects. The following studies represent efforts to improve further technical assistance programs.

1. Native American Tribal Lands - Development of a data base locating all tribal lands in the U.S. is in progress. Data has been transferred for matching geothermal resource data to the Indian lands. Both the resource base and Native American lands data will be transferred to magnetic tape for permanent retention.
2. Federal Building Conversion Study - A case study was begun during the transition quarter assessing potential energy savings if all federal buildings near a geothermal source were to utilize the resource for maximum replacement of fossil fueled energy usage. A partial list of federal buildings has been compiled. Indexing these buildings by latitude, longitude, federal department and approximate size has been initiated. Matching these buildings to geothermal resources will be accomplished using a data processing matching code developed for the Indian lands study.

VI. BOISE DEMONSTRATION SPACE HEATING

L. E. Donovan

A joint federal-state Boise Demonstration Space Heating Project was formally initiated late in 1974. The first phase had five primary objectives in mind. Those were:

1. To determine if the geothermal resource located along the Boise Front Fault is adequate to support further exploitation and an additional large scale commitment to a long-term utilization of geothermal fluids for space heating.
2. To determine the costs and practicality of retrofitting existing building heating systems to geothermal using the expected low temperature (170-180°F) water.
3. To prepare a conceptual design of a geothermal distribution system and discharge system that would be suitable for the stated application.
4. To examine the environmental questions requiring resolution assuming the project is pursued to completion.
5. To build and test the proposed system for demonstrating actual costs of construction and operation.

With the exception of some on-going material testing, additional reservoir engineering tests and continued liaison with state officials, this first phase came to an end at the close of the summer, essentially carrying the work to a point where the Boise Project could be continued by the state or private developers with little or not Federal involvement. The above five project objectives were successfully completed.

1. PROGRESS DURING THE REPORTING PERIOD

1.1 Geophysical Study

The Boise State University Geology Department completed additional electrical resistivity measurements along the Boise Front. Extending north and west from the Freestone Canyon or the exploratory drilling area, an additional 200 plus data points were collected. These additional points more than double the area covered previously for resource definition and evaluation. Data reduction techniques are presently being applied to provide a composite of the Boise Front resource. A report covering this geophysical work is in preparation at Boise State and should be complete during the first quarter of FY-77.

1.2 System Design

As reported last quarter, the State of Idaho has received funding through the Pacific Northwest Regional Commission to initiate the implementation portion of the Boise Project. Hardware has been received and

partially installed for the conversion of the State Health Labs to geothermal heating. These buildings will use the existing Warm Springs Geothermal System for expediency. This conversion will serve as a model to resolve environmental and institutional problems for the larger expanded project. The INEL has provided engineering assistance for this first conversion plan in the areas of heat exchanger selections, material recommendations and discharge concepts.

1.3 Exploratory Drilling and Well Testing

Two successful geothermal wells were completed, both with significant artesian flow (neither has been pumped yet) and at the temperatures predicted and needed (160 to 170°F). (See Section IV for a complete description of these wells.

1.4 Material Evaluation

Corrosion and deposition testing continued through the summer using the Warm Springs Geothermal System. Tests as originally initiated are scheduled through the fall of 1977. Results to date, even though not complete or conclusive, have ruled out several material selections. Low carbon steel, with some reservations, appears to be the most economical section for above ground piping and equipment components. As material samples are continually monitored, it is anticipated material selections will become more refined. Results of the underground test piping samples will not be known until the conclusion of the one year test.

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