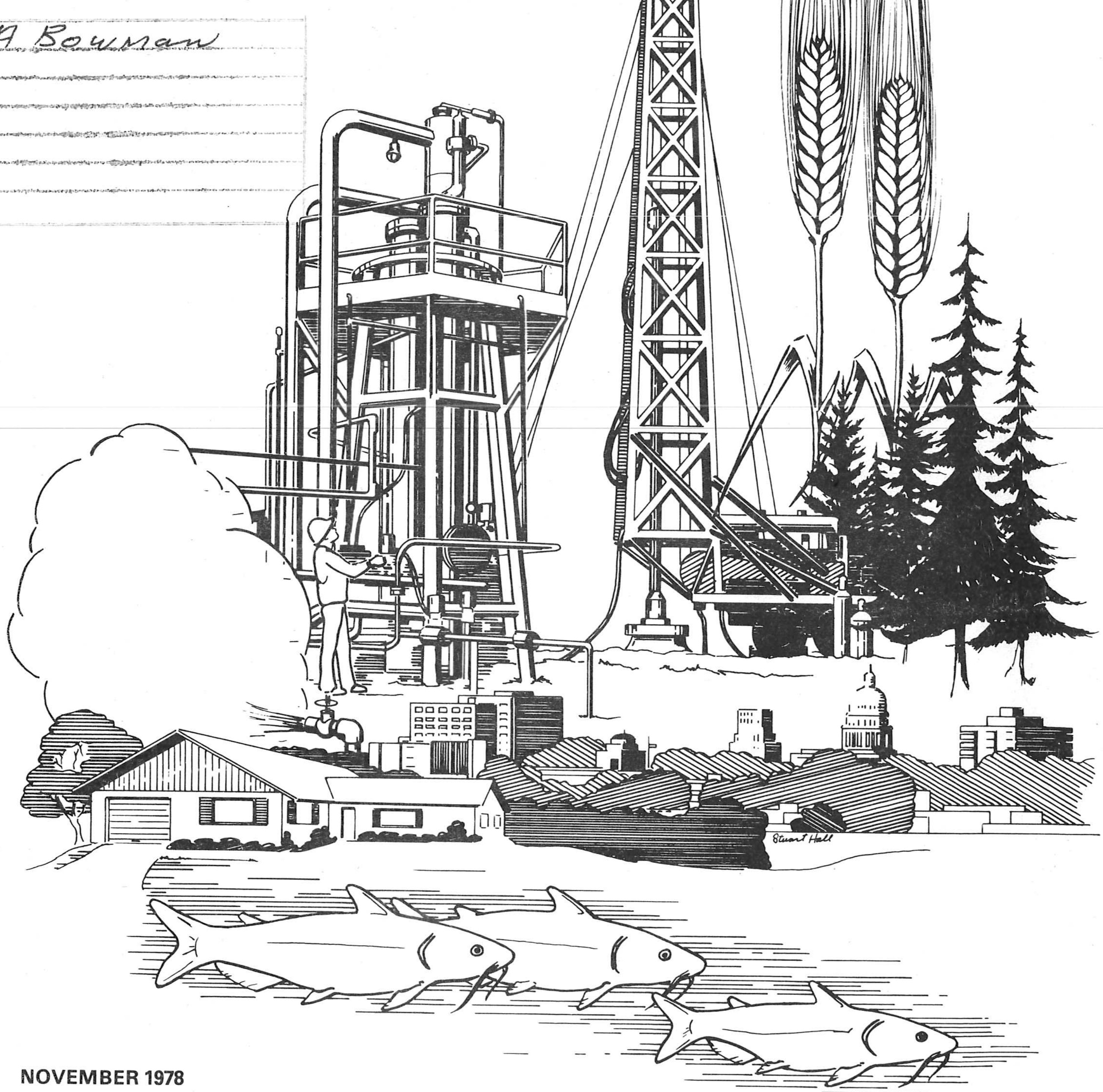
SEMIANNUAL PROGRESS REPORT FOR THE IDAHO GEOTHERMAL PROGRAM

TREE-1295

APRIL 1 TO SEPTEMBER 30, 1978



NOVEMBER 1978
EG&G IDAHO, INC.
IDAHO NATIONAL ENGINEERING LABORATORY

THE U.S. DEPARTMENT OF ENERGY

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161
Price: Printed Copy $6.00; Microfiche $3.00

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TREE-1295
Distributed Under Categories:
UC 66-a, -b, -c, -d, -e, -g, -j
Geothermal Energy

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

Edited by G. L. Blake

EG&G IDAHO, INC.
Idaho Falls, Idaho 83401

Published November 1978

PREPARED FOR THE
U.S. DEPARTMENT OF ENERGY
IDAHO OPERATIONS OFFICE
UNDER CONTRACT NO. EY-76-C-07-1570

ABSTRACT

This report discusses research and development performed by the Idaho Geothermal Program between April 1 and September 30, 1978. It describes well drilling and facility construction at the Raft River geothermal site. It explains efforts to understand the geothermal reservoir, and it summarizes attempts to predict the wells' potential. Investigations into the direct uses of geothermal water, such as for industrial drying, fish farming, and crop irrigation, are reported. The report also describes the operation of the facility's first electrical generator. Construction of the first 5-megawatt power plant is recounted. The design effort for the second pilot power plant is also described. University of Utah work with direct-contact heat exchangers is outlined. The report summarizes special environmental studies of injection tests, ferruginous hawks, and dental fluorisis. It describes the regional planning effort for accelerated commercialization. Demonstration projects in Oregon, Utah, and South Dakota are noted. A bibliographical appendix lists each internal and external report the Idaho Geothermal Program has published since its beginning in 1973.

SUMMARY

The Raft River fluid supply and injection system, which will serve the first 5-megawatt pilot plant, neared completion during the period. Crews drilled production well RRGP-5 and injection wells RRGI-6 and RRGI-7, and they deepened well RRGI-4. Researchers continued pump tests, and the pipeline network was enlarged. Engineers evaluated the new wells, studied the reservoir, and began a chloride monitoring program.

Researchers continued direct-use experiments at the test site. A fluidized-bed industrial dryer was successfully tested. Catfish, tilapia, and tropical shrimp responded well to culturing in geothermal water. Field studies for the agriculture experiment were completed; anaylsts agreed that with proper management, Raft River geothermal water could be used to irrigate crops.

The prototype electric generator was operated successfully, supplying the local power grid with enough electricity to light the nearby town of Malta. Crews began constructing the first 5-megawatt pilot plant, and researchers performed a number of support engineering tests. Preliminary designs for a second pilot power plant also neared completion, and University of Utah personnel continued to investigate the use of direct-contact heat exchangers.

Seven environmental monitoring wells were completed during the period. Biologists finished the first phase of the ferruginous hawk study. The fluorosis study neared completion without identifying human fluorosis with any particular Raft River source.

The regional planning process gained impetus with the publication of a regional commercialization plan. The planners analyzed the resources and needs of states in the Rocky Mountain Basin and Range Region, and they agreed on both preliminary and long-term goals for geothermal development.

Six demonstration projects received Department of Energy funds through the Project Opportunity Notice program. EG&G personnel supported the Department of Energy in the technical administration of the project contracts.

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I. THE RAFT RIVER FACILITY

The Raft River Geothermal Site is located in southern Idaho's Raft River Valley, south and west of the small town of Malta (see Figure 1). Contractors for the Department of Energy's (DOE's) Idaho Geothermal Program have conducted field experiments at the Raft River facility since 1973. Engineers from the DOE's Idaho National Engineering laboratory (INEL) have been testing various applications for the valley's medium-temperature geothermal brines. The 150°C (300°F) water has often been used directly, as for culturing fish and irrigating crops (see Section III). Part of the research program also calls for the design, construction, and testing of pilot power plants (see Section IV). During recent report periods, EG&G Idaho and a number of subcontractors began the construction of the fluid supply and injection system that will serve Raft River's first pilot power plant[a]. during the period covered by this report – from April 1 to September 30, 1978 – crews drilled three geothermal wells.

1. FLUID SUPPLY AND INJECTION SYSTEMS – R. D. Sanders

Drilling crews completed RRGI-6 early in the period, sinking the new injection well to a depth of 1181 meters (3875 feet)[b]. RRGI-7 was drilled just south of the sixth well, to a depth of 1176 meters (3858 feet). A map of the wells' locations is shown in Figure 2. A new production well, RRGP-5, was completed to approximately 1382 meters (4534 feet). Also during the period, crews began deepening an existing injection well; RRGI-4, which will be used as a production well, had been deepened to 1056 meters (3464 feet) by September 30, 1978. (See Section II for an analysis of the new wells' potentials).

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[a] For information about the previous report period, see the Semi-annual Progress Report for the Idaho Geothermal Program, October 1, 1977 to March 31, 1978[1].

[b] RRGI stands for Raft River Geothermal Injection well; an E or P in place of the I would indicate the well was intended for exploration or production.

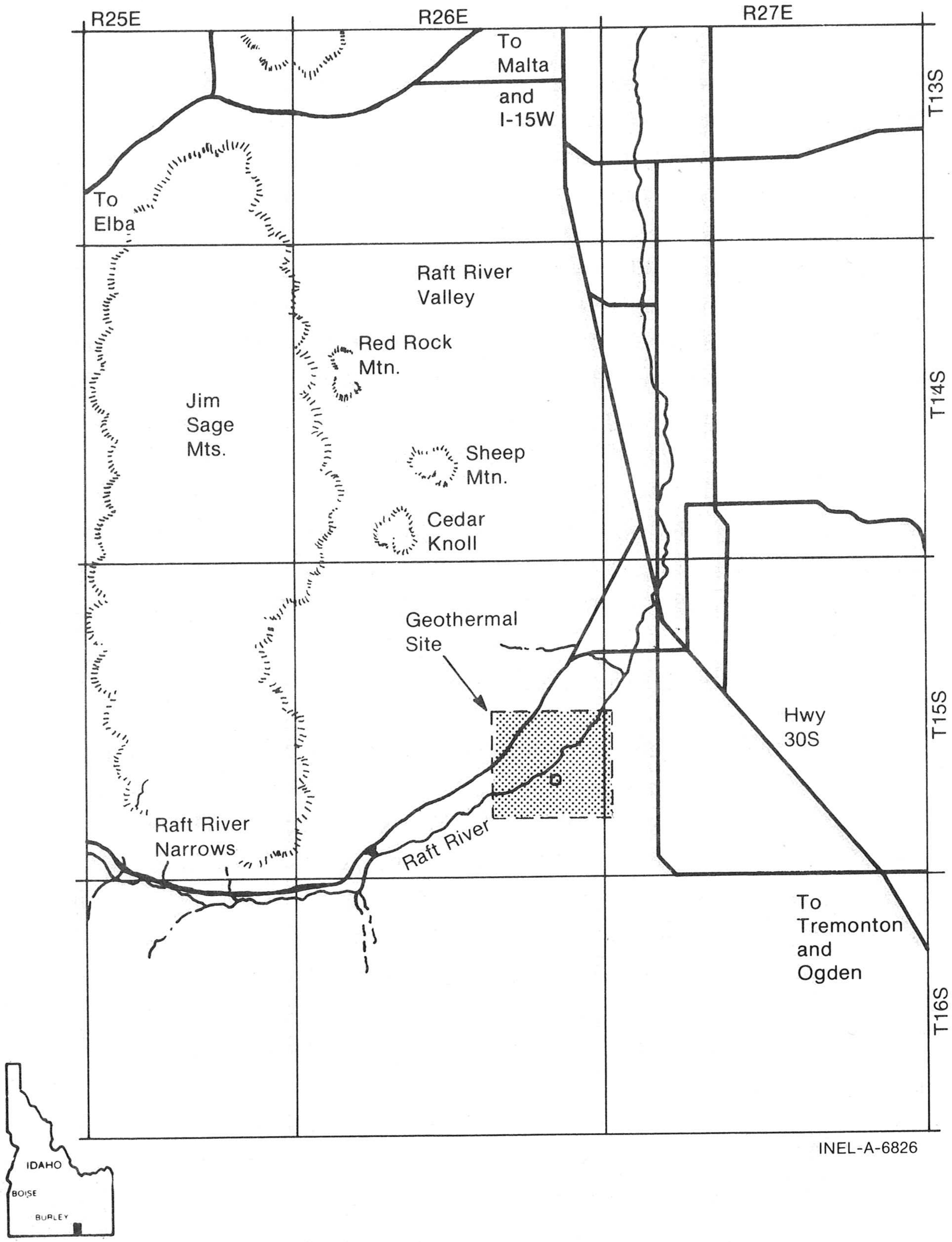

Fig. 1 Location of Raft River Geothermal Site.

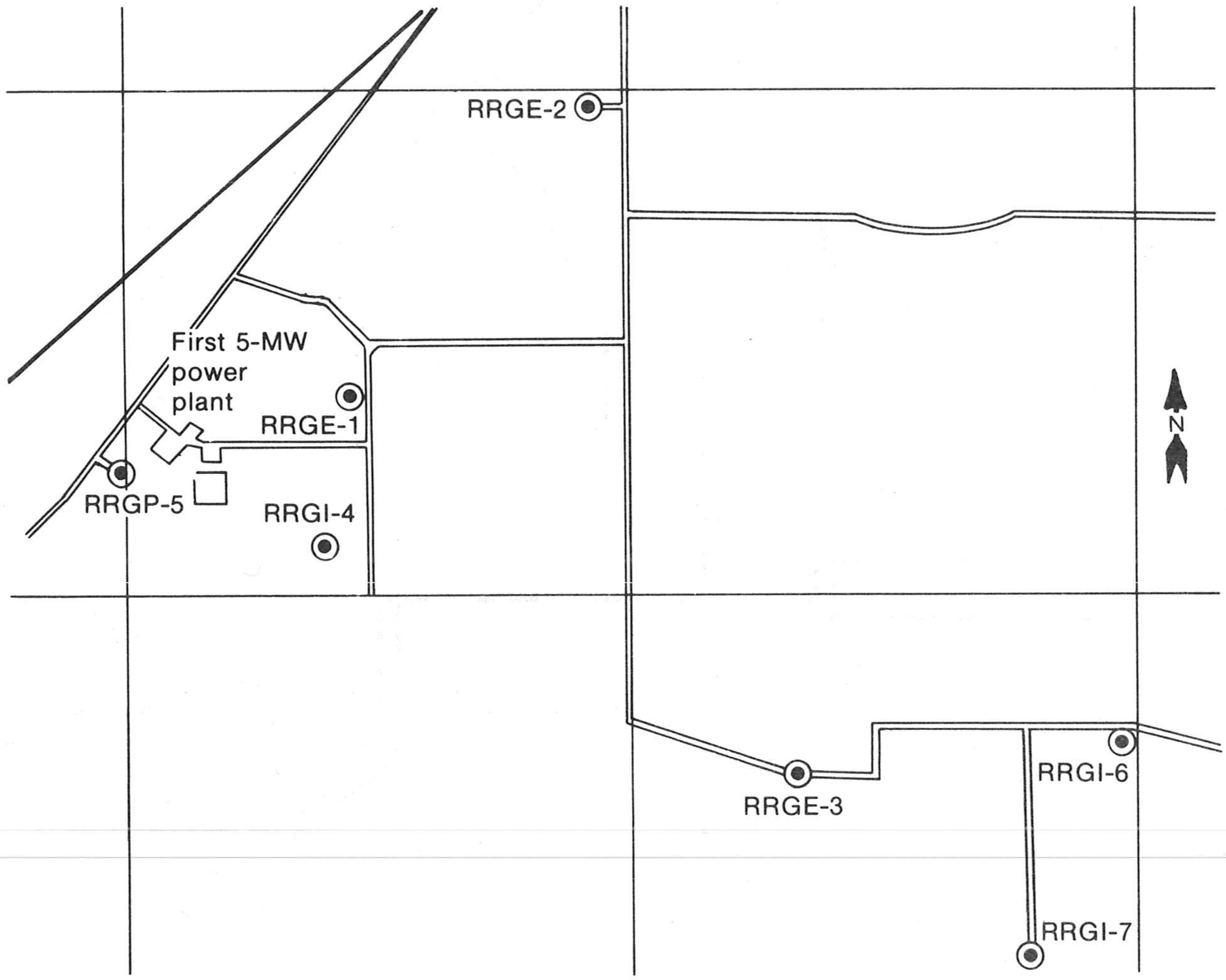

Fig. 2 Location of Raft River geothermal wells.

Approximately 75% of the piping required to carry fluid to and from the first 5-megawatt power plant is complete. Crews are now constructing the main line from the plant site to the injection area; completion is scheduled for November 1, 1978. A contract was awarded for the line from RRGE-3 to RRGI-7, but the contract has been delayed because RRGI-7 has not performed well as an injection well. The remainder of the piping, mainly wellhead hook-ups, will be completed during the next reporting period. Figure 3 shows the routes and current status of the main piping system.

One new pump was installed during the period, and it is now being tested. A line-shaft vertical-turbine pump was installed in RRGE-2

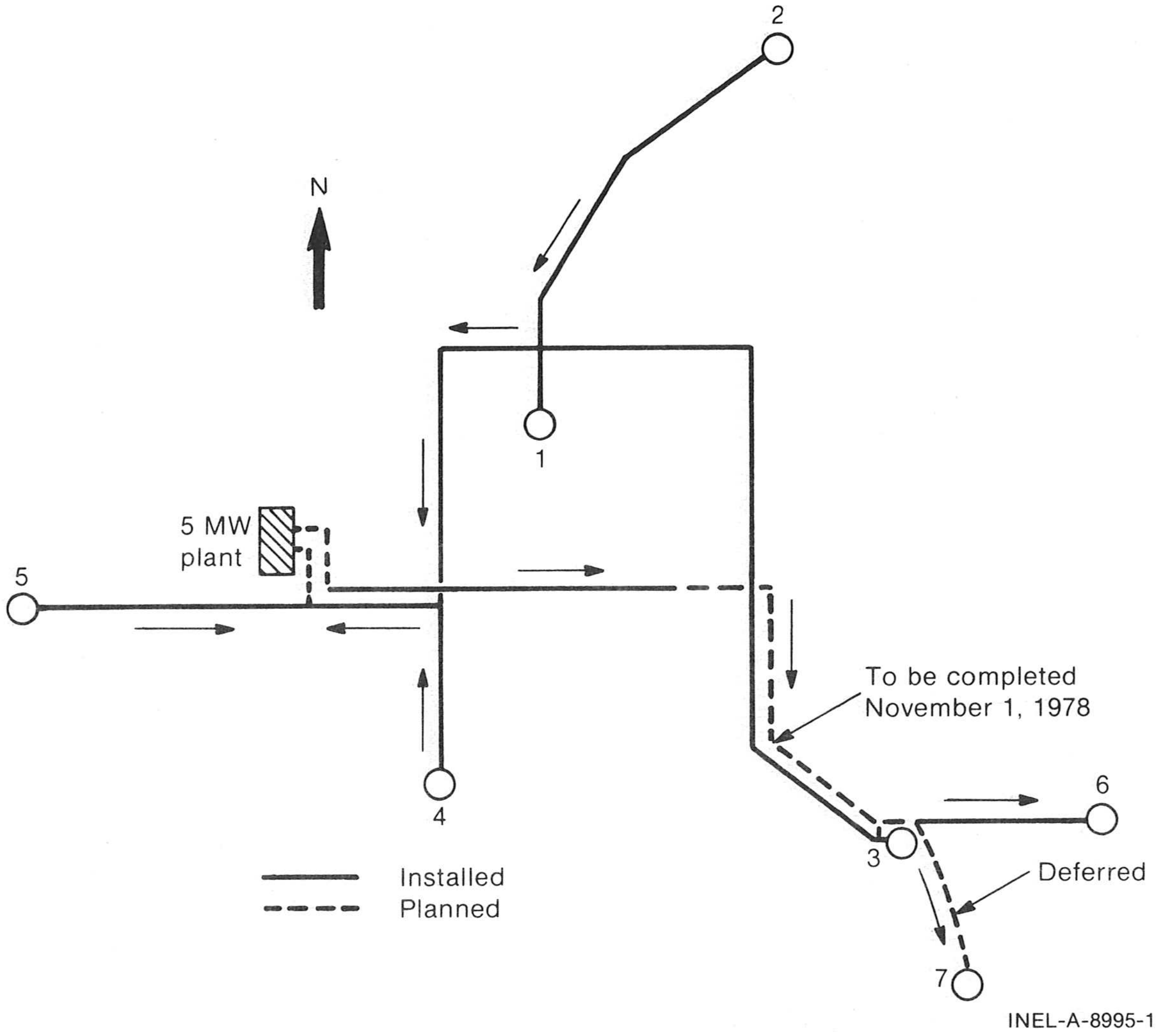

Fig. 3 Pipelines for the fluid supply and injection system.

during May. The 187-kilowatt (250-horsepower) pump was set at 240 meters (800 feet). It has operated for a total of 257 hours at flow rates ranging from 32 to 44 liters per second (500 to 700 gallons per minute).

The submersible pump that was installed in RRGE-3 on May 7, 1977, was operated for a total of 1359 hours. On April 10 the pump shut down, apparently because of a down-hole electrical problem. On May 23, 1978, EG&G personnel pulled the pump and returned it to the manufacturer for teardown and inspection. EG&G participated in the inspection. The electrical problem was caused by water in the motors, but the route by which water entered the motors could not be definitely established. The motor-housing seals are suspect, however; the company has been using a different seal design on newer pumps. The refurbished unit, which was returned to EG&G in September 1978, includes the new motor-seal design. The other pump components were in very good condition, showing very little wear, corrosion, or other deterioration.

2. OTHER CONSTRUCTION — G. M. Millar

A number of significant improvements were made at the Raft River facility during the second half of FY-78. A site master plan was established to specify guidelines for future site improvements and construction projects[2]. In consonance with this plan, the final construction of Building 608 was completed. This 9 x 22-meter (30 x 72-foot) building is located in the RRGE-1 compound. The prototype generator control room, the site conference room, an instrumentation and calibration shop, and the site administrative office are all now contained in this building. Building 614, the 9 x 15-meter (30 x 49-foot) addition to Building 608, is scheduled for completion early in FY-79. Building 614 will house a lunchroom, men's and women's restrooms and dressing rooms, a first-aid room, and the new site office.

An office trailer complex was also established 25 meters (82 feet) south of the RRGE-1 compound. It will provide improved working spaces for the DOE site representative, the site supervisors, and the resident engineer. To improve site cleanliness and provide better personnel access, the RRGE-1 compound parking area was paved with a hot asphalt mix. In addition, road crews shaped and graded all site roads and applied a top coat of dry road mix. In all, approximately 8 kilometers (5 miles) of roads were repaired. Finally, a safety fence was installed around the prototype generator. The construction of other projects, including the first pilot power plant, is detailed in the chapters that follow.

II. THE RAFT RIVER RESOURCE

Hydrogeologists continued to evaluate the chemistry of individual wells and to assess the nature of the reservoir as a whole. They carefully studied the wells drilled during the period, and began a program to monitor chloride in the Raft River waters.

1. SUMMARY OF RAFT RIVER GEOTHERMAL WELLS - D. W. Allman, D. Goldman, L. B. Nelson, W. L. Niemi

1.1 RRGE-1

The first well appears to be capable of producing 50 liters per second (800 gallons per minute) for five years with a pump setting of 224 meters (800 feet). This assumes the presence of one boundary, as well as interference effects from other production wells (a boundary is a change in transmissivity, as evidenced by variation in pressure during a well flow test). During a high-production-rate test on December 10, 1975, however, the well supplied 63 liters per second (1000 gallons per minute) for 370 minutes, and the wellhead temperature declined $5^{o}C$ ($9^{o}F$) to a temperature of $129^{o}C$ ($265^{o}F$). Data suggest that wellhead temperature will eventually decline when pumping-water levels are less than 179 meters (586 feet); drawdowns of this magnitude apparently induce cooler water to enter the well bore.

1.2 RRGE-2

With two barrier boundaries, and assuming interference effects from other production wells, researchers predict RRGE-2 can produce 34 liters per second (540 gallons per minute) for five years with a pump setting of 244 meters (800 feet). The ratio of the pumping rate to the slope of the data on a semilogarithmic plot of wellhead pressures versus time is dependent on Q; in other words, the greater the rate of withdrawal from the well, the poorer the well's ability to produce water. This dependency also indicates that significant errors in predicting drawdown can result if the pumping rate during a test is not approximately equal to that of the five-year projection.

1.3 RRGE-3

This well continued to produce the highest-temperature water in the Raft River area. Analysis during the period indicated that the use of RRGE-3 as a production well will cause favorable interference effects with nearby injection wells.

1.4 RRGI-4

Injection testing of this 866-meter (2840-foot) well was concluded in June. Hydrogeologists performed the tests to determine the characteristics of an intermediate zone above or adjacent to a major geothermal producing zone(s), and to ascertain the feasibility of injecting cool, unaerated water into the intermediate zone. There were difficulties that caused errors of unknown magnitude in the estimated value for the effective reservior Kh (intrinsic transmissivity). The hydrogeologic relationships suggest the well penetrated the Narrows Structure, a fault zone typical of basin-and-range geology. This hydrogeoligic fracture system appears to be hydraulically connected to the Bridge Fault, which is the major producing zone for RRGE-1 and RRGE-2. The results of the testing were presented at the second Lawrence Berkeley Laboratory Well Symposium, and they will be published during the coming period.

1.5 RRGP-5

The fifth well was drilled on the upthrown side of the Narrows Structure. The well was cased with 34-centimeter (13-3/8-inch) casing to 460 meters (1508 feet). At 1382 meters (4534 feet), drilling operators ran a preliminary test and reported a flow of 69 liters per second (1095 gallons per minute) at 127°C (260°F) with 345 megapascals (50 pounds per square inch) back pressure.

Drilling continued to 1497 meters (4911 feet), where crews encountered difficulties and had to kill the well's artesian pressure. It was necessary to prevent steam from flashing in the borehole during a tool recovery operation. Crews used 128,000 kilograms (141 tons) of salt over a ten-day period.

To be certain shallow aquifers were not contaminated, a number of surrounding wells were monitored before, during, and after the fifth well was killed. Chemists tested the water samples for chloride and for total dissolved solids, and none of the samples showed any evidence of salt contamination. See Section II-3 for a description of the monitoring program.

About 65% of the salt was recovered and accounted for. The rest could not be located, because geophysical borehole logging equipment failed, and because an extended period of time had elapsed since the salting. Geophysical logging of the borehole indicated a 3-liters-per-second (50-gallons-per-minute) upward movement to a thief zone just below the casing. Maximum downhole temperature was only 135^{0}C (275^{0}F), but this could easily have been influenced by the drilling fluid and by the 1.3 x 10^3 cubic meters (3.5 x 10^5 gallons) of water used for the salting operations. A short 60-minute flow test suggested the well might have yielded at least 126 liters per second (2000 gallons per minute) for five years.

In order to stop upward fluid flow, crews set a cement plug in the well at 1050 meters (3450 feet). They then used air-lifting in an attempt to recover the salt lost in the thief zone, and this caused the slow withdrawal of good-quality water. Casing was set and cemented at 1042 meters (3417 feet). Drilling through the plug below the liner was unsuccessful. The bit wandered to the side and a new hole was drilled. The new hole is only 3 meters (10 feet) from the old one. The present hole has not yet been rigorously tested, but preliminary data suggest a yield of 44 liters per second with a drawdown of 2800 megapascals (700 gallons per minute with a drawdown of 400 pounds per square inch).

1.6 RRGI-6

Well RRGI-6 was drilled to a depth of 1185 meters (3889 feet) and cased from the surface to 517 meters (1696 feet). A 50-liters-per-second (800-gallons-per-minute) injection test was run for 310 minutes. The test suggested that if an injection rate of 76 liters per second (1200 gallons per minute) were maintained for five years, it would result in a wellhead pressure of at least 4700 megapascals (682 pounds per square inch) assuming interference effects of 140 megapascals (20 pounds per square inch) from other Raft River wells. The initial rapid buildup in wellhead pressure during testing suggests high-pressure gradients in the immediate vicinity of the well bore. Well stimulation techniques are recommended to improve production rates.

1.7 RRGI-7

The seventh well has been drilled to a depth of 1176 meters (3858 feet) and cased from the surface to 625 meters (2049 feet). A step injection test, during which 53 liters per second (840 gallons per minute) were injected for 56 minutes, suggested an injection rate of 25 liters per second (400 gallons per minute) for five years would result in a wellhead pressure of 4830 megapascals (700 pounds per square inch) assuming 690 magapascals (100 pounds per square inch) of interference. A small pressure response during injection was detected at RRGE-3. As with RRGI-6, the effect of injection on water quality and heads in overlying aquifers is not yet fully understood; environmental engineers are now making a careful study of injection test results (see Section V).

1.8 Resource Modeling

The U.S. Geological Survey's Water Resources Division in Reston, Virginia, began a joint project with the EG&G reservoir engineering group. The two groups will produce a three-dimensional, five-layer computer model of the Raft River resource. It will be an anisotropic, nonhomogeneous, finite-difference model. It should simulate the fractured nature of the Raft River system, considering all the spatial data available.

2. CHEMICAL LOGGING OF RRGI-6 - C. A. Allen, R. E. McAtee

When engineers chemically log a well, they monitor well water for certain chemicals while the well is being drilled. The researchers make a graph showing the way the concentrations vary with depth. The completed graph is the chemical log of the borehole. Conductivity, pH, and the concentrations of Cl^-, F^-, Na^+, Ca^{++}, and SiO_2 are checked at intervals of from 15 to 122 meters (50 to 400 feet). When the drill penetrates an aquifer, the drill water dilutes the groundwater. The dilution can be seen in the log, and reservoir engineers can analyze the data and deduce what type of aquifer the drill has encountered. Chemical species used as geothermometers indicate aquifer temperatures. Other chemical changes indicate the water's chemical composition. The first objective of this study was to obtain this information and establish parameters for the aquifers penetrated by RRGI-6.

A careful study of the data revealed something unexpected; the ratio of the concentrations of calcium to bicarbonate versus depth formed a log similar to the temperature log taken when the well was completed. Figure 4 shows both logs. Except for the fact that the chemical log was displaced uphole about 30 meters (100 feet), the logs display an unusual correspondence. Analysts believe the displacement is the result of the leakage or diffusion of geothermal water into the structure above the geothermal aquifer. This means the aquifer could be anticipated before the drill penetrates it. The information could help engineers determine when to set the well casing.

Researchers are now studying other chemical species and their ratios. The preliminary evaluation of some species indicates a study of their logs could complement the measurement of such geological factors as permeability and conductivity.

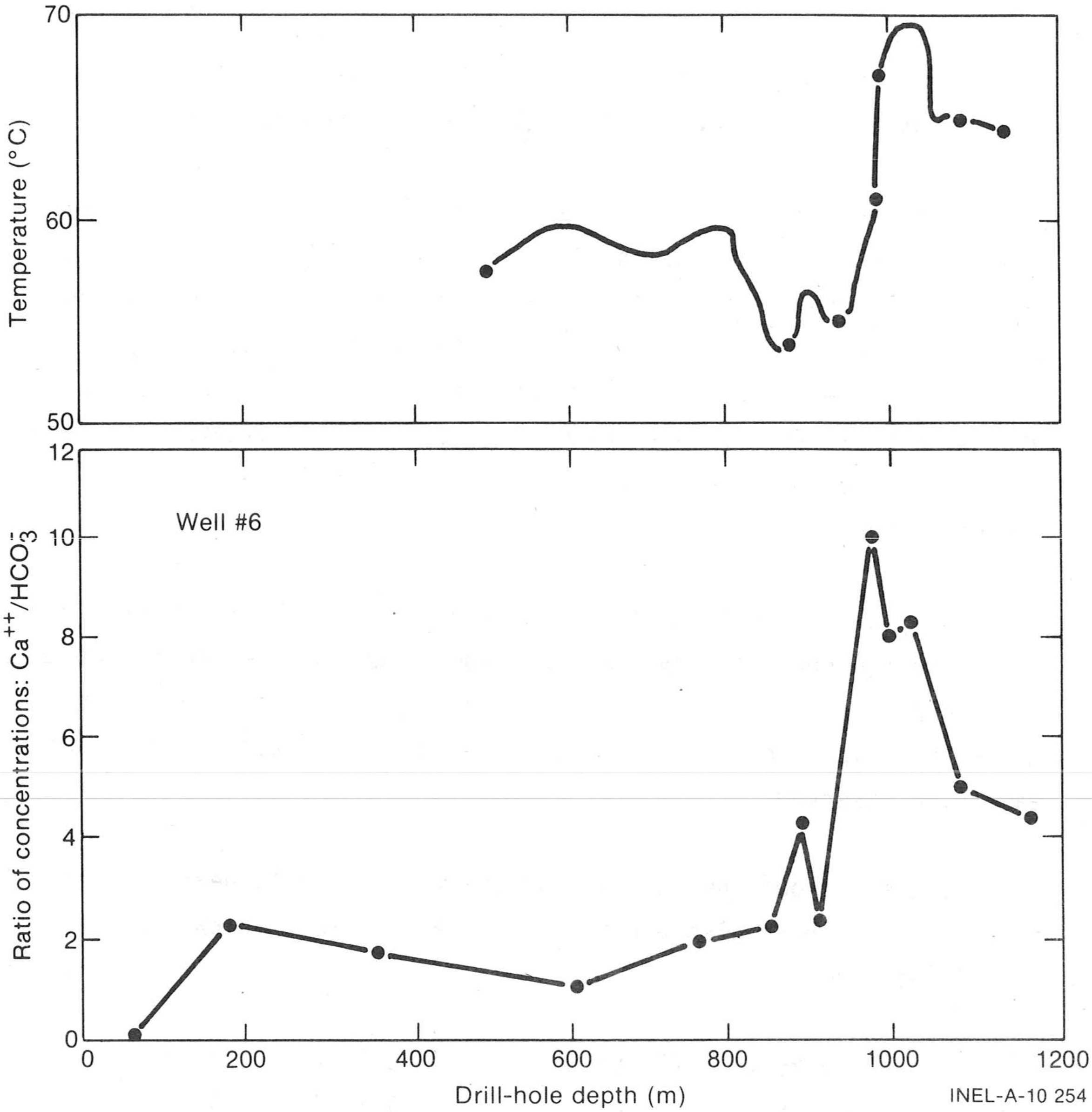

Fig. 4 Chemical and temperature logs of RRGI-6.

3. CHLORIDE MONITORING PROGRAM - C. A. Allen, R. E. McAtee

The chloride monitoring program was initiated on June 23, 1978, in order to monitor possible salt contamination in wells near geothermal well RRGP-5. Workers had injected large amounts of salt into the well to prevent steam from flashing in the borehole during a tool recovery operation. Wells used for the monitoring program were selected for their location and depth. The chloride monitor wells form two concentric semicircles around RRGP-5. Researchers hoped to detect any salt contamination before it could reach domestic and irrigation wells in the immediate vicinity of the Raft River geothermal site.

Engineers had chemically analyzed many of the wells once a week since May 1977, and the wells had been nonroutinely analyzed since their completion. The chloride concentrations from these analyses were used as baseline data, to indicate the chemistry of the wells prior to the tool recovery incident. The information obtained from monitoring will warn observers of any contamination; it will indicate the concentration of the salt; and it will reveal the velocity and direction of the saltwater flow.

Analyses performed on the water samples from the monitoring wells determine the conductivity and the chloride and sodium concentrations. These analyses are performed on the same day the water samples are collected. The concentrations are graphed against time, and trends can easily be observed.

Figure 5 shows the location of the monitor wells near the geothermal site. Here also are the legal descriptions of the monitoring-well locations:

15 S 26 E	23 abd 1	13 S 27 E	19 bcc
15 S 26 E	23 ddd 1	13 S 27 E	32 cbc
15 S 26 E	23 ddc	14 S 27 E	7 bac
15 S 26 E	23 bbc	14 S 27 E	20 bcc
15 S 26 E	24 bad 1	14 S 27 E	32 cbc
15 S 26 E	24 bcd 1	14 S 27 E	32 bdd
15 S 26 E	24 cad 1	15 S 27 E	6 abc 1
15 S 26 E	26 cab	15 S 27 E	6 dddd
15 S 27 E	18 cac 1		

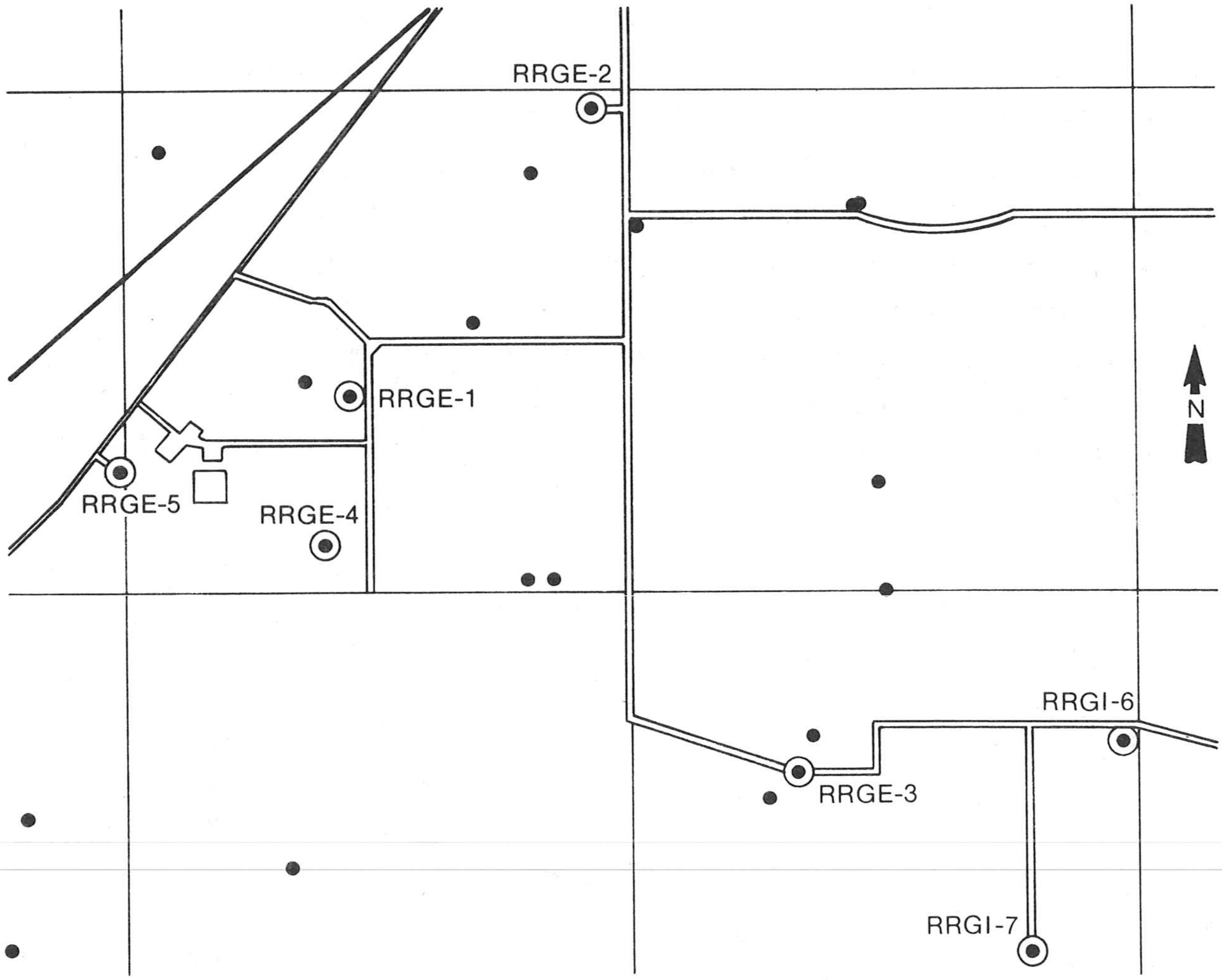

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Fig. 5 Chloride monitor wells near Raft River geothermal wells.

The monitoring program will continue on all flowing wells at the Raft River Geothermal Site, but the sampling of the irrigation wells was discontinued when the farming season ended and the irrigation wells were shut down. None of the chemical data collected so far have shown any increase in sodium or chloride concentration.

4. TESTS OF SALT REMOVAL FROM RRGP-5 - C. A. Allen, R. E. McAtee

Engineers conducted analyses throughout the salt-removal flow test at RRGP-5. The flow test began July 1, 1978, at 12:44 A.M., and continued until July 7, 1978, at 10:00 P.M. During this period the well was either induced to flow by pumping water into the well bore and using air-lifting techniques, or allowed to flow under artesian pressure. Water samples were taken at 15- to 60-minute intervals, and chloride-ion-concentration and conductivity determinations were made. Engineers calculated the volume of the water and the mass of the salt removed. A total of 18,920 cubic meters (5,000,000 gallons) of water were flowed, carrying 83,000 kilograms (92 tons) of salt out of the well bore. The conductivity of water flowing from the well was 350,000 $\mu S/cm^2$ ($\mu mhos/cm^2$) at the start of the flow and 4000 $\mu S/cm^2$ ($\mu mhos/cm^2$) at the end of the flow test. Figure 6 plots the total weight of salt removed versus the total volume of water flowed.

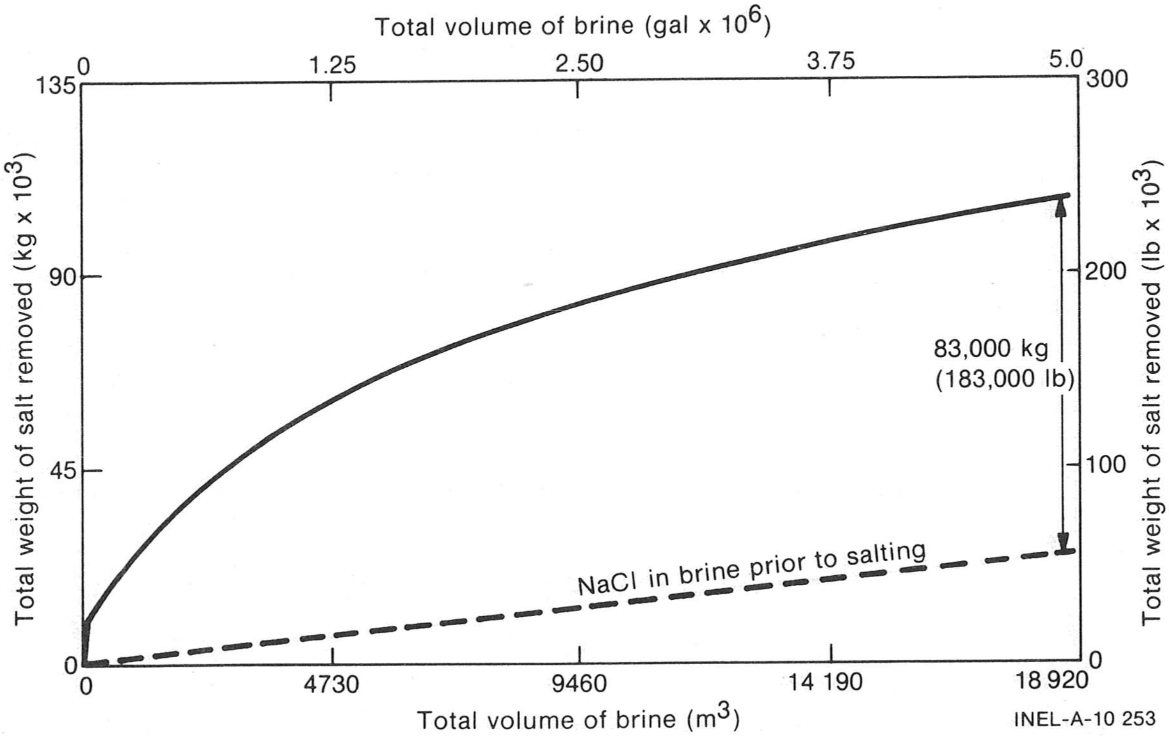

Fig. 6 Salt removed from RRGP-5.

In addition to furnishing the data needed to determine the total weight of salt removed from the fifth well, the conductivity profile of the flow test furnished other useful information. Flow was initiated by pumping fresh water through the drill stem, to the bottom of the borehole. This forced the column of saltwater out of the borehole, and samples were taken at 15-minute intervals. Researchers thus obtained a conductivity and chloride-ion-concentration profile of the static water column in the borehole. Figure 7 shows the plot of conductivity versus depth. The depth relates to the hole volume and, consequently, to the initial flow of the well. The low conductivity reading in the first dip of conductivity curve "A" corresponds to a known intermediate-zone aquifer. The second part of conductivity curve "A" slopes downward as

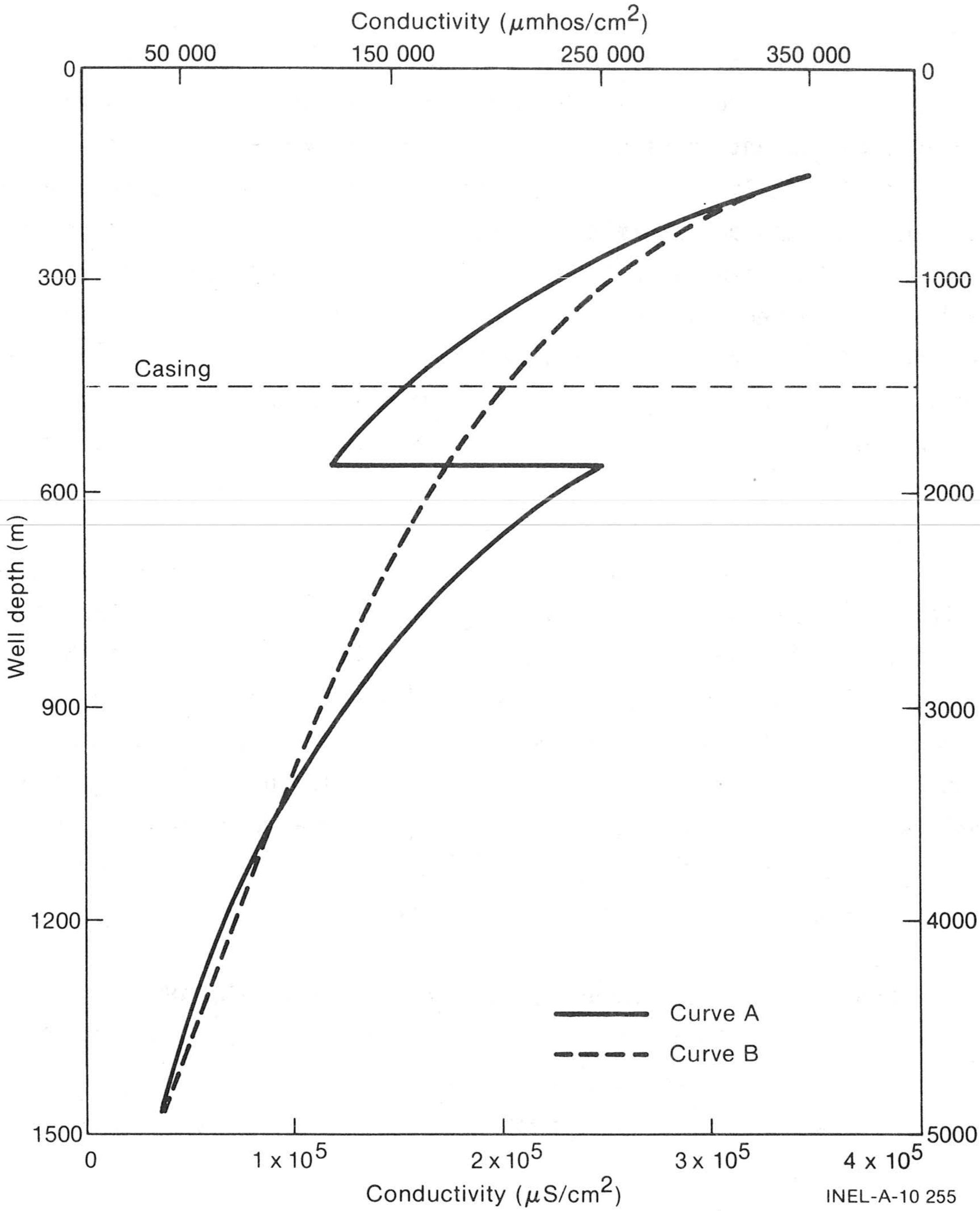

Fig. 7 Conductivity profile of RRGP-5.

it approaches total depth. The well's water chemistry was changing while the well was shut in after the final tool recovery work and before the flow test started. The total shut-in time was 15 hours and 16 minutes. The reduction in conductivity at the 488-meter (1600-foot) level, as well as where the depth approaches total depth, is due to a dilution of the salt water by an influx of fresher water.

This information may be used in three ways. First, it can be used to determine the aquifer in which the unrecovered salt is located. Second, the amount of salt lost while the well was shut in can be determined. Finally, the flow rate through the well bore and between the two aquifers can be determined. The greater dilution at total depth indicates the fresh water flowed from that direction uphole to the 488-meter aquifer. The high conductivity reading below the 488-meter aquifer could only be explained by a cross flow at the 488-meter aquifer. Without cross flow, the conductivity curve would be a continously decreasing curve from just above the 488-meter aquifer, as shown in curve "B" of Figure 7.

Calculating the volume of water it would take to dilute the salt water in the column, and considering that the dilution took place during the time the well was shut in, it could be determined that 15,873 kilograms (18 tons) of NaCl entered the 488-meter aquifer. The volume of dilution water and the well shut-in time can be used to determine the flow rate for the cross flow and for the flow between the geothermal aquifer and the 488-meter aquifer. They were determined to be 0.6 liter per second (9.8 gallons per minute) and 1.97 liters per second (31.3 gallons per minute), respectively.

Unfortunately, the amount of salt removed from the 488-meter aquifer was not determined. This would have required a more complex chemical measuring technique than there was time to develop before the flow test. It can only be assumed that salt was drawn from both aquifers during the flow test.

In conclusion, the conductivity profile of RRGP-5 provided a model for groundwater flow while the well was shut in. Further studies of the well under these conditions are no longer possible, as the well casing sealed out the 488-meter aquifer. However, these findings may be applied to other well-drilling operations where some measurable chemical species has been added in high enough concentrations for a well chemical profile to be determined.

III. DIRECT APPLICATIONS - R. J. Schultz

Geothermal energy can be used to produce electricity, as at the Geysers facilities north of San Francisco, or it can be used more directly, as for industrial processing or space heating. The direct applications are attractive for many reasons; they are very efficient, putting more of the water's energy to work, and they can require much simpler equipment and demand more modest investments. Shallower wells with cooler water and less abundant flows can be used profitably.

EG&G engineers are investigating a number of direct applications, with a view toward substituting geothermal energy for the energy derived from expensive fossil fuels. The medium-temperature waters found in the Raft River valley are characteristic of the geothermal waters commonly found throughout the West. The next few years will see both the development of plans for their use and the fabrication of hardware to implement the plans.

1. FLUIDIZED-BED DRYER - R. C. Schmitt

One of the most innovative new pieces of geothermal hardware is a low-temperature dryer that uses the heat of geothermal water to dry wastes produced during potato processing. Experimenters tested the dryer during the period, drying both an activated sludge biomass slurry and wastes produced during the caustic dry-peel process. The potato wastes came from the participating J. R. Simplot Company's plant at Burley, Idaho.

The biomass slurry is produced during the secondary waste-treatment process at the Burley plant, and it is similar to waste produced during biological treatment steps in many food processing streams. The material poses problems of disposal. When dewatered and processed, the material is a protein-rich food suitable for animal and fish consumption. A companion experiment at Raft River will involve feeding operations and diet studies, using the dried materials at a commercial fish farm. A centrifuge at the Burley plant reduces the slurry's moisture content to about 90% before the material is delivered to Raft River.

Thermal energy for the dryer comes from geothermal water of about 132^{o}C (270^{o}F). The hot brine circulates through the tube side of a heat-exchange tube bundle (Figure 8) that has a heat-transfer area of 1.8 square meters (19 square feet). Air has been used to fluidize the bed of sand surrounding the tubes, but the use of flashed geothermal water to produce steam for this purpose was also investigated. The wet material passes through a colloid mill for uniform particle sizing of about 1.27 microns (0.000039 inch), and then through an atomizing nozzle for injection into the heated bed.

During the test, the dryer successfully dried materials that contained from 5 to 13% solids. The process produced both a sand-like, granular material (mean particle diameter: 0.4 millimeter) and fines with a flour-like texture. Overall heat-transfer coefficients of from 130 to 160 W/m^{2}-K (23 to 28 Btu/h-ft^{2}-^{o}F) were experimentally determined for the tube bundle. Steam was not an acceptable atomizing medium because it caused the bed particles to agglomerate after short periods of operation.

Analysts also studied the economics of a scaled-up plant using this kind of dryer. The output of an average potato plant waste stream could amount to 23 metric tons (25 dry tons) per 24 hours, operating 250 days per year. A plant of this size would require about 6 megawatts of heat. With a product valued at \$180 to \$360 per metric ton (\$200 to \$400 per ton), the pay-back period on initial capital equipment would be from 1-1/2 to 3 years. Researchers conclude that properly designed geothermal dryers could be of value to the food industry; they would convert wastes into valuable, salable products, and they would remedy problems of handling and disposal.

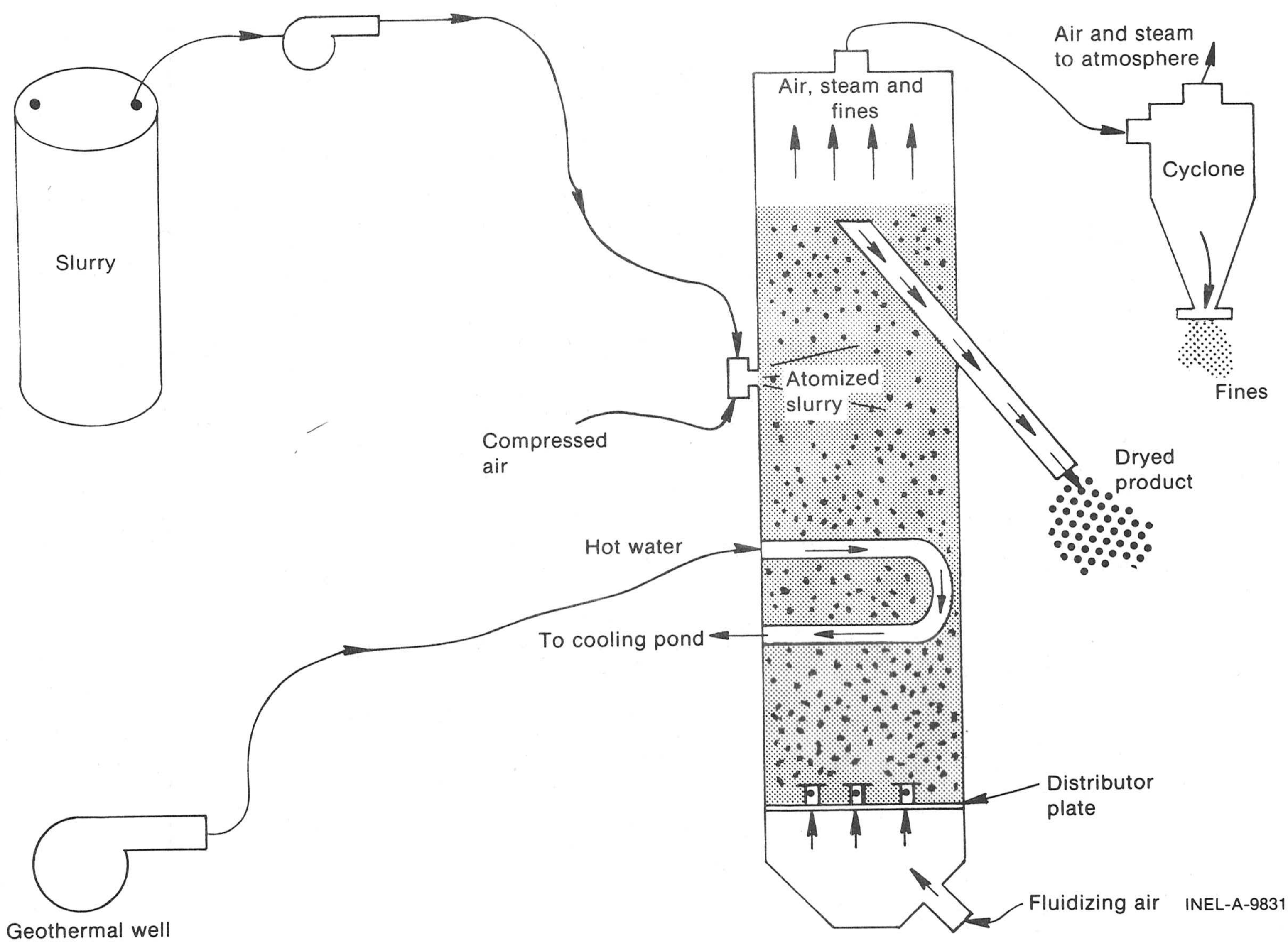

Fig. 8 Flow diagram of geothermal dryer.

2. AQUACULTURE - J. F. Sullivan

Aquaculture is another commercial venture that may profit from the direct application of geothermal energy, and Raft River experimenters continued to assess the technical and economic feasibility of the application. Since a geothermal well can supply a continuous flow of constant-temperature water, the cost of year-round intensive culturing should be dramatically reduced.

Biologists stocked the Raft River raceways with channel catfish, tilapia, and giant freshwater shrimp. Channel catfish are the most widely cultured warm-water fish in the U.S. Approximately 30 million kilograms (33,000 tons) are raised annually, primarily via pond culture in the southeast. The U.S. market is well established, with demand exceeding current supply. Since the optimal temperature range for this species is between 26 and 30°C (79 and 86°F), catfish are ideally suited for geothermal aquaculture.

Members of the genus tilapia are warm-water cichlids, freshwater fish that have been of major importance in Near Eastern and African fisheries since 2500 B.C. The tilapia has a high production potential, and only the common carp is more widely cultured. However, colder winter months constrain the culturing of tilapia in the U.S. The fish cannot survive water temperatures below about 13°C (55°F). Culturing these organisms in temperature-controlled geothermal fluids should alleviate the problems associated with overwintering and may produce an additional crop during the normally unproductive winter months.

Tropical Malaysian shrimp are also well suited for geothermal aquaculture. The shrimp have been cultured in the U.S. for less than ten years and are still strictly a gourmet food. There is nevertheless a market in the U.S., and the market should increase as people become familiar with freshwater shrimp.

A grow-out experiment with all three species was completed during the period, and data are now being analyzed. In such an experiment, culturists study the fish until the animals reach marketable size. Preliminary results indicate that channel catfish cultured outdoors in geothermal water grew as quickly as control fish raised in a successful commercial facility in Buhl, Idaho[a]. Catfish cultured indoors at Raft River grew more slowly, however. The retarded growth could have been caused by artificial lighting, smaller raceways, or stress induced by human activity within the facility. Since large-scale geothermal operations will be outdoor systems, the results are not discouraging. In addition, the catfish cultured in the geothermal water were firm and palatable.

Shrimp reared in the outdoor ponds grew at exceptional rates; the outdoor Raft River shrimp grew from 0.50 to 0.66 millimeter per day (0.020 to 0.026 inch per day), and the indoor shrimp grew from 0.25 to 0.33 millimeter each day (0.0098 to 0.013 inch per day). These rates compare favorably with values reported in the literature, and they indicate that this species may be well suited for culture in geothermal fluids.

Tilapia growth exhibited trends similar to those shown by the shrimp and catfish, but neither Raft River group grew as fast as those in Buhl. Tilapia spawned repeatedly, however, and the young did achieve rapid growth rates[b].

Biologists observed one unexpected but very encouraging fact; disease-related mortality was negligible. Since disease is a major problem in most fish farms, these results are particularly interesting. It may be due to the water's salinity (total dissolved

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[a] Fish Breeders of Idaho, Inc.

[b] Phase II of the tilapia study was directed by Dr. Fred Rose of Idaho State University. Don Campbell, Chris Kent, and Linn Watson worked on the experiment.

solids: 1560 miligrams per liter, or 0.208 ounce per gallon), or to the disease-free nature of geothermal fluid when it is utilized directly from the resource. Bioaccumulation analyses also demonstrated that in spite of the concentrations of dissolved solids, heavy metals (copper, zinc, cadmium, and mercury) were not concentrated in the fish tissues and would not affect the marketability of the products.

Following the grow-out phase of experimentation, the aquaculture facility was redesigned to accommodate extensive nutritional trials (see Figure 9). Personnel added more temperature- and flow-control units, enlarged culture ponds, replaced culture units, and installed environmental controls in the aquaculture building[a].

Geothermal water at 130°C (266°F) flows from a 1520-meter (4990-foot) well. About 7% of the water is flashed to steam as the pressure is lowered in a flasher/separator, and the water temperature drops to 97°C (207°F). Water temperature is lowered again, to less than 26°C (79°F), as the flow is sprayed into two cooling ponds. Finally, to regulate the temperature of the water that enters the culture units, the cooling-pond water is mixed with warmer geothermal fluid. The temperature of culture water must be accurately controlled in order for the fish to achieve optimal rates of growth. The geothermal water moves by gravity flow through the aquaculture system, and the effluent is contained in a reserve pond.

The indoor system includes two eight-chamber units, each with a capacity of 85 liters (22 gallons). There are also four circular fiberglass tanks with a combined capacity of 6340 liters (1648 gallons). Outdoor facilities include six raceways (which together hold 6340 liters, or 1648 gallons) and two extensive culture ponds (each of which contains 100 cubic meters, or 3500 cubic feet). The outdoor ponds are constructed in sequence for a semipolycultural experiment; two or more species will be cultured, and each will occupy a different

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[a] The nutritional studies are under the direction of Drs. Bill Klontz and Marshall Beleau of the University of Idaho.

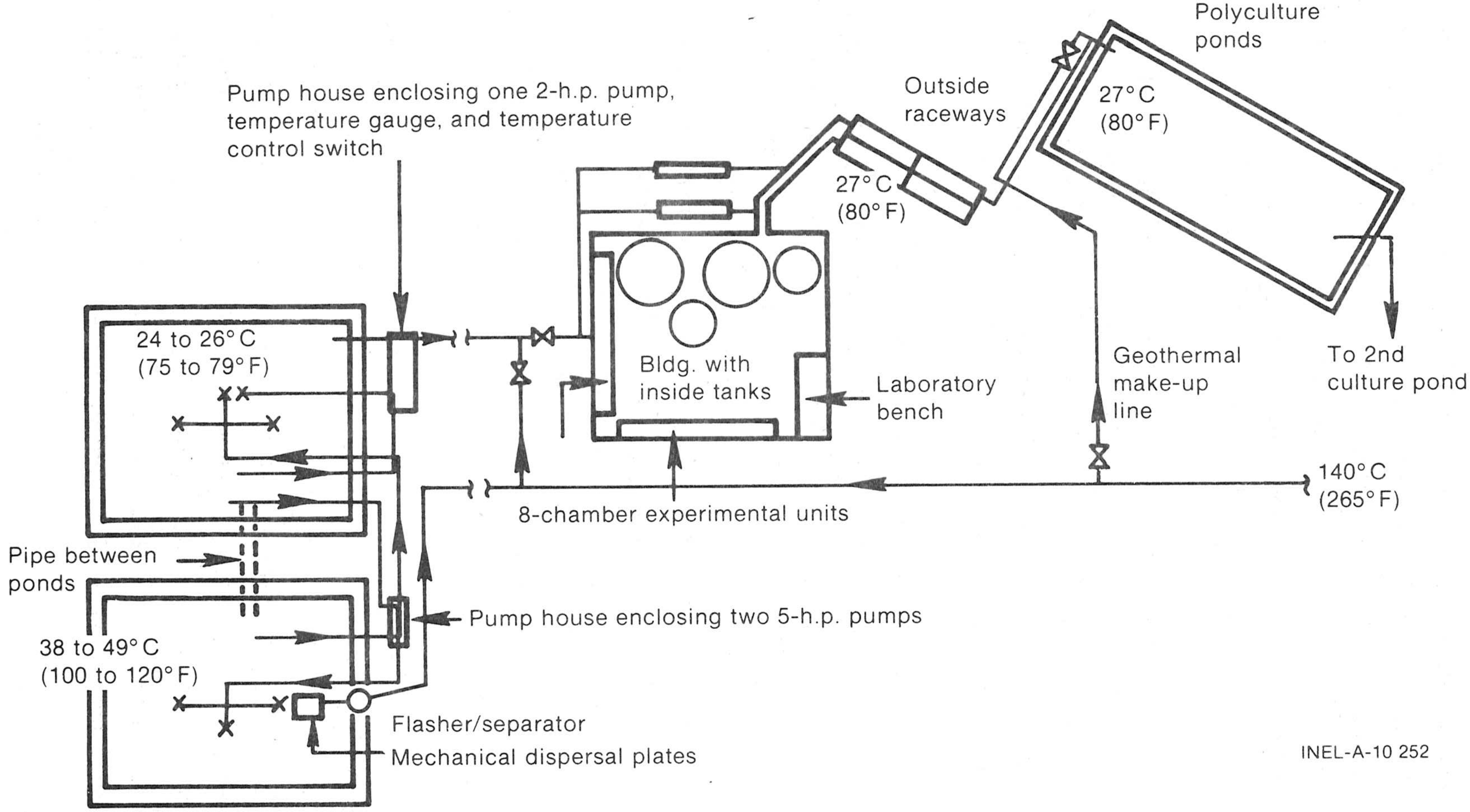

Fig. 9 Aquaculture experiment layout.

niche in the system. Nutrients in the indoor units will produce algae, which should be consumed by downstream carp and shrimp. The culture units and ponds are flow-through systems in which oxygen is continuously replenished and from which organic metabolic by-products are removed.

Following the modifications, the facility was restocked with channel catfish and carp. Malaysian shrimp will be added at a later date. Carp were chosen for experimental purposes because they are strictly herbivorous, they grow quickly, they efficiently convert food to a source of high-quality protein, and they are the most widely cultured species in the world.

Experimenters are currently conducting extended growth tests; investigating the nutritional requirements of the cultured organisms; assessing the adequacy of various diets, including biomass and potato wastes dried with geothermal fluids; and performing marketing and economic analyses of the fish and shrimp products.

3. AGRICULTURE - N. E. Stanley

Experimenters completed the three-year irrigation experiment during the period[a]. The study has examined the possibility of using cooled geothermal water to irrigate crops. The potential benefits to the arid West are obvious. A conventional power plant must consume cooling water. A geothermal facility could be a net producer of water, and the excess could be used for irrigation. The application could also reduce the cost of injecting fluids that have been used to generate power.

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[a] Dr. Howard Peterson of Utah State University's Irrigation Engineering Department has been the primary consultant for this work.

Field studies terminated with the collection of post-harvest crop and soil samples during late September 1978. Utah State University's Crop and Soil Testing Laboratory is currently analyzing the samples, and final results will be published during the coming period. Preliminary results derived from crop samples collected during mid-season 1978 are available, however. These early data support the findings of 1977 studies, and analysts agree that with proper management Raft River geothermal water can be used to produce economic crops.

IV. ELECTRIC APPLICATIONS

One of the central objectives of the Raft River project is to determine whether economically competitive electricity can be generated from a medium-temperature geothermal resource. Geothermal power plants in other locations are designed to use fluids hotter than 176°C (350°F). The Raft River geothermal water is not as hot; it is between 140 and 150°C when pumped out of the wells, and it will be 143°C or slightly less when it reaches the power plant. While high-temperature geothermal reservoirs are rare, moderate resources like that at Raft River seem to be common throughout the West. If these medium-temperature waters can produce electricity at competitive prices, geothermal energy can supply much of the West's growing need for energy.

The idea is to use a binary cycle. Hot geothermal water passes through heat exchangers, where it heats a secondary fluid. Secondary fluid vaporizes and expands as it is heated, driving a turbine connected to a generator. The geothermal system is self-contained, and no steam escapes; the hot waters are injected back into the ground. The working-fluid vapor cools in a condenser, liquefies, and returns to the heat exchangers to begin another cycle.

1. PROTOTYPE GENERATORS -

T. W. Lawford, R. R. Piscitella, J. F. Whitbeck

The first test of a medium-temperature cycle began in April, when a small prototype generator came on line at the Raft River site. Preliminary data generated by low-power tests indicate the system operates in a very stable manner without automatic controls. This unit has supplied a total of about 200 kilowatt-hours of electrical power to the Raft River Rural Electric Cooperative's power grid. The system can generate as much as 60 kilowatts.

A number of tests are now underway. Ruptured diaphragms in the working-fluid feed pump have limited operations, and modifications that have reduced the differential pressure across the diaphragms are now being tested. A plan for baseline tests has also been developed; this testing will primarily evaluate turbine performance, paying special attention to the increased power that can be achieved by taking advantage of changes in ambient temperature.

A second prototype plant is now being constructed by the Barber-Nichols Engineering Company for DOE and the Lawrence Berkeley Laboratory. The 500-kilowatt plant, which will use direct-contact heat exchangers, will be brought to Raft River for testing in about a year. Site preparation and test planning activities were initiated at the end of this report period.

2. FIRST 5-MEGAWATT PILOT PLANT

2.1 Turbine Generator - W. E. Waters

The first 5-megawatt pilot plant was originally designed as a thermal loop; valves were to have simulated the presence of a turbine. During the Title-II design of the thermal loop, however, researchers gained approval to incorporate a turbine-generator. A subcontract for the preparation of the turbine-generator specification was let to a consultant firm in January 1978. This specification was further modified by EG&G at the beginning of this report period.

Requests for proposals were mailed to prospective bidders in May. The expected bid date was mid-July. The bids were delayed approximately 7 weeks while planners reviewed the advantages and disadvantages of radial-inflow and axial turbine designs. The analysis did not reveal any decided advantage for either design, and administrators agreed to proceed with the procurement of a radial-inflow turbine.

Two bids were received in September, and a review team was organized to perform both technical and cost reviews. The team recommended the bid that was lower in cost and rated slightly higher in technical expertise. The award endorsement is in the final approval stage at DOE.

2.2 Pilot-Plant Facility - J. D. Frasca

Construction of the pilot-plant facility began in August. The excavation of the cooling-tower and process area has now been completed, and the concrete for the cooling-tower base has been poured. Crews are now assembling forms and rebar for the cooling-tower walls. The concrete for the major footings that support the vessels in the process area has been poured. Building areas have been excavated, and crews were assembling the concrete forms and rebar for the building footings as the period closed. Excavation for the electrical substation and the holding ponds continues.

2.3 Project Management - H. M. Burton

In April 1978 a full-time project manager was assigned to the first 5-megawatt pilot plant project. A management plan was issued and implemented on July 14. The comments of DOE-ID personnel have been incorporated into the draft, and finalization of the FY-79 budget will allow organizers to issue the finished plan in November. A project work-breakdown structure was also developed, and detailed costs and schedule networks were prepared. A performance report on this project is currently being provided in the monthly reports. Staffing is complete. At the close of the period both the overall project schedule variance and the overall project cost variance were 0%. (Both figures are based on a starting date of June 1, 1978.)

2.4 Data Acquisition and Control System - B. N. Hood

Engineers also completed the design of the data acquisition and control system during the period. The system will be used to monitor and control the fluid supply and injection system and the pilot power plant, among other things. The design provides for real-time data display to support supply and injection testing. Figure 10 illustrates the final design with a functional interface diagram.

The total system will be implemented in three distinct phases. The first phase will comprise the fluid supply and injection control system. The data acquisition capability of this system has been expanded to include the acquisition of data from the monitor wells, in addition to the data from the supply and injection wells. The initial capability will permit the monitoring of real-time data, including alarm conditions, with the capability to record data in a printed form. This phase should be operational by January 1979. The expansion of the system to record data on magnetic tape is being considered.

The second phase of implementation will involve the installation of the data acquisition system. This system will acquire data from site experiments, as well as from the geothermal field itself. It will also permit the processing of data and the running of analysis programs. The estimated operational date for this phase of the system is March 1979.

The third and final phase of implementation will include the data-acquisition and process-control system for the 5-megawatt power plant. This system will acquire all the data necessary to operate and evaluate the power plant. It will also obtain geothermal field data from the fluid supply and injection control system. The installation of this system is scheduled for March to August, 1979.

2.5 Support Engineering - J. F. Whitbeck

The support engineering tasks associated with the first 5-megawatt plant include materials and fouling testing, long-lead equipment procurement, plant performance testing, and design review. Design-review tasks and the heat-exchanger fouling tests have been completed.

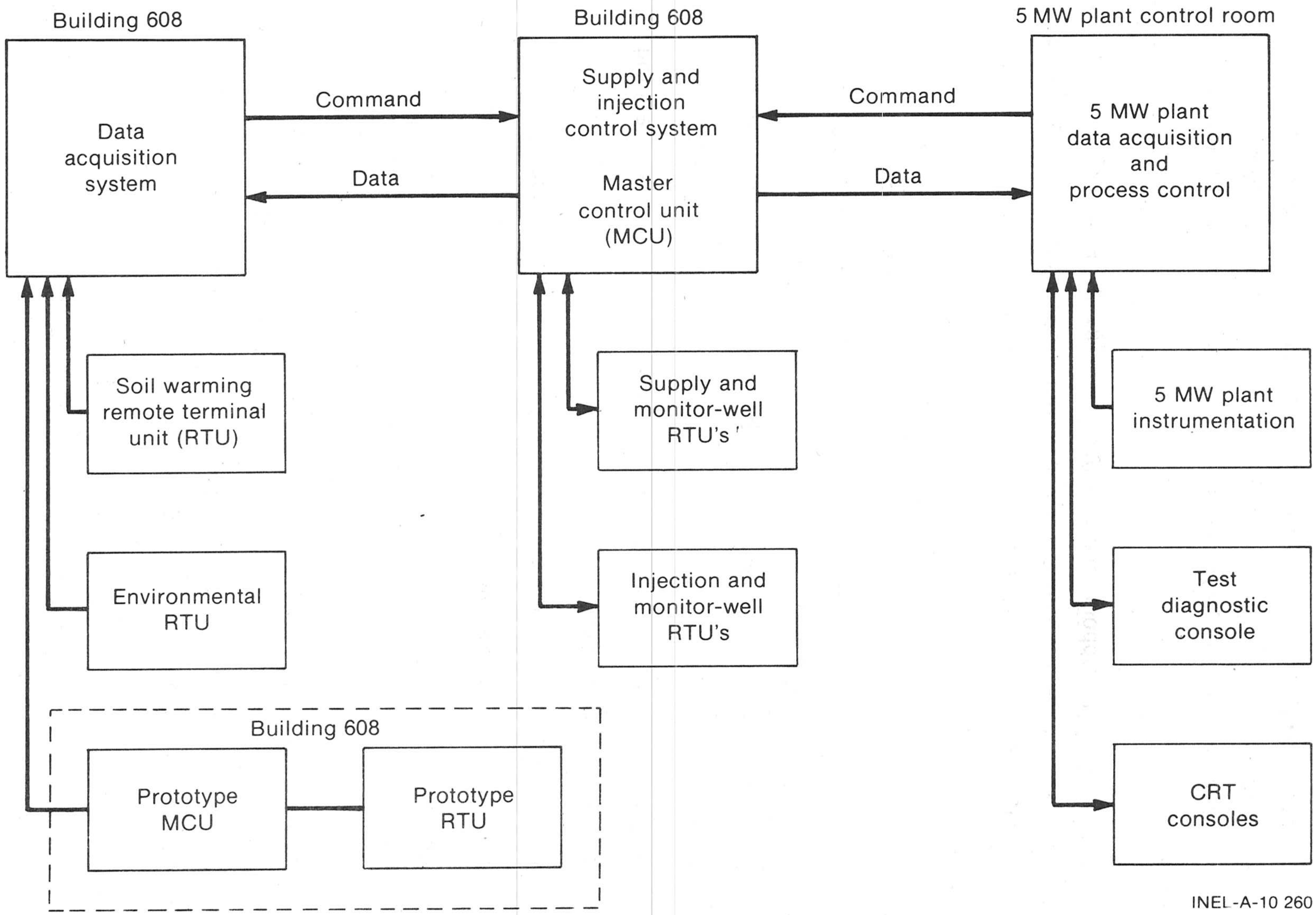

Fig. 10 Data acquisition and control system.

Long-lead equipment procurement is in its final phase. Primary efforts are now directed at developing a detailed test plan for the power plant, obtaining long-term corrosion data, and establishing the treatment necessary for using a portion of the plant effluent as cooling-tower makeup. These tasks are discussed in the following sections.

2.5.1 Design Support and Procurement (R. R. Piscitella). The major heat-exchange components are nearing completion. The status of each of the long-lead components is as follows:

TABLE I

STATUS OF LONG-LEAD HEAT-EXCHANGE COMPONENTS

Component	Status
Low-Pressure and High-Pressure Preheater	Storage
Condenser and Condensate Storage Tank	Storage
High- and Low-Pressure Boilers	Hydrotesting
Isobutane Feed Pumps	Testing
Geothermal Boost Pumps	Fabrication
Substation Transformers	Fabrication
Cooling Tower	Prefabricated

2.5.2 Corrosion Tests (R. L. Miller). The materials-selection process for the first 5-megawatt power plant and supporting facilities is essentially complete. Tests indicate that admiralty brass will be adequate for heat-exchanger components in contact with hot geothermal fluids. Further testing is being carried out to verify the adequacy of the materials selected. Researchers also want to be confident of the long-term stability of these materials in geothermal fluids from wells other than RRGE-1.

Some anomalies have been identified in the materials test data. The closed circles in Figure 11 identify alloys in the copper-zinc and the copper-nickel alloy systems that have been corrosion-tested at Raft River; the open circles identify commerical alloys in these systems and in the copper-nickel-zinc alloy system. Figure 12 shows the results of our tests of these materials (closed circles). The graph suggests that:

(1) The copper-nickel alloys have much higher corrosion rates than copper-zinc alloys of similar copper content.

(2) Aluminum bronze with about 4.5% nickel has a corrosion rate that is significantly greater than that of a nickel-free aluminum bronze of similar copper content.

(3) The corrosion rate increases as copper content increases - until the content reaches 90%. (The corrosion rate must decrease when copper content is between 90 and 100%, because commercially pure copper exhibits a relatively low corrosion rate.)

(4) RRGE-1 fluid appears to be less aggressive than in earlier tests.

The data shown in Figure 12 are largely based on the materials represented by the closed circles in Figure 11. The results are at variance with those reported for seawater applications for the same materials. This emphasizes how carefully an engineer should avoid assumptions based on experience in other fields.

Further testing is required to fully assess the contribution of nickel to the corrosion of copper-based alloys. Concentrations of nickel do not affect nickel-based super alloys in the same manner; these super alloys are among the most corrosion-resistant materials tested.

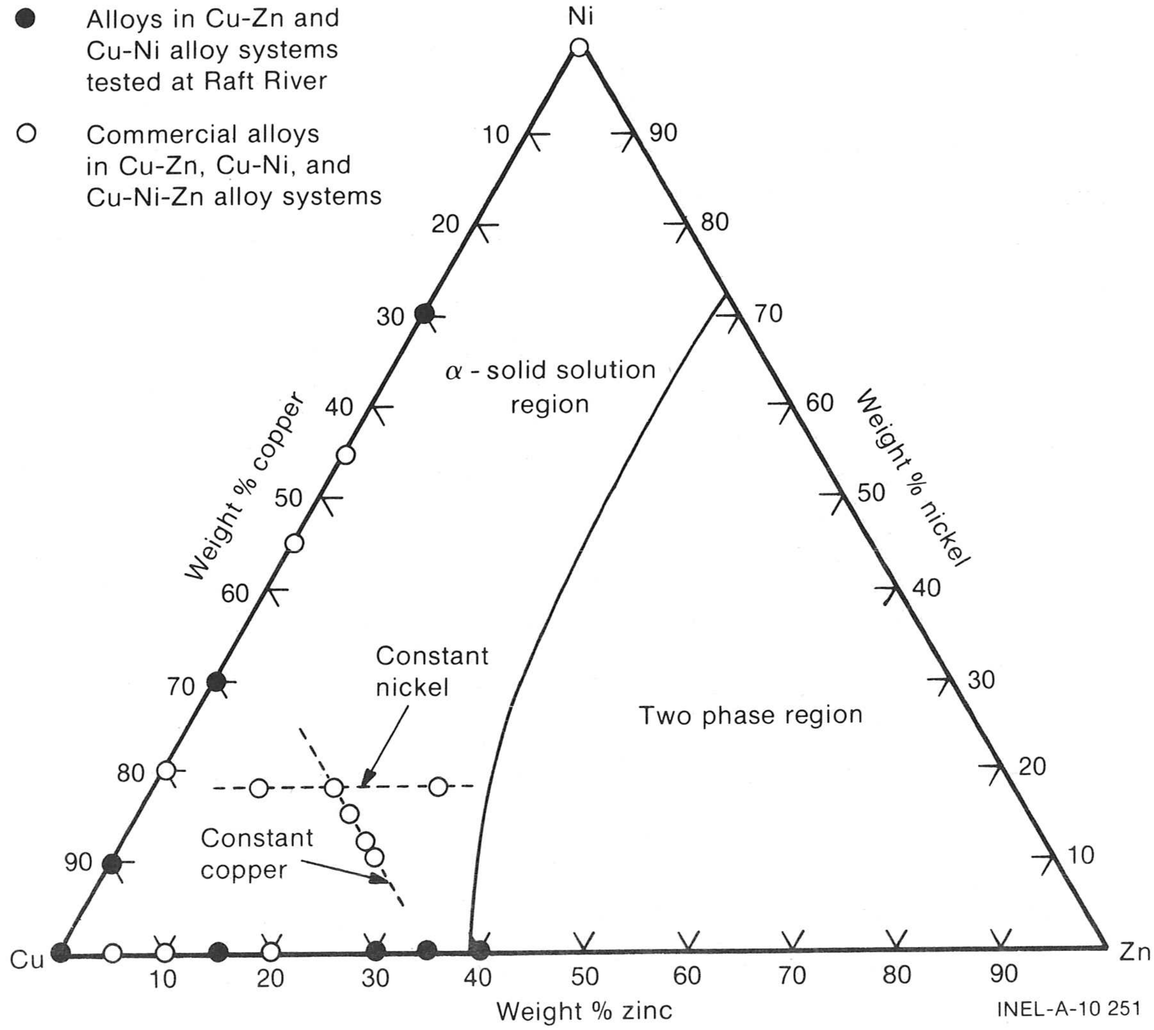

Fig. 11 Composition of alloys tested in Raft River corrosion tests.

Materials tests planned for FY-79 and later are designed to evaluate the reliability of remote corrosion-monitoring sensors, to study the effects of velocity on corrosion, and to establish long-term stability data on the materials used in the first pilot power plant. Experimenters will conduct instrumented probe tests, controlled-velocity corrosion test, and a long-term corrosion test. The results of these tests will help establish operating parameters, maintenance schedules, and procedures for the first 5-megawatt plant.

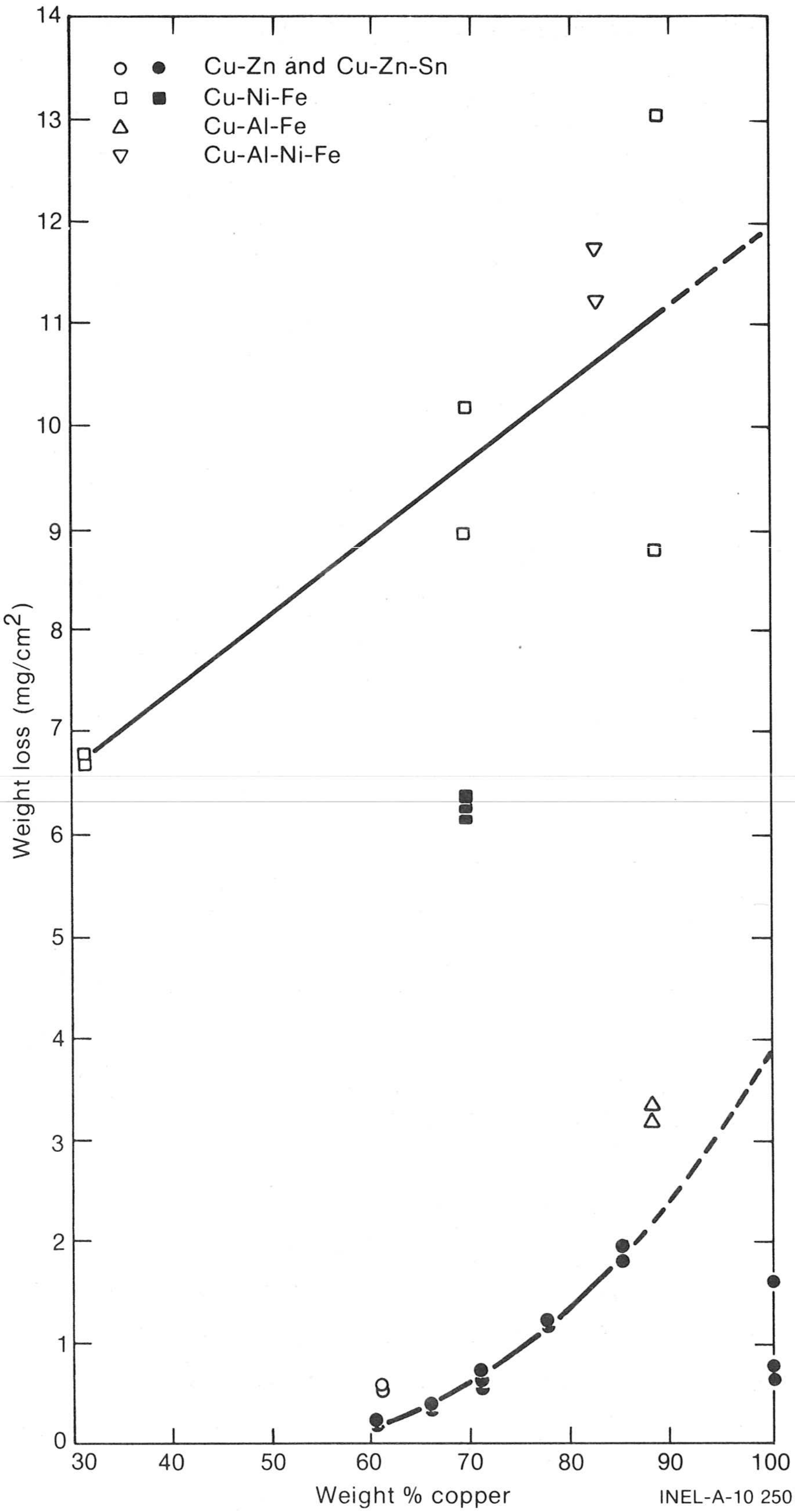

Fig. 12 Weight loss of copper-based alloys exposed to Raft River geothermal fluid.

2.5.3 Heat-Exchanger Fouling Tests (T. W. Lawford, G. L. Mines). Because of problems with the cooling system radiator, the heat-exchanger test loop was shut down twice during the period. The first admiralty brass tube, AB-1, experienced approximately 54 weeks of actual flow. AB-2 underwent about 42 weeks of similar operation. The calculated fouling resistance was 2.71 x 10^{-5} K-m^2/W (1.54 x 10^{-4} ft^2-hr-^oF/Btu). The heat-exchanger fouling tests have now been terminated, and no further work is planned.

2.5.4 Test Plan and Evaluation (T. W. Lawford). Work also began on the revision of the preliminary test plan for the first 5-megawatt pilot plant. The plan will outline general procedures for three distinct types of tests: those dealing with the entire system, those dealing with individual components, and those verifying the thermodynamic properties of isobutane, the working fluid. The overall objective of the test series is to provide insight into the dual-boiling binary cycle being used at Raft River. The first plant will use conventional components, such as shell-and-tube heat exchangers. The operation of the plant in the floating power mode will be evaluated against predicted performance.

Planners have identified specific objectives for the tests:

(1) Confirmation of system and component performance at both clean and design conditions.

(2) Generation of data for component design.

(3) Study of the system transients to ensure plant safety and help refine operating procedures, and to verify and calibrate computer codes to be used in the design and development of other, similar plants.

The work dealing with the system as a whole is nearly complete. A document containing the final test plan is scheduled for completion during January of the next report period.

2.5.5 Water Treatment Program (R. L. Miller). The purpose of the water treatment program has been to devise a way of removing silica from the geothermal water to be used for cooling-tower makeup. A series of jar tests was conducted in accordance with ASTM D-2035-74 ("Coagulation-Flocculation Jar Test of Water"[3]). The tests were designed to determine the chemical feed requirements necessary to reduce the silica concentration to 10 to 15 parts per million using dolomitic lime. The initial tests were based on conventional water treatment experience, and experimenters were able to reduce silica concentrations to 70 parts per million. This was a level much lower than they had hoped to achieve with standard chemical systems, but it was clear no system using dolomitic lime could meet the requirements.

The difficulties encountered in achieving silica reduction are believed to be a result of the water's chemical nature and its high silica content; the water has an ionic strength of approximately 0.4, and the concentration of silica is about 180 parts per million. Experimenters ran a large number of jar tests to find a system that would meet the design specifications. These systems all used magnesium as the chemical reagent. The magnesium was evaluated according to kind (light versus dense, etc.) and form (slurry versus clear solutions). The researchers found several adequate systems that used magnesium in solution rather than in a slurry. "Adequate" is tentatively being defined as a reduction in silica concentration to approximately 30 parts per million.

Testing plans for the coming period involve a series of spinner tests and a bench-scale pilot-plant cooling-tower test. The spinner tests will be conducted in accordance with ASTM D-2688-70 ("Corrosivity of Water in the Absence of Heat Transfer"[4]). These tests will evaluate several corrosion-dissolved solids. The total dissolved solids will indicate the number of concentration cycles that may be expected in the cooling tower.

A bench-scale pilot-plant cooling tower will be designed and built to simulate the operating conditions in the pilot plant's chemical treatment system, cooling tower, and condenser. Researchers will run preliminary system tests to determine tower characteristics and to ensure its applicability as a test model. The results of the jar and spinner tests will be incorporated into the test model system, and the bench-scale model will then be used to evaluate the chemical pretreatment system. The pretreatment system will include silica reduction to prevent silica scale, and the corrosion-inhibitory system will prevent corrosion in a continous-flow system.

3. SECOND 5-MEGAWATT PILOT PLANT - O. J. Demuth, T. W. Lawford, J. F. Whitbeck

While crews constructed the first pilot power plant, Utilization Technology personnel conducted a preliminary design analysis of the second 5-megawatt power plant. The overall objective of this effort is to develop the concept of a binary geothermal cycle incorporating direct-contact heat exchangers.

Work during this period can be summarized as follows: the analysis of possible working-fluid recovery systems; the thermodynamic analysis of improved cycles; and the development of a digital computer code to allow optimization of direct-contact cycles by means of parametric studies.

3.1 Preconceptual Design Study

Program personnel published an internal EG&G report, GP-141, in August 1978. The report, "Preconceptual Design Study for the Second Raft River 5-MW (gross) Dual-Boiling Direct-Contact Pilot Plant," detailed the analyses of several direct-contact dual-boiling cycles for use with two different fluids: a Raft River-type, 143°C (290°F) fluid with 52 parts per million dissolved nitrogen, and an East Mesa-type, 171°C (340°F) fluid with 2000 parts per million dissolved carbon dioxide[5]. The report specifically studied methods for reducing the loss of working fluids. Researchers concluded that the direct-contact cycle could utilize geofluid as effectively as could a shell-and-tube cycle. Because direct-contact heat exchangers are cheaper to build than their shell-and-tube counterparts, it appears a direct-contact plant would have the economic advantage if auxiliary equipment costs and power requirements are not excessive.

3.2 Chemical Processes for Working-Fluid Recovery

When a power plant uses conventional thermo-mechanical systems like compressors, flash tanks, and heat exchangers to recover working fluid, the systems introduce parasitic losses to the cycle. Energy Incorporated of Idaho Falls, Idaho, received a subcontract to make preliminary designs of chemical recovery systems. The effort will determine if adequate recovery can be accomplished with smaller parasitic losses, to generate electricity less expensively than more conventional systems.

The initial work on the subcontract dealt with the selection and evaluation of methods for recovering working fluid from condenser vent vapors. The methods considered included the approach planned as a backup system for the Lawrence Berkeley Laboratory (LBL)/Barber-Nichols 500-kilowatt direct-contact pilot plant. In the approach that received primary attention, working-fluid vapor would be dissoved in a light oil, the noncondensable gas would be vented, and the working fluid would be separated from the oil by a distillation process. Penalties to the cycle were evaluated for various operating conditions.

Follow-on studies will select and evaluate chemical processes for recovering working fluid from spent geothermal fluid before injection. They will also examine ways to extract the fluid from cooling water, in case a wet cooling tower is used in combination with a direct-contact condenser.

3.3 Improved Cycles

EG&G researchers are also conducting thermodynamic analyses of improved power cycles. Concepts under study include:

(1) Use of a preflash to remove most of the dissolved non-condensable gas from the geothermal fluid upstream of the direct-contact boilers. Energy in the steam from the flash would be used to boil a small fraction of the working fluid. (This approach, suggested by LBL, is planned for the LBL 500-kilowatt direct-contact pilot plant.)

(2) Triple-boiling direct-contact cycles.

(3) Mixed-fluid direct-contact binary cycles.

(4) Staged condensing for both single and mixed fluids.

Some preliminary analyses have been completed for mixed-fluid cycles and for triple-boiling cycles; these analyses are summarized in the next paragraphs. Superficial consideration of staged condensing for a single fluid suggests that the use of a two-stage condenser could result in a 6 or 7% improvement in net cycle power output at the same geothermal fluid flow; analysis is needed to assess this concept.

Engineers have estimated state points and power balance for a triple-boiling pentane cycle that utilizes Raft River geothermal fluid. Use of a third boiler introduces the thermodynamic advantage of transferring heat from the geothermal fluid to the working fluid through a smaller temperature increment than for either a single- or dual-boiling system. The penalty in heat-exchanger costs for the additional boiler is expected to be significantly smaller for direct-contact boilers than for shell-and-tube boilers, making the cycle more attractive for the direct-contact cycle application.

Table II shows a comparison of a dual- and a triple-boiling pentane cycle, including estimates of parasitic losses associated with working-fluid recovery. The table indicates that with the addition of a third boiler, an improvement in wet-cycle power at the same geofluid flow is estimated to be about 9%. Effects on plant costs have not been estimated.

The working-fluid recovery system assumed for the cycle consists of (1) compressing and cooling the condenser vent products to recover working fluid from the mixture of working-fluid vapor, steam, and nitrogen vented from the condenser; (2) flashing the geothermal fluid before injection to recover dissolved working fluid, and (3) flashing cooling water after it leaves the direct-contact condenser to recover dissolved working fluid before the cooling water enters the wet cooling tower. For the calculations summarized in Table II, working-fluid (pentane) losses were assumed to be 3.1 grams per second (25 pounds per hour) from condenser vent vapors, 0.8 gram per second (6 pounds per hour) reinjected with geothermal fluid, and 0.4 gram per second (3 pounds per hour) lost from the wet cooling tower.

Calculations have been initiated for the evaluation of dual-boiling binary cycles using a working fluid. Engineers also initiated an evaluation of dual-boiling cycles using a working fluid consisting of mixed hydrocarbons. The pontential advantage of such a working fluid lies in its boiling and condensing behavior, and in the possibility of finding a suitable mixture which can expand through the turbine without attaining substantial condensation or superheat. Mixed hydrocarbons boil and condense over a range of temperatures at a fixed pressure. With the mixed working fluid in couterflow heat-exchange configurations, boiling and condensation may be accomplished with a smaller average difference in temperature between the working fluid and the geofluid or the cooling water, respectively, than can be

TABLE II

COMPARISON OF DUAL- AND TRIPLE-BOILING DIRECT-CONTACT PENTANE CYCLES USING RAFT RIVER GEOTHERMAL FLUID

Factor	Double Boiling	Triple Boiling
Boiler temperatures (°C)	110, 77	121, 99, 71
Condensing temperatures (°C)	40	40
Geofluid exit temperature (°C)	69	65
Geofluid flow (kg/sec)	151	151
Pentane flow (kg/sec)	89	93
Cooling-water flow (kg/sec)	912	964
Turbine power (MW)	3.35 + 1.65 = 5.00	2.41 + 1.96 + 1.08 = 5.45
Geofluid delivery power (MW)	0.04	0.09
Pentane feed power (MW)	0.05 + 0.05 = 0.10	0.03 + 0.05 + 0.04 = 0.11
Wet cooling-tower power (MW)	0.56	0.60
Reinjection pump power (MW)	0.12	0.12
Condenser-vent pentane recovery power (MW)	0.10	0.10
Power assignable to pentane recovery from cooling water (MW)	0.27	0.29
Net power (MW)	3.81	4.15

attained with a pure hydrocarbon. The corresponding reduction in irreversibility may result in better cycle thermodynamic efficiency and a more favorable utilization of geothermal fluid. Of course, other fluid properties, such as vapor pressure at a given temperature and heat of vaporization, also influence cycle performance.

The evaluation of the mixed-fluid cycles for the second pilot plant is in its early stage; however, researchers completed a preliminary analysis of a dual-boiling direct-contact cycle using a mixture of half isobutane and half isopentane with Raft River geothermal fluid. The results of that analysis suggested that the mixed fluid may improve utilization effectiveness. To complete the study, different fluids must be considered, and schemes for attaining an effective counterflow heat exchange during condensation of the mixed fluids must be devised and assessed.

3.4 Digital Computer Program Development

The development of a digital computer program that will calculate the state points and power balance for direct-contact cycles was started during the period. A consideration of working-fluid recovery systems is included. The purpose of the program is to permit optimization of selected cycles by conducting parametric studies.

The initial version of the program treats direct-contact binary cycles using single working fluids. Working-fluid-recovery systems included in the initial version are (1) compressing and cooling condenser vent vapors, and (2) flashing the geothermal fluid prior to injection, and pumping the resulting working-fluid and water vapors into the condenser. The program provides for the effects of dissolved noncondensables and for the mutual solubilities of working fluid and geothermal fluid. The initial version was in the checkout stage as the period ended.

4. DIRECT-CONTACT HEAT EXCHANGERS - R. F. Boehm, H. R. Jacobs (University of Utah)

In the direct-contact heat exchanger, heat is transferred from one fluid to another when the two are intimately mixed. This kind of exchanger was originally examined for application as the primary heat exchanger in binary-cycle geothermal power plants, and the concept is now being applied to a number of engineering designs. The heat exchangers in both a 500-kilowatt (electric) plant at East Mesa, California (being constructed by Barber Nichols for the Lawrence Berkeley Laboratory) and in an Arkansas plant where heat is being reclaimed from a chemical brine (being constructed by the Daedelian Associates for Arkansas Power and Light) will utilize methods developed by H. R. Jacobs at the University of Utah.

Work at the University during this period included the completion of almost all the scheduled tests for understanding the primary heat exchangers. This has included studies of both the boiling and preheating modes, as well as basic work on homogeneous nucleation. Analytical tools are still being developed. In addition, considerable emphasis was given to understanding the capabilities of direct-contact condensers for binary power plants.

4.1 Systems Analyses[a]

Work was performed on a computer routine to size a direct-contact spray-column heat exchanger utilizing the method of R. Letan[6,7]. There is a primary difference between this program and earlier approaches; this program utilizes variable properties, so that a temperature distribution through the column can be determined. The temperatures of the drops, the continous phase, and the wakes as a

[a] J. Lamph and S. Cook were student assistants for the systems analysis.

function of distance through the column are calculated results, as are the length and diameter of the spray column. This program, then, should be significantly more accurate and productive than the earlier approaches, which made calculations based only on local holdup and did not calculate a temperature distribution.

Researchers have written a subroutine that solves three simultaneous, nonlinear, differential equations, as required by the total solution. Researchers have also developed curve-fits for the densities and specific heats of the dispersed and continuous phases as functions of temperature. In addition, a working subroutine to calculate the dispersed phase drop temperature with variable properties has been written.

In another approach, a sizing equation for spray-tower heat exchangers was programmed as a subroutine to be used with the master analysis program DIRGEO (DIRect-Contact GEOthermal). Both the constant-property theory of Letan[6] and the empirical curve-fit of the work of Woodward[8] are now available.

4.2 Condenser Studies

4.2.1 Collapsing Bubble Analysis[a]. In a direct-contact binary cycle, one method of condensing the working fluid might be in the form of a vapor bubble train, surrounded by the cooling water. By looking at the condensation of a single bubble, a theoretical model for the bubble collapse can be derived.

The models developed under the present contract have made an important advance over earlier work; the condensate film has now been taken into account[9]. Due to discrepancies between the theory and

[a] The student assistant for this work was B. Major.

available experimental data, the potential flow condition has been relaxed. This allows for a separate velocity profile across the film thickness and the thermal boundary-layer thickness.

It was found that the improved hydrodynamics in the film and boundary layer had no effect on the rate of bubble collapse, relative to that predicted assuming potential flow. It also required using a numerical method to solve the more complex equations involved; however, this pointed out that truncation of the series solution developed by Jacobs and Fannar to predict the average heat transfer could not be limited to only six terms.

The next step was to correct for the noncondensables present in the bubble. These noncondensables tend to reduce the partial pressure of the condensing vapor, thus reducing its saturation temperature. The presence of the noncondensable is the cause of the incomplete condensation of the bubble as its saturation temperature approaches the temperature of the cooling water.

In the first model to account for noncondensables, the decrease in vapor pressure was taken into account assuming complete mixing of the noncondensables and the condensing vapor. This method still overpredicts the rate of bubble collapse, as shown in Figure 13.

A more correct model might take into account the decrease in concentration of the vapor at the bubble wall, which is due to the buildup of noncondensables. Thus, a mass-diffusion model was set up to explain these events inside the bubble; the model combined diffusion and convection at the bubble wall. This last assumption accounted for the deviation assuming an entirely mixed medium, and gave an almost point-for-point prediction of the experimental results, as shown in Figure 13. It also indicated that much smaller amounts of noncondensables can effectively inhibit bubble collapse.

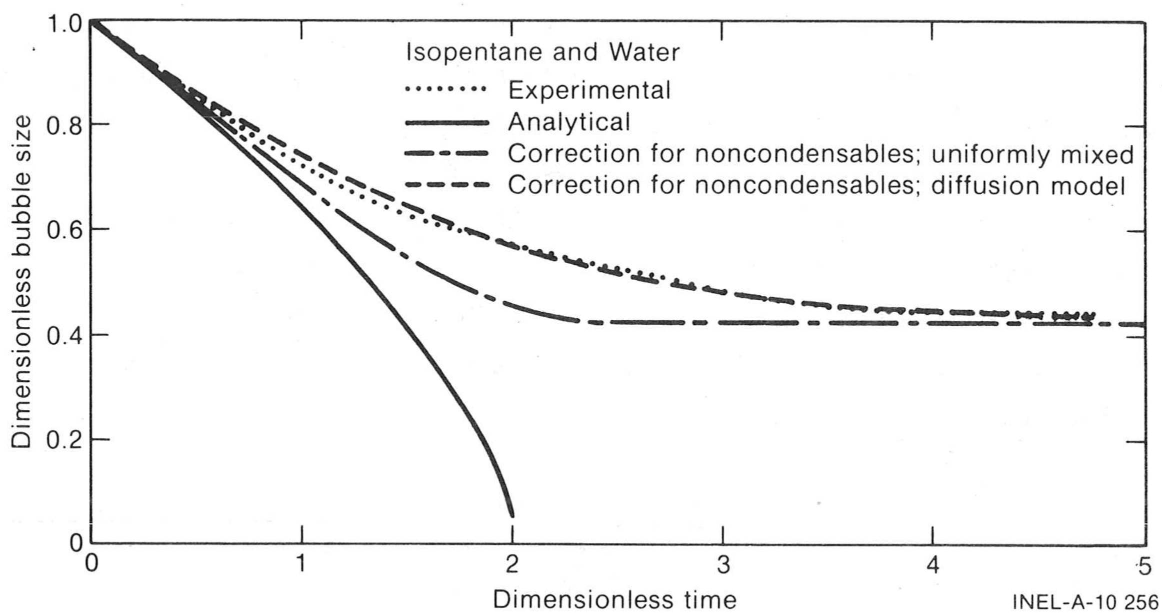

Fig. 13 Results of collapsing-bubble condenser studies.

4.2.2 Packed-bed Studies[a]. K. Thomas' preliminary studies of a model packed-bed condenser, in which water was sprayed on a bed in the presence of Refrigerant 113, were reported in the previous semiannual progress report[1]. His work utilized spheres and Berl saddles. Studies continued with the same apparatus. Experimenters used a Flexipac packing, which should demonstrate a higher condensation efficiency because of a larger area per unit volume.

To help understand the mechanics of a bed packed with spheres, a single sphere is being instrumented with thermocouples. It will be used to study condensation of R-113 in water. The purpose of the particular experiment is to determine the interfacial heat-transfer coefficient, and to see if it changes as water flows around the sphere.

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[a] R. Skidmore assisted with these studies.

4.3 Preheaters[a]

A direct-contact preheater test loop was installed in the Heat Power Laboratory at the University in early June, in order to determine the operating characteristics of this component of a direct-contact binary power plant. Figure 14 shows a schematic of the preheater test loop. The preheater was a spray-column type, 1.83 meters long and 15.3 centimeters in diameter (6 feet long and 6 inches in diameter). Hot water was supplied by a steam kettle. The water was pumped to the top of the preheater and injected through slots in a pipe extending down into the column.

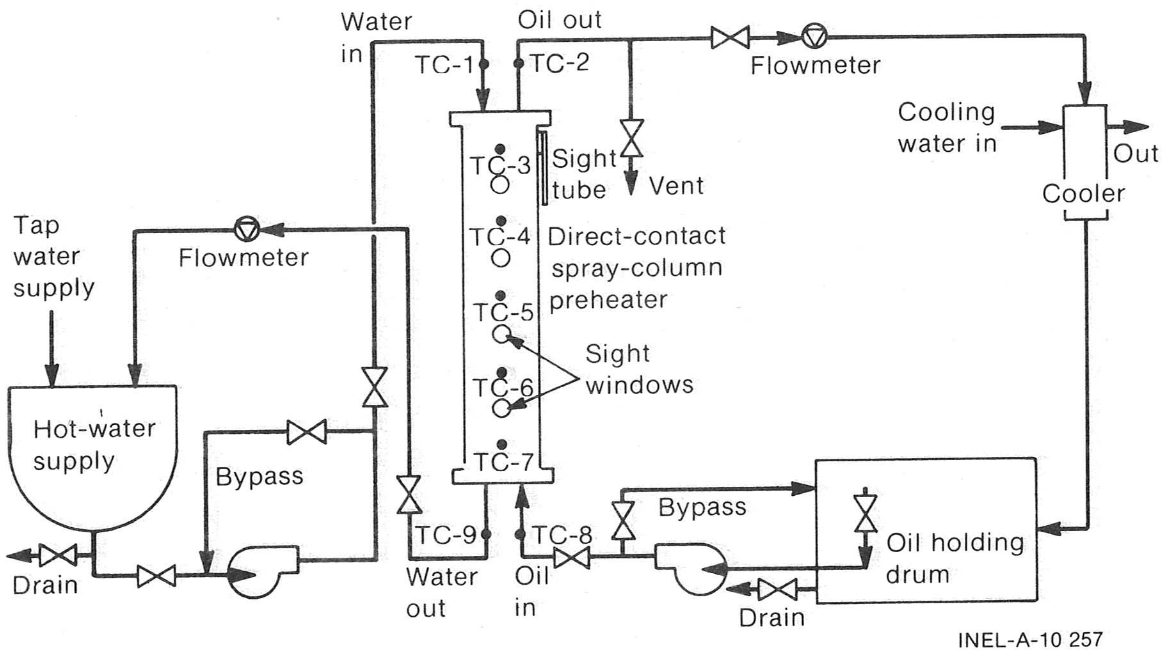

Fig. 14 Direct-contact preheater test loop.

Primarily because of safety requirements, the working fluid was Chevron insulating oil. The oil was pumped from a barrel and injected into the bottom of the preheater, through an 8.89-centimeter (3.5-inch)

[a] The student assistants on this project were S. Plass and S. Cook.

nozzle with interchangeable dispersion plates. The oil exited at the top of the preheater and was cooled before returning to the holding barrel. Water flow rates varied from 0.095 to 0.25 liter per second (1.5 to 4 gallons per minute). Oil flow rates varied from 0.06 to 0.16 liter per second (1.0 to 2.5 gallons per minute). The hot water was supplied at 82^{o}C (180^{o}F) for all tests.

The results of the tests are presented in Figure 15. For volumetric flow ratios of approximately 2.5, the results agree well with the Woodward model[8]. At lower flow ratios, however, considerable deviation from the Woodward model results for holdup greater than 5%. The model proposed by Letan[6,7] appears to be significantly more accurate than the Woodward model, but it still normally underpredicts the heat transfer.

4.4 Homogeneous Nucleation[a]

Fundamental studies are analyzing the variables that affect direct-contact boiling. Researchers are pursuing both analytical approaches, which use a computer, as well as experimental studies, which analyze small drops of one volatile fluid on another hot, immiscible fluid in a highly controlled environment. The analytical evaluation of dependent variables is nearly completed. Results to date are shown in Table III.

Experimental studies have produced a number of significant results. First, researchers have concluded that any type of boiling is highly unlikely for single drops; evaporation probably prevails over the entire range of operation in a direct-contact heat exchanger. Experiments with a pentane-glycerol system, which can be made to film-boil, show film-boiling to be from 20 to 30 times slower than pure evaporation.

[a] C. Kodres assisted with this study.

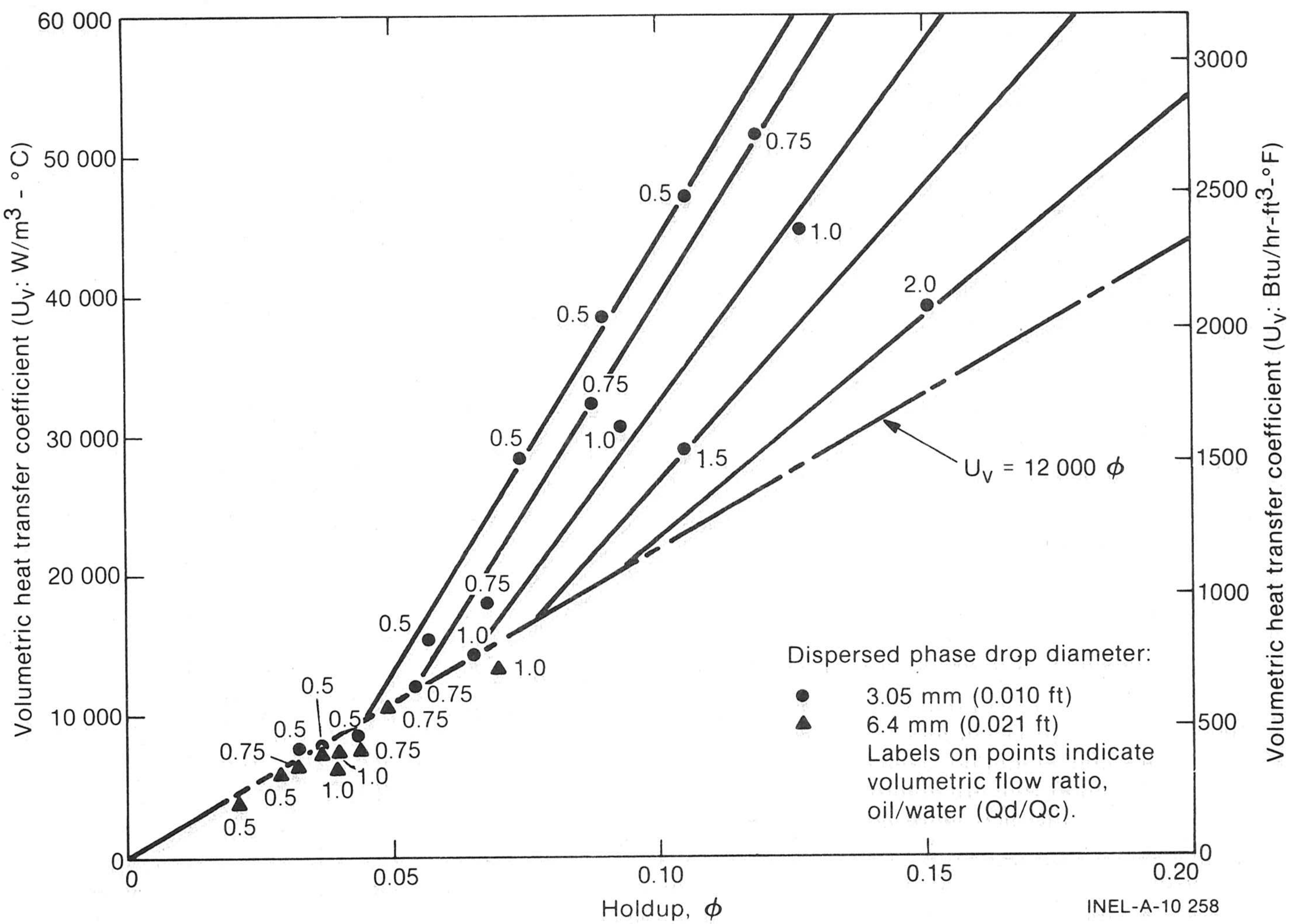

Fig. 15 Direct-contact preheater performance.

TABLE III

RESULTS OF ANALYTICAL STUDIES
OF HOMOGENEOUS NUCLEATION

Major Variable Affecting Evaporation	Significant Effect on Evaporation	Negligible Effect on Evaporation	Still to be Evaluated
(1) Partial pressure in surrounding vapor film	(1) Thermal conductivity of lens	(1) Thermal conductivity of hot fluid	(1) Latent heat of vaporization
(2) Thickness of lens	(2) $T_{hot\ fluid}$	(2) $T_{initial}$ of lens	(2) Scattering coefficient
		(3) Initial size of droplet	
		(4) Convection	

The numerical model predicting the rate of evaporation forecasts somewhat slower evaporation than that observed experimentally, primarily for low values of $T_{c.p.}-T_{sat}$; future models should take into account the fact that the ambient gas contributes a partial pressure to the vapor film, thus lowering the effective T_{sat}.

In other experiments using n-pentane with actual Raft River well water (see Figure 16), the evaporation mode dominates. However, a compact lens is never formed; the droplets spread very thin, but do not usually break up. This greatly increases the evaporation rate. The same effect was observed with tap water; a compact lens was not formed unless the water was saturated with pentane.

Finally, it seems clear the dominant resistance to evaporation is the resistance to heat transfer through the lens. This is true even when temperatures are below saturation. The expected dominance of mass transfer away from vapor film as the major resistance has never materialized, even at temperatures as much as 30°C below saturation.

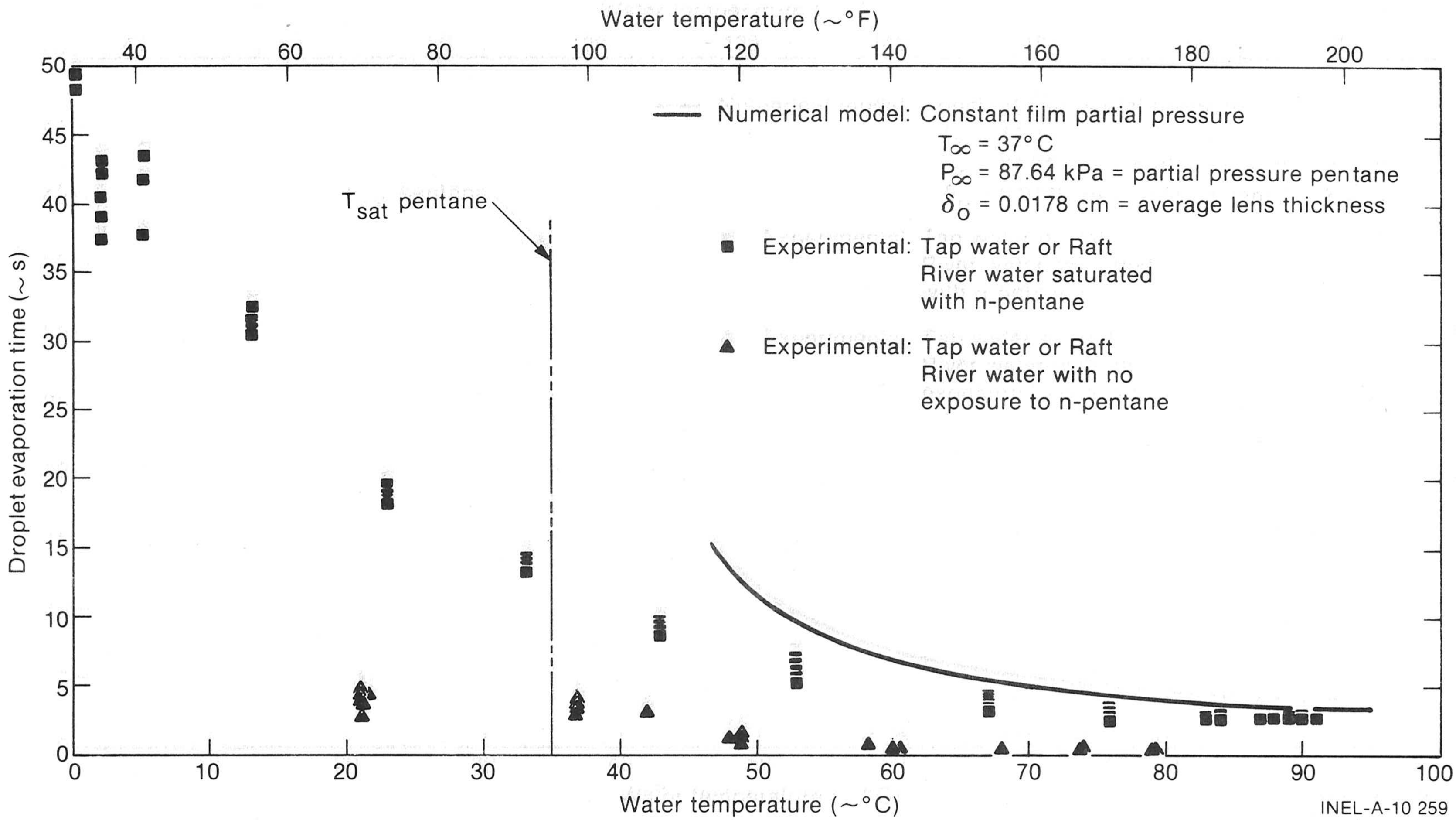

Fig. 16 Evaporation rates of n-pentane droplets floating on water.

4.5 Source Book on Geothermal Energy

A chapter on direct-contact heat exchangers for inclusion in the planned Department of Energy source book on geothermal energy has been written and submitted to the editors at Brown University. The editors have concluded their review favorably, and have returned the manuscript for minor revisions relating primarily to format requirements.

V. ENVIRONMENTAL CONSIDERATIONS — S. G. Spencer

Researchers continued to monitor the Raft River environment during the last six months, studying air quality, meteorology, water quality, subsidence, and seismicity, as well as the behavior of different terrestrial and aquatic species. They also conducted special research studies and undertook a Snake River Basin environmental overview project. Special studies included the monitoring of injection-test results, research into raptor disturbance, and a study of dental fluorosis in Raft River children. This section will briefly discuss these special studies, but the details of this and other environmental work will be presented primarily in the annual environmental report soon to be printed[10].

Seven environmental monitoring wells, ranging in depth from 150 to 390 meters (490 to 1280 feet), were drilled near existing or planned geothermal injection wells. Researchers will use the wells to monitor changes in shallow-aquifer hydrology and water quality, which may be caused by intermediate-depth injection (below 600 meters, or 1970 feet). For example, experimenters monitored three wells during an injection test on RRGI-4. They reported the following results:

TABLE IV

RESULTS OF MONITORING INJECTION TEST ON RRGI-4

Well	Depth (m)	Distance from Injection Well (m)	Pressure Increase (MPa)
MW-1	399	210	34
USGS-3	434	700	97
BLM Offset	123	1200	14

Considering their locations, the USGS-3 and the BLM Offset wells showed significant responses. This indicates that these two wells, along with RRGI-4, penetrate the Narrows Fault Structure. The subdued response of

MW-1 suggests that it overlies but does not penetrate the Narrows Structure.

In September biologists completed the first phase of the ferruginous hawk study[a]. They wished to know how sensitive the hawks are to different kinds of disturbance. Nests in the Raft River and the Curlew valleys were subjected to human-induced disturbances ranging from the use of an automobile to the continuous operation of a generator. The nature of the birds' responses, as well as the distance at which they began to react to the disturbances, were monitored and recorded. Data were highly variable, but the first season's study clearly showed that the disturbances caused some birds to abandon their nests. In addition, the biologists observed reduced rates of production in nests that were not abandoned. The study will be completed in 1979, at which time the investigators will recommend buffer zones and request limitations on activities that are likely to disturb the hawks.

Researchers also began to draw preliminary conclusions from the fluorosis study. They had intended to document instances of fluorosis in humans, and they wanted to relate the cases to the valley's sources of fluoride (including geothermal fluid). Utah State University faculty members examined a total of 270 school-aged children[b]. They also tested the fluoride content of the valley's waters. Lesions typical of dental fluorosis were identified in 52 cases, but there was little correlation between the clinical data and the concentration of fluoride in the water supply used by each child. The shallow groundwater system has undergone considerable hydrologic and chemical

[a] Dr. Clayton White of Brigham Young University directed this study. He was aided by personnel from the U.S. Fish and Wildlife Service, the U.S. Bureau of Land Management, the Idaho State Department of Fish and Game, and EG&G Idaho Inc.

[b] Drs. Shupe, Olson, and Peterson of the Utah State Research Foundation conducted this examination.

change in the last two years, and this may have affected the correlation. The results indicated that some of the children have ingested fluoride from sources other than water supplies.

VI. REGIONAL PLANNING — J. A. Hanny

1. THE PLANNING PROCESS

Early in the period, EG&G Idaho and the Department of Energy's Idaho Operations Office and Division of Geothermal Energy prepared a regional plan for the accelerated commercialization of geothermal energy[11]. Researchers assessed the resources and analyzed the needs of each state in the Rocky Mountain Basin and Range (RMB&R) Region: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota, South Dakota, Utah, and Wyoming. The regional team agreed on preliminary goals, which are shown in Table V.

A draft market penetration analysis for the region will also be published during the first quarter of fiscal year 1979. The analysis will match hydrothermal resources with potential users, and it will forecast rates of commercialization. State planning teams will prepare detailed scenarios and identify required incentives.

Federal and state governments, research groups, utilities, developers, and others are involved in the planning process through workshops, questionnaires, and personal contacts. Figure 17 illustrates the regional DOE program, showing the relationship of planning activities to the project as a whole. Exploration, hardware development, and research are not included in the DOE commercialization program. These activities are not part of the three national regions' efforts.

Regional planning includes program coordination, policy development, and state commercialization planning and outreach. The intent is: (1) to provide for program development, coordination, reporting, and information dissemination, as well as for schedule, fiscal, planning, and work-change control; (2) to identify and resolve regulatory, legal, economic, and other institutional restraints that impede the use of geothermal energy; and (3) to prepare state geothermal commercialization plans to perform outreach functions with potential users. Figure 18 illustrates the actual planning process.

TABLE V

COMMERCIALIZATION GOALS FOR ROCKY MOUNTAIN BASIN AND RANGE REGION (Goals Subject To Revision)

	Present	1985	2000	2020
Electric Capacity (MWe)	9	300 [a]	9500 [b]	35,000 [c]
Direct Thermal Applications (MW equivalents)	25	200	2000	60,000
Electrical Applications (Equivalent fossil-fuel energy, quads/yr)	0	0.025	0.79	2.91
Direct Thermal Applications (quads/yr)	0.001	0.006	0.06	1.80
Total Energy (quads/yr)	0.001	0.031	0.85	4.71
Barrels of Oil Equilvalent	$1x10^6$/yr	$5.3x10^6$/yr	$144x10^6$/yr	$793x10^6$/yr

[a] Assuming an additional 150 megawatts of proven reserves established by 1980.

[b] Assuming commercialization of 8000 megawatts of proven, potential, and inferred resources and 1500 megawatts of high-grade undiscovered resources.

[c] Assuming the economically competitive reservoir temperature is lowered to 150°C (300°F).

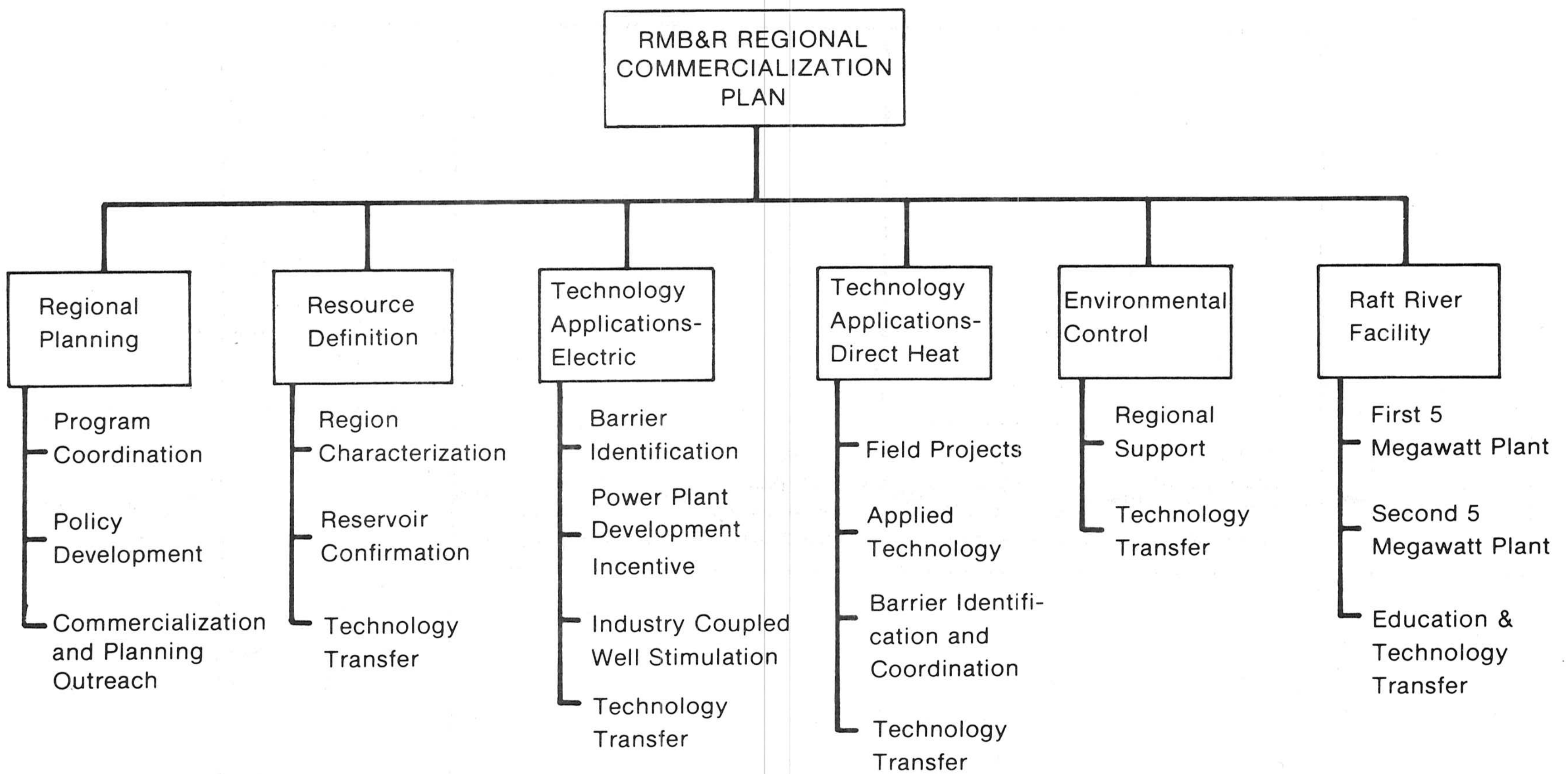

Fig. 17 Regional commercialization program outline.

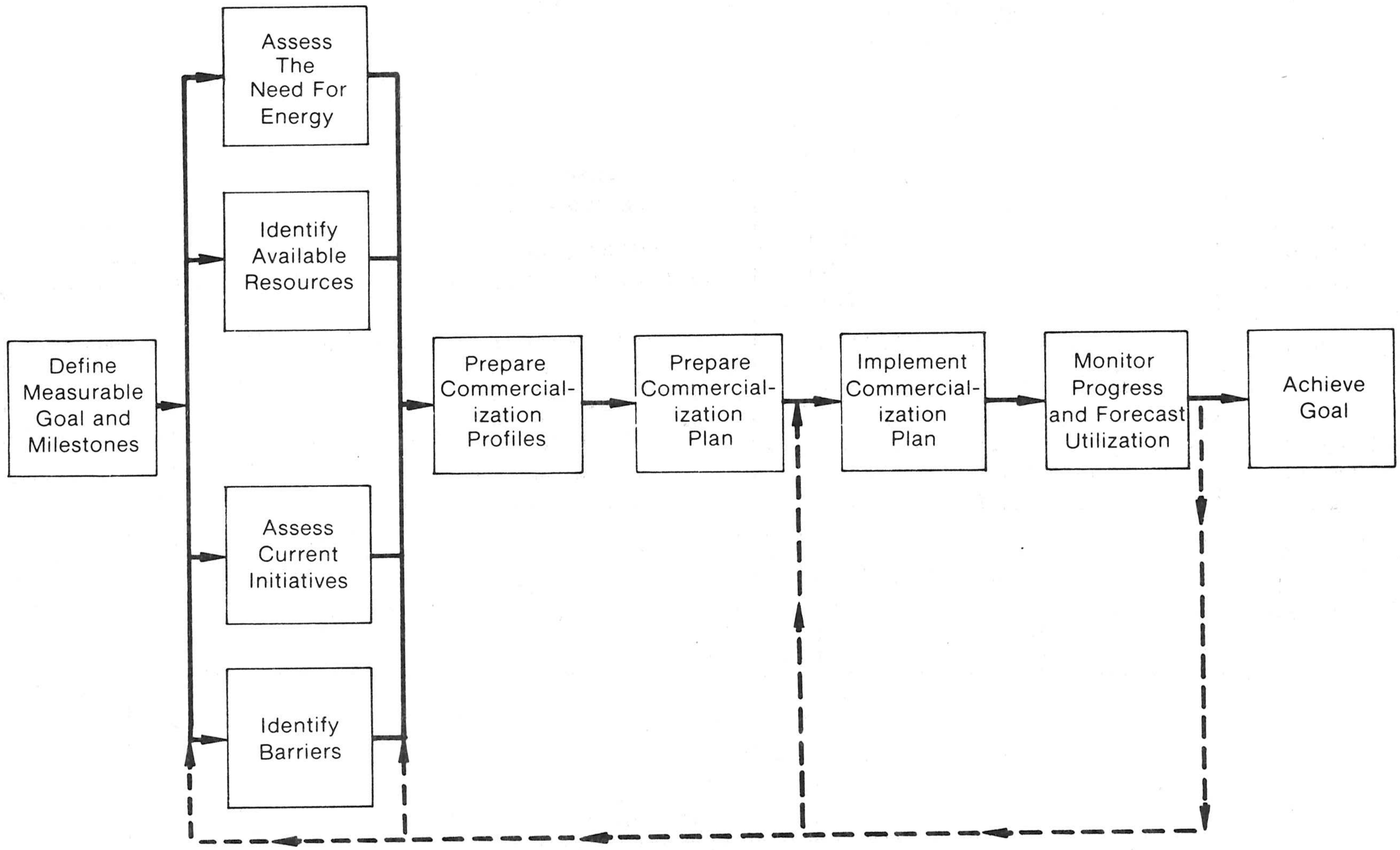

Fig. 18 Regional planning process.

2. ENERGY SUPPLY AND USE

Both an accurate tally of energy supplies and an understanding of energy-use patterns were necessary for the early planning effort, and planners have fashioned a comprehensive picture of energy supply and use throughout the region. This report will relate a summary of the regional situation; a reader interested in the details concerning an individual state may turn to the commercialization plan [11].

The region is a net energy exporter, as shown in Figure 19. If uranium is included in the computation, the region exports about 70 to 75% of the energy it produces. If uranium is not included as a source of energy, an analyst would conclude that 40% of the region's energy production is exported.

The industrial sector is the region's leading consumer of energy. Industry uses more natural gas than any other source of energy - about 45% of industry's total energy supply is gas. Oil supplies 33% of industrial needs. Coal is used primarily for the generation of electricity.

Although it varies from state to state, major industrial consumers in the region use low- to intermediate-heat energy sources for at least a part of their energy needs. These industries include food and kindred products; wood and lumber products; and stone, clay, and glass products. In some of the states, mining is a major consumer of the energy derived from electricity, natural gas, and diesel fuel. Transportation is the second largest energy-consuming sector in the region. Transportation activities use mostly oil, plus a small quantity of natural gas.

Population centers vary greatly in size, latitude, and altitude. These factors have a direct bearing on the amount of energy required for the residential and commercial sectors. The percentage of their total energy budgets that these sectors must consume for space conditioning and water heating thus varies a great deal, ranging from 50 to 90%.

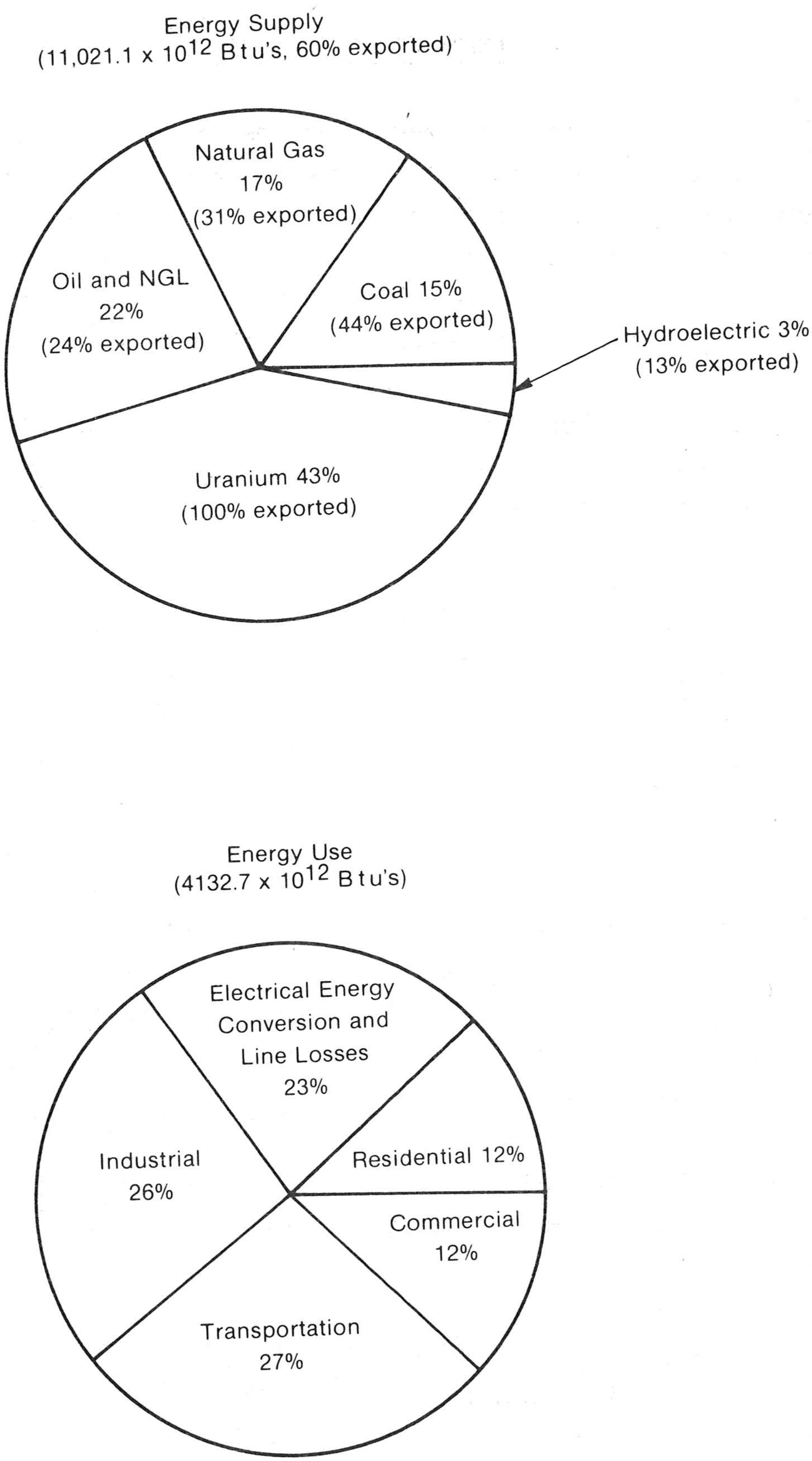

Fig. 19 Regional energy supply and use.

3. BENEFIT ANALYSIS

Potential benefits from the development of the geothermal resource in the Rocky Mountain Basin and Range Region are varied and important, and the commercialization planners carefully analyzed these benefits. Development could mean employment-level increases, industrial growth, energy independence, balance-of-payment advantages, additional tax revenues, capital investments, and an improved environment. Federal, state, and local governments will derive fiscal benefits if the hydrothermal resource is effectively developed. Using reasonable assumptions, it is estimated that the return of revenues through income taxes and federal royalties will approach $5.1 billion by the year 2000 if the regional goals are met. Cumulative income to the federal budget will be on the order of $35 billion by the year 2000. The accompanying tax revenue to the state and local governments in the region is estimated to be $28 million in the year 1985, $340 million in the year 1995, and $638 million in the year 2000 - for a cumulative total of $4.3 billion through the year 2000.

To receive this level of financial benefit, however, industry must make significant capital investments. By 1985, $360 million will be required; $1.9 billion will be needed by 1990, $4.4 billion by 1995, and $8.2 billion by the year 2000.

Displacing the use of oil and gas with hydrothermal energy will also be of great benefit; about 1 billion barrels of oil could be displaced through the year 2000. At today's oil prices of about $12 per barrel, this would mean a total balance-of-payment advantage in excess of $11 billion.

The estimates from which the above calculations were developed are shown in Figure 20. Figure 21 illustrates the regional benefits data[a].

[a] This benefit analysis assumed (1) cost of one barrel oil = $12; (2) no inflation on projections; (3) electric power rate = 30 mills/kilowatt-hour; (4) liquid and gas fuel rates = $3/million Btu; (5) investment capital = $715/kilowatt installed capacity; (6) 1 megawatt of hydrothermal energy on line = 5,100 barrels of oil/year for direct-heat applications, and 14,200 barrels of oil per year for electric applications; (7) 48% federal taxation; and (8) 10% federal royalty payment.

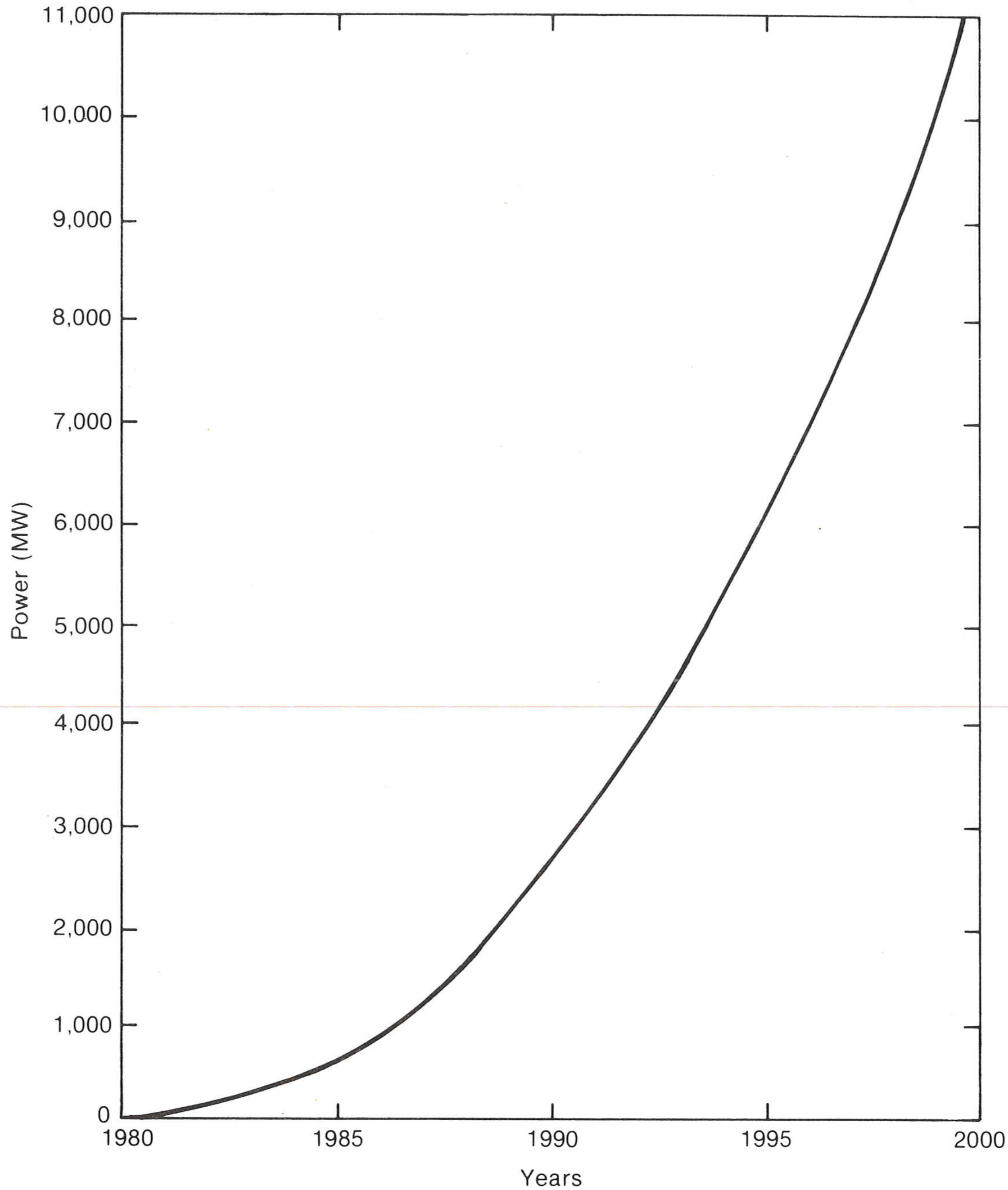

Fig. 20 Projection of power on line.

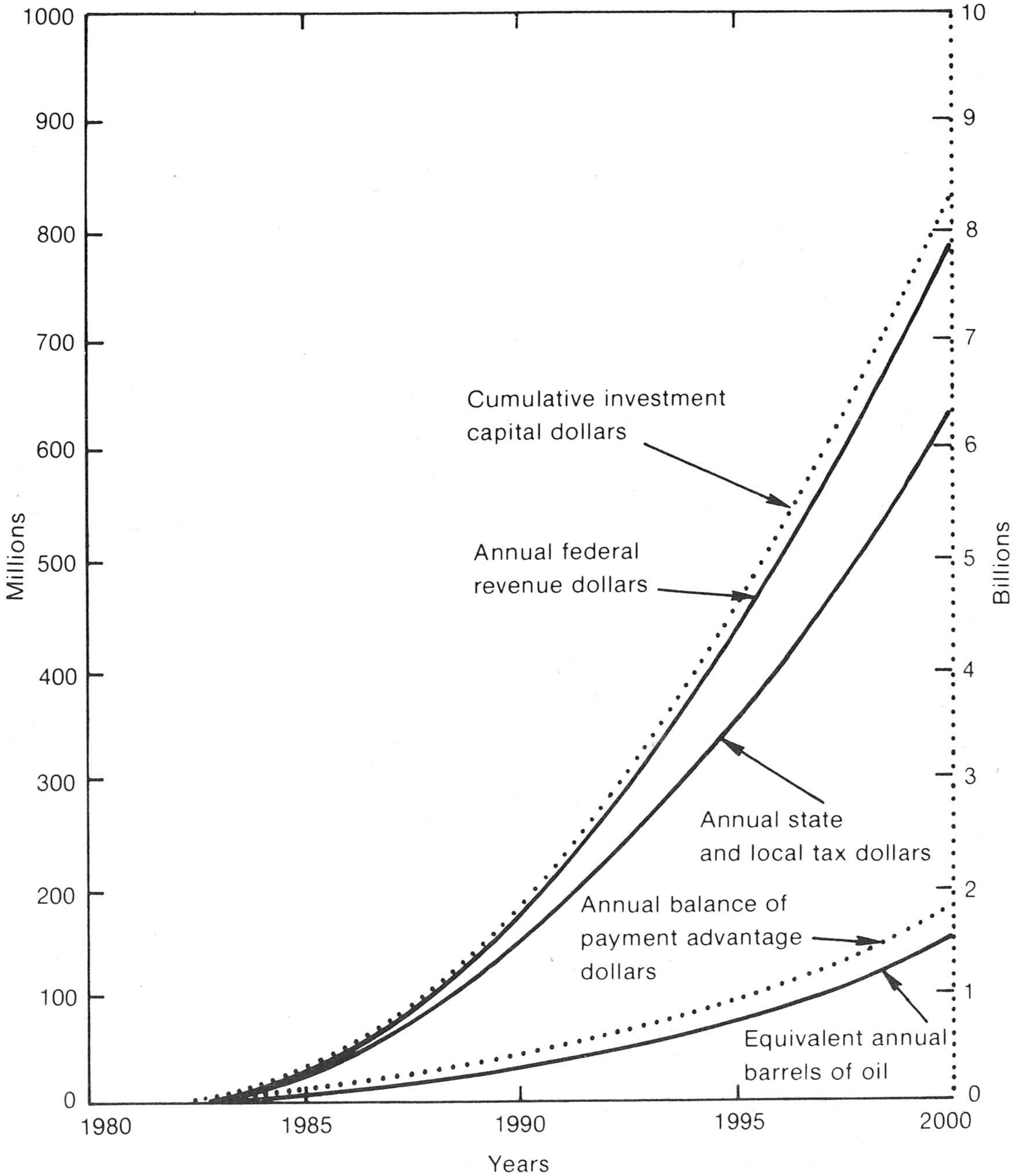

Fig. 21 Regional benefits of commercialization.

4. REGIONAL WORKSHOPS

The regional team held workshops to initiate the program effort and coordinate the plan preparation with industry representatives, state government officials, environmental groups, and other interested parties. The regional commercialization plan was presented at the annual Geothermal Resources Council (GRC) meeting held at Hilo, Hawaii during July 1978. A questionnaire was also circulated at the GRC meeting, to learn how people feel about various parts of the regional plan. After the Hilo meeting, all those who had been mailed copies of the regional plan were also sent copies of the questionnaire. Table VI is a summary of the responses received to date. A report that provides additional information, including responses by groups with various interests in commercialization, is now being prepared.

TABLE VI

RESPONSES TO DEVELOPMENT QUESTIONNAIRE

Initiative	For (%)	Against (%)	No Opinion (%)
1. Collective planning with industry, state, local, and other federal entities, attempting to develop a regional commercialization plan that has the active support of all those involved.	86	14	0
2. Industry-coupled, cost-shared drilling to confirm new reservoirs.	79	18	3
3. Publication of data acquired under the Industry-Coupled Program and the generation of case studies of different types of reservoirs.	89	10	1
4. 50-MW(e) demonstration plant at the Valles Caldera.	48	40	12
5. Support of R&D to develop better drilling and completion technology, reservoir stimulation techniques, exploration technology, and advanced conversion equipment.	88	8	4
6. Support for development of well-head generators (5 to 10 MW).	71	19	10
7. Loan quaranty program.	72	15	13
8. Reservoir insurance.	37	37	26
9. Tax treatment equivalent to fossil fuels.	88	4	8
10. Support of combined developer-utility analysis of reservoir-development economics, to provide a common ground for negotiations.	56	29	15

TABLE VI (continued)

Initiative	For (%)	Against (%)	No Opinion (%)
11. User assistance for direct-heat applications, to provide initial guidance on resource potential and surface equipment needs.	73	20	7
12. State-coupled program for a state-by-state inventory of low- and moderate-temperature resources for direct-heat applications.	70	26	4
13. Further support of direct-heat-applications demonstrations in the region.	72	26	2

VII. DEMONSTRATION PROJECTS — L. E. Donovan

As one way of hastening the commercialization of geothermal energy, the Department of Energy conducts the Project Opportunity Notice (PON) program. DOE shares the costs of direct geothermal utilization projects with the private companies, municipalities, or individuals that are conducting each demonstration. The Program Management Branch of EG&G's Idaho Geothermal Program supports DOE in the technical administration of these demonstration project contracts. Six Region-II projects were underway during the period.

1. ONTARIO, OREGON

Ontario, Oregon, is located 92 kilometers (57 miles) northwest of Boise, Idaho. The Ontario Ore-Ida Foods, Inc. plant processes potatoes, corn, and onions. It is currently dependent on natural gas and oil for process heat. This demonstration project will substitute geothermal energy for the potato-processing heat and space heat, and the system will supply hot potable water. Heat loads now amount to about 97,200 megawatt-hours annually (33.2 x 10^{10} Btu's per year). DOE will fund $2,256,000 of the $4,850,000 undertaking. The environmental report and the geophysical work that precedes the selection of a well site have been completed.

2. MONROE CITY, UTAH

Monroe City is a community of 1,500 people, 257 kilometers (160 miles) south of Salt Lake City, Utah. The local economy is based primarily on agriculture. The project will entail the drilling of one production and one injection well, to support a district heating system. Geothermal fluid from the production well will be piped through a central heat exchanger, and then to the injection well. The expected production temperature is 121^{o}C (250^{o}F), at 32 liters per second (500 gallons per minute). The system will initially heat the South Sevier High School, the Monroe City Hall, and the fire station, and it could later be expanded to include the major areas of Monroe. The total system will be capable of a load of 6,000 kilowatts. DOE will pay for $924,000 of the $1,589,029 project. An environmental report has been completed, and two small exploratory holes have been drilled in anticipation of well-site selection.

3. PHILIP, SOUTH DAKOTA

The town of Philip is located approximately 129 kilometers (80 miles) east of Rapid City, South Dakota. Three buildings in the school complex will be retrofitted to use geothermal energy for space heating. The scope of the project requires the drilling of a well into the Madison Aquifer and the conversion of the present steam and electrical heating systems to hot-water systems. Instrumentation will be installed to monitor system performance and to provide data for other potential users. As currently planned, water discharged from the heating system will be piped into a rural water distribution system. The project will cost $483,762; DOE will contribute $383,762. The environmental report has been completed, and the well drilling specification/bid package has been sent out for bid.

4. PIERRE, SOUTH DAKOTA

St. Mary's Hospital and Capitol Lake Plaza, located in Pierre, South Dakota, are currently heated by fossil-fuel systems. This project will demonstrate the feasibility of utilizing low-temperature water from a 640-meter (2,100-foot) Madison well for space heating. The characteristics of the aquifer in this area are not well known. Therefore, the water quality and well production characteristics will be closely monitored after the well is completed. Based upon the water temperatures and quality, heating and ventilating system modifications will be designed and the hospital retrofitted to utilize the geothermal fluid. The Capitol Lake Plaza heating system will also be modified so that hot-water coils can be installed in the existing forced-air ducts. Expansion of the distribution system to other commercial businesses is considered feasible. DOE will finance $344,570 of the $460,361 total cost. An environmental report has been completed, and the well drilling specification/bid package has been sent out for bid.

5. BOX ELDER, SOUTH DAKOTA

The Douglas school complex and the City of Box Elder are located approximately 23 kilometers (14 miles) northeast of Rapid City, South Dakota. Box Elder is currently drilling a well for domestic water use, and city officials have consented to heating a portion of the Douglas High School with the geothermal water. The water from the Madison Aquifer will be pumped directly from the well through insulated pipe to reheat coils located in the existing ductwork. The geothermal coils will be placed in series with the existing reheat coils, and the control of the geothermal system will be integrated into the conventional heating system thermostats. The system will be fully instrumented to determine actual performance. It will cost $529,822; DOE will pay $212,180 to support the effort. An environmental report has been completed.

6. HAAKON COUNTY, SOUTH DAKOTA

Geothermal water from an artesian well that has flowed since 1959 will be used to dry grain and to heat three ranch homes, a shop, an insulated barn, and livestock shelters on the Diamond Ring Ranch in Haakon County, South Dakota. The construction phase will begin in the spring of 1979, and should be completed that summer. The construction will consist of laying PVC pipelines and connecting the wellhead to the various structures requiring heat. After flowing through the central heat exchanger, the geothermal fluid will be used as stock water. It will then be discharged into a reservoir system now used for both geothermal-well and runoff catchment. The environmental report and the preliminary system design have been completed for this $266,779 project. DOE will contribute $166,479.

VIII. REFERENCES

1. G. L. Blake (ed.), Semiannual Progress Report for the Idaho Geothermal Program, October 1, 1977 to March 31, 1978, TREE-1278 (July 1978).

2. G. M. Millar, Draft Raft River Facility Master Plan (to be published December 1978).

3. Coagulation-Flocculation Jar Test of Water, American Society for Testing and Materials, ASTM D-2035-74 (1974).

4. Corrosivity of Water in the Absence of Heat Transfer, American Society for Testing and Materials, ASTM D-2688-70 (1970).

5. O. J. Demuth, Preconceptual Design Study for the Second Raft River 5-MW (gross) Dual Boiling Direct Contact Pilot Plant, GP-141 (August 1978).

6. R. Letan, Design of a Particulate Direct Contact Heat Exchanger: Uniform, Countercurrent Flow, ASME 76-HT-27 (August 1976).

7. R. Letan and E. Kehat, "The Mechanism of Heat Transfer in a Spray Column Heat Exchanger," American Institute of Chemical Engineers Journal, 14, 3 (May 1968) pp 398-405.

8. T. Woodward, "Heat Transfer in a Spray Column," Chemical Engineering Progress, 57, 52 (1961).

9. H. R. Jacobs, H. Fannar, and G. C. Beggs, "Collapse of a Bubble of Vapor in an Immiscible Liquid," Sixth International Heat Transfer Conference, 1978, 2, pp 383-388.

10. S. G. Spencer, Annual Environmental Report for the Idaho Geothermal Program (to be published December 1978).

11. Regional Hydrothermal Commercialization Plan, U. S. Department of Energy, Division of Geothermal Energy and Idaho Operations Office; EG&G Idaho, Inc.; and the University of Utah Research Institute, Earth Science Laboratory (July 14, 1978).

APPENDIX A

PUBLICATIONS OF THE IDAHO GEOTHERMAL PROGRAM

APPENDIX A

PUBLICATIONS OF THE IDAHO GEOTHERMAL PROGRAM

The following tables list reports and brochures published by employees of the Idaho Geothermal Program. Copies of external reports are on file at the INEL Technical Library, 457 Broadway, Idaho Falls, Idaho 83401. External reports (and additional copies of this progress report) can be ordered from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161. Obtain brochures by writing G. L. Blake, EG&G Idaho, Inc., Box 1625, Idaho Falls, Idaho 83401, or by calling 208-526-9212. Internal reports are available only to employees of EG&G Idaho, Inc.

A future progress report will contain a list of journal and magazine articles, as well as a list of presentation papers, that have been written by program personnel.

TABLE A-I

EG&G IDAHO, INC.: EXTERNAL REPORTS

TREE Number	Author	Date	Title
1008	J. F. Kunze, ed.	10-76	Geothermal R&D Project Report for Period April 1, 1976 to June 30, 1976
1016	J. F. Kunze	1-77	The Potential for Utilizing Geothermal Energy for Space Heating in Reconstructed Sugar City, Idaho
1023	D. T. Neil	11-76	Geothermal Shell and Tube Heat Exchanger Augmentation
1030	J. F. Kunze	12-76	Geothermal R&D Project Report for Period July 1, 1976 to September 30, 1976
1039	I. J. Ingvarsson, et. al.	12-76	Determination of the 5-MW Gross Nominal Design Case Binary Cycle for Power Generation at Raft River, Idaho
1048	R. C. Schmitt, et. al.	1-77	Beneficial Uses of Geothermal Energy Description and Preliminary Results for Phase I of the Raft River Irrigation Experiment
1085	W. C. Kettenacker	3-77	Two-Dimensional Simulation of the Raft River Geothermal Reservoir and Wells
1108	I. J. Ingvarsson, et. al.	4-77	Working Fluid and Cycle Selection Criteria for Binary Geothermal Power Plants with Resource Temperatures in the Range of 220°F to 400°F

TABLE A-I (continued)

TREE Number	Author	Date	Title
1114	J. F. Kunze, et. al.	4-77	Asbestos-Cement Pipeline Experiment at the Raft River Geothermal Project
1134	J. F. Kunze	5-77	Geothermal R&D Project Report for Period October 1, 1976 to March 31, 1977
1135	A. S. Richardson, et. al.	5-77	Energy Oriented Study of Fluidized Bed System
1162	L. L. Mink, et. al.	10-77	Geothermal Potential of the West Boise Area
1164	C. J. Shaffer	8-77	Floating Power Optimization Studies for the Cooling System of a Geothermal Power Plant
1176	R. L. Miller	10-77	Results of Short-Term Corrosion Evaluation Test at Raft River
1182	I. A. Engen	2-78	Residential Space Heating Cost: Geothermal vs Conventional Systems
1256	J. F. Kunze	3-78	Geothermal R&D Project Report for Period April 1, 1977 to September 30, 1978
1278	G. L. Blake, ed.	7-78	Semiannual Progress Report for the Idaho Geothermal Program, October 1, 1977 to March 31, 1978
1295	G. L. Blake, ed.	11-78	Semiannual Progress Report for the Idaho Geothermal Program, April 1 to September 30, 1978

TABLE A-II

EG&G IDAHO, INC.: INTERNAL REPORTS

GP Number	Author	Date	Title
101	D. L. Larson	7-77	Evaluation of ERDA Loan Guarantee
102	D. L. Larson, et. al.	8-77	Evaluation of ERDA Loan Guarantee; Applications for CUI Venture
103	S. G. Spencer	8-77	Withdrawal of Lands for Federal Geothermal Development in the Raft River Valley
104	J. F. Kunze, et. al.	8-77	August Monthly Report
105	S. M. Prestwich	8-77	Raft River Well Cost Summary
106	S. M. Prestwich	8-77	Drilling and Completion Report, Raft River Geothermal Injection Well Number 4
107	J. F. Kunze, et. al.	9-77	LPAD-I-255-459-475
108	J. F. Kunze, et. al.	9-77	LPAD 430, Reservoir Engineering
109	J. F. Kunze, et. al.	9-77	LPAD 322, Second Generation Heat Exchangers
110	J. F. Kunze, et. al.	9-77	LPAD 255 and 459, Moderate Temperature Hydrothermal
111	J. F. Kunze, et. al.	9-77	LPAD 571 and 461, Environmental
112	J. F. Kunze, et. al.	9-77	LPAD 315, Nonelectric
113	J. F. Kunze, et. al.	9-77	September Monthly Report
114	J. F. Kunze, et. al.	10-77	October Monthly Report

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GP Number	Author	Date	Title
115	R. L. Miller	10-77	Materials Testing Plan and Schedules for the Raft River Geothermal Logs Facility
116	S. G. Spencer	11-77	Snake River Plain Work Statement
117	S. G. Spencer	11-77	Environmental LPAD
118	J. G. Keller	11-77	Heat Pumps Primer for use with Low-Temperature Geothermal Resources
119	J. F. Kunze, et. al.	11-77	November Monthly Report
120	S. G. Spencer, J. F. Sullivan	12-77	Environmental Report, Raft River Geothermal Power Plant
121	S. G. Spencer	12-77	Environmental Report, Raft River Injection Monitor Well System
122	W. D. Gertsch	12-77	Preliminary Assessment on the Development of Geothermal Energy at Hill Air Force Base
123	J. F. Kunze, et. al.	12-77	December Monthly Report
124	J. H. Ramsthaler, et. al.	1-78	Management Plan for Fluid Supply and Injection System
125	S. G. Spencer	12-77	Environmental Assessment, Raft River Geothermal Injection Well (RRGI-6) and Transfer Pipeline
126	S. G. Spencer	1-78	Environmental Assessment, Raft River Geothermal Injection Well (RRGI-7) and Transfer Pipeline

TABLE A-II (continued)

GP Number	Author	Date	Title
127	F. B. Simpson	1-78	January Monthly Report
128	S. G. Spencer	9-77	Environmental Assessment, Raft River Geothermal Production Well (RRGP-5) and Associated Development
129	G. L. Mines	2-78	INEL Interim Evaluation of RGI East Mesa Project
130	J. J. Lofthouse	2-78	Raft River Geothermal Site Safety Assessment Document
131	F. B. Simpson	2-78	February Monthly Report
132	F. B. Simpson	3-78	March Monthly Report
133	J. F. Sullivan	4-78	Monitor Well Plan
134	F. B. Simpson	4-78	April Monthly Report
135	J. F. Whitbeck	5-78	Draft Proposal for Geothermal Cycle Working Fluid Properties Research
136	S. G. Spencer, J. F. Sullivan	5-78	Environmental Assessment, Geophysical Core Hole Drilling
137	S. G. Spencer	5-78	Environmental Assessment, Sugar City, Idaho
138	G. L. Mines	5-78	INEL Initial Evaluation of the Current Status of RGI East Mesa Project
139	F. B. Simpson	5-78	May Monthly Report (Subsequent monthly reports have not been cataloged as formal reports)

TABLE A-II (continued)

GP Number	Author	Date	Title
140	C. J. Bliem	6-78	INEL Initial Evaluation of the MAPCO/RGI GLGP Application for Westmoreland Geothermal Project
141	O. J. Demuth	8-78	Preconceptual Design Study for the Second Raft River 5-MW (gross) Dual Boiling Direct Contact Pilot Plant
142	E. G. DiBello	8-78	Technical Evaluation for Honey Lake Hydroponic Loan Guaranty Application

TABLE A-III

AEROJET NUCLEAR COMPANY: EXTERNAL REPORTS

ANCR Number	Author	Date	Title
1138	J. F. Kunze, et. al.	4-74	A Low Temperature Demonstration Geothermal Power Plant in the Raft River Valley
1139	J. F. Kunze	2-74	Program Plan for FY-1974 Geothermal R&D Project
1155	J. F. Kunze, L. G. Miller	3-74	Idaho Geothermal R&D Report for Period December 16, 1973 to March 15, 1974
1175	J. F. Kunze, et. al.	8-74	Idaho Geothermal R&D Report for Period March 16, 1974 to July 15, 1974
1190	J. F. Kunze, et. al.	10-74	Geothermal R&D Project Report for Period July 16, 1974 to September 30, 1974
1203	J. W. Neitzel	4-75	Cooling Methods Study for the Proposed Raft River Geothermal Power Plant
1204	S. G. Spencer	1-75	Environmental Report, Deep Geothermal Test Wells in the Raft River Valley
1205	G. A. Reimann, H. W. Shutz	2-75	Choosing Material for the Raft River Geothermal Power Plant
1208	J. F. Kunze, et. al.	2-75	Geothermal R&D Project Report for Period October 1, 1974 to December 31, 1974

TABLE A-III (continued)

ANCR Number	Author	Date	Title
1210	J. F. Whitbeck	7-75	Design Concepts for Flash Steam Systems for use with Medium Temperature Geothermal Water
1211	J. F. Kunze, et. al.	4-75	Geothermal Space Heating Project Involving State Owned Buildings in Boise, Idaho
1213	C. R. Nichols, K. M. Hollenbaugh	6-75	Geological Aspects of the National Potential for Non-Electrical Utilization of Geothermal Resources
1214	J. F. Kunze, A. S. Richardson	6-75	National Program Definition Study for the Non-Electrical Utilization of Geothermal Energy
1220	P. A. Roberts	6-75	Fish Culture Utilization of Geothermal Energy
1221	A. A. Bishop	6-75	Use of Geothermal Water for Agriculture
1222	J. F. Kunze	6-75	Idaho Geothermal R&D Project, Project Report for Period January 1, 1975 to March 31, 1975
1224	J. F. Whitbeck	7-75	Review and Tentative Selection of a Working Fluid for Use with a Medium Temperature (300°F) Geothermal Resource

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ANCR Number	Author	Date	Title
1226	R. H. Dart, D. T. Neill, J. F. Whitbeck	12-75	Conceptual Design and Cost Evaluation of Organic Rankine Cycle Electric Generating Plant Powered by Medium Temperature Geothermal Water
1241	J. G. Keller, et. al.	6-75	Geothermal Space Heating of a Geothermal Drill Rig
1245	W. W. Madsen, I. J. Ingvarsson	12-75	Analysis of the Binary Cycle for Geothermal Power Generation
1246	L. E. Donovan, A. S. Richardson	9-75	Feasibility/Conceptual Design Study for Boise Geothermal Space Heating Demonstration Project Building Modifications
1247	J. F. Kunze	9-75	Geothermal R&D Project Report for Period April 1, 1975 to June 30, 1975
1256	L. D. Torgerson, A. S. Richardson	9-75	Feasibility Review for Geothermal Conversion of Existing H&V Systems on the Boise Geothermal Space Heating Project
1258	L. E. Donovan	12-75	Feasibility/Conceptual Design Study for Boise Geothermal Space Heating Demonstration Project Distribution and Disposal System
1260	D. G. Swink, R. J. Schultz	4-76	Conceptual Study for Utilization of an Intermediate Temperature Geothermal Resource

TABLE A-III (continued)

ANCR Number	Author	Date	Title
1261	R. C. Stoker	10-75	Drilling Plan Boise Slim (2-3/8-in. diameter) Holes Demonstration Space Heating Project, October 1975
1279	S. G. Spencer	11-75	Environmental Assessment, Boise Demonstration Geothermal Space Heating Project
1281	Geothermal Task Force	12-75	Geothermal R&D Project Report for Period July 1, 1975 to September 30, 1975
1283	J. F. Kunze	1-76	Geothermal R&D Project Report for Period October 1, 1975 to December 30, 1975
1295	C. J. Shaffer	1-76	Geothermal Steam Plant Modeling and Power Tradeoff Studies
1317	A. S. Richardson	7-76	Survey of Industrial Dryers for Solids
1318	J. F. Kunze, J. F. Whitbeck	5-76	A Plan for Developing Moderate Temperature/ Low Salinity Geothermal Resources
1319	J. F. Kunze	6-76	Geothermal R&D Project Report for Period January 1, 1976 to March 31, 1976

TABLE A-IV

AEROJET NUCLEAR COMPANY: INTERNAL REPORTS

CI Number	Author	Date	Title
1266	J. F. Kunze	1-75	Program Plan for FY-1975 Idaho Geothermal R&D Project
1268	A. S. Richardson	3-75	FY-1975 Program Plan for INEL Non-Electric Geothermal Projects
1271			(Republished as ANCR-1256)
1274	Geothermal Task Force	8-75	Conceptual Design Report Geothermal Demonstration Power Plant, 10 MW Experimental Binary System

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CURRENTLY AVAILABLE BROCHURES

Title	Date
Geothermal Energy Beneficial Use Experiments	7-78
Idaho Geothermal Project	10-78
Prototype Power Plant, Raft River Geothermal Test Site	7-78
Regional Hydrothermal Development Plan, Executive Summary, July 1978	7-78
Rules of Thumb for Geothermal Direct Applications	7-78

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