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ASSESSMENT OF A GEOTHERMAL APPLICATION
AT TUCSON, ARIZONA

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U.S. Department of Energy

Idaho Operations Office • Idaho National Engineering Laboratory

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ABSTRACT

This study assessed the potential of using a geothermal energy source thought to underlie a large computer company's new facility near Tucson, Arizona. This energy source would be used with existing technology to meet the air conditioning and heating requirements of the proposed one million-square-foot expansion that would double the size of the facility. Cost data generated in this study could also be used to make economic determinations of retrofitting the existing, electrically driven centrifugal chillers with hot geothermal water-fired absorption chillers.

FOREWORD

The Geothermal Technical Assistance Program was developed under the premise that the majority of groups or individuals with available geothermal resources do not have the experience or manpower necessary to do a preliminary engineering and economic feasibility evaluation for geothermal energy projects. In order to disseminate technical information and to facilitate expanded use of geothermal energy resources, assistance was provided through FY-1981 in a consulting format on a first-come, staff-and-funds-available basis. Technical assistance can relate to conceptualization; engineering; economics; water chemistry implications for environmental, disposal, and material selection considerations; and planning and development strategies. This report is one of a series adapted from consultation provided to requesters either through in-house efforts or through limited efforts sub-contracted to local engineering firms. The Geothermal Technical Assistance (GTA) reports in this series, which are listed below, will be available early in 1982 to those with interest in specific geothermal applications.

<u>GTA Report No.</u>	<u>EG&G Report No.</u>	<u>Title</u>
1.	EGG-GTH-5512	<u>Aquaculture Facility Potential at Boulder Hot Springs, Boulder, Montana</u>
2.	EGG-GTH-5521	<u>Preliminary Geothermal Disposal Considerations, State Health Laboratory, Boise, Idaho</u>
3.	EGG-GTH-5573	<u>Geothermal Conversion at Veterans Hospital, Boise, Idaho</u>
4.	EGG-GTH-5574	<u>Geothermal Applications for Highway Rest Areas</u>
5.	EGG-GTH-5575	<u>Geothermal Applications for a Tannery</u>
6.	EGG-GTH-5599	<u>Preliminary Conceptual Design for Geothermal Space Heating Conversion of School District 50 Joint Facilities at Pagosa Springs, Colorado</u>
7.	EGG-GTH-5617	<u>Selected Geothermal Technical Assistance Efforts (comprising short descriptions of ten space heating projects, five district heating projects, and three heat exchanger projects)</u>

<u>GTA Report No.</u>	<u>EG&G Report No.</u>	<u>Title</u>
8.	EGG-2137	<u>Geothermal Source Potential and Utilization for Methane Generation and Alcohol Production</u> (subcontractor report)
9.	EGG-2138	<u>Geothermal Source Potential and Utilization for Alcohol Production</u> (subcontractor report)
10.	EGG-2139	<u>Potential Geothermal Energy Applications for Idaho Elks Rehabilitation Hospital</u> (subcontractor report)
11.	EGG-2144	<u>Technical Assistance Report on a Geothermal Heating Utility for Lemmon, South Dakota</u> (subcontractor report)
12.	EGG-2145	<u>Economic Analysis for Utilization of Geothermal Energy by North Dakota Concrete Products Company</u> (subcontractor report)
13.	EGG-2146	<u>Geothermal Feasibility Analysis II for Polo School District No. 29-2, South Dakota</u> (subcontractor report)
14.	EGG-2147	<u>Preliminary Feasibility Study of Heating and Cooling Alternatives for Nebraska Western College, Scottsbluff, Nebraska</u> (subcontractor report)
15.	EGG-2148	<u>Inventory of Thermal Springs and Wells Within a One-Mile Radius of Yucca Lodge, Truth or Consequences, New Mexico</u> (subcontractor report)
16.	EGG-2149	<u>Space Heating for Spa Facilities at Ojo Caliente, New Mexico</u> (subcontractor report)
17.	EGG-2150	<u>Geothermal Heated Office Building at Glenwood Springs, Colorado</u> (subcontractor report)
18.	EGG-2151	<u>Final Report--Dickinson Geothermal Study, Dickinson, North Dakota</u> (subcontractor report)
19.	EGG-2152	Cancelled
20.	EGG-2153	<u>Comparison of Two Options for Supplying Geothermal Energy to the Veterans Administration Medical Center, Marlin, Texas</u> (subcontractor report)

<u>GTA Report No.</u>	<u>EG&G Report No.</u>	<u>Title</u>
21.	EGG-2154	<u>Geothermal Utilization at Castle Oaks Subdivi- sion, Castle Rock, Colorado (subcontractor report)</u>
22.	EGG-2155	<u>Space Heating for Twin Lakes School Near Gallup, New Mexico (subcontractor report)</u>
23.	EGG-2156	<u>Pumping Tests of Well Campbell Et Al. No. 2, Gila Hot Springs, Grant County, New Mexico (subcontractor report)</u>
24.	EGG-GTH-5739	<u>Geothermal Deicing of Highways and Bridge Structures</u>
25.	EGG-GTH-5740	<u>Assessment of a Geothermal Application at Tuscon, Arizona</u>
26.	EGG-GTH-5741	<u>Heat Pump Systems for Spring Creek, Montana</u>
27.	EGG-GTH-5779	<u>Pipe Selection Guide</u>

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ASSESSMENT OF A GEOTHERMAL APPLICATION AT TUCSON, ARIZONA

INTRODUCTION

Rapidly escalating energy costs and indications of an appropriate accessible geothermal resource led a large computer company to investigate using geothermal energy for space conditioning in a planned enlargement of its facilities. An Exxon Corporation exploration well, located within three miles of the facility had reportedly encountered hot (147°C) geothermal brine at a depth of 3,830 metres. Existing facilities, completed in 1979, would be approximately doubled by the construction of a one-million-square-foot addition to be completed by 1984.

PRESENT ENERGY USE IN PHASE I

Phase I of the facility was completed and in partial operation by late 1979. The existing buildings require a peak cooling load of approximately 4,496 tons of air conditioning, 60% of which arises from heat generated during normal plant processing operations. The monthly totals for cooling and heating are shown in Table 1.

TABLE 1. COOLING AND HEATING LOADS BY MONTH

	<u>Cooling Load</u> (in million Btu)	<u>Load</u> <u>Factor</u> (%)	<u>Heating Load</u> (in million Btu)
Jan	9,824	40.8	1,897
Feb	7,851	32.6	2,475
Mar	12,629	52.4	1,629
Apr	12,123	50.3	1,183
May	19,623	81.4	273
Jun	22,088	91.6	0
Jul	25,527	105.9	0
Aug	23,745	98.5	0
Sept	22,276	92.4	0
Oct	17,481	72.5	730
Nov	10,285	42.7	1,897
Dec	9,802	40.7	2,333
TOTALS	193,253		12,417

The major portion of chilled water is produced at night during offpeak electric rate time. Electric centrifugal chillers produce the chilled water, which is stored in underground tanks for the following day's use. The load factor shown in Table 2 is a percentage of time required for the two existing 1,350-ton chillers to operate and meet the monthly cooling demand. During July, for example, the chillers operate and store chilled water at night and also operate during the day to meet the high summer cooling load, which results in constant unit operation. Domestic hot water is also provided by the electric chillers operating in a heat recovery mode.

TABLE 2. ENERGY REQUIREMENTS (Phase II)

Maximum cooling load	3654 tons
Maximum domestic water (105°F)	70 gpm
Maximum heating water (130°F)	70 gpm

PHASE II ENERGY REQUIREMENTS

It is the purpose of this study to assess the potential for a geothermal resource to provide the air-conditioning and heating requirements for the proposed second development phase. From data received, Phase II would have a heating and domestic hot water load similar to Phase I, and have a cooling load of 3,654 tons. (See Table 2.)

It was further assumed that all chilled water lines and components need not be addressed in this report.

GEOHERMAL AIR CONDITIONING SYSTEM

The air conditioning load could be met with lithium bromide absorption-type water chillers fired by water temperatures between 160 and 300°F. Maximum efficiencies, of course, are realized in the upper end of this temperature range. A source of cooling water is required and is usually provided by cooling towers. Commercial absorption units are available with air-conditioning capacities as large as 1,600 tons; however, several smaller sized units could more closely match the air conditioning requirements. For

example, under partial load conditions, the number of operating chillers can be reduced to most effectively match the required load conditions. For the purposes of this study a total of four 610-ton units were selected to meet the 3,654 tons of additional capacity for Phase II. Other sizes could be selected and would be equally as valid. These four units were chosen with installed capacity lower than that required to met the peak demand since storage potential was assumed similar to Phase I. Space limitations will also play an important part.

The absorption chillers have a coefficient of performance of approximately 67%. New double-staged absorber water chillers are currently on the market with reported coefficients of 95-99%, which would improve overall project economics. A 67% coefficient was used in this report, however, to realistically illustrate the energy analysis under partial load conditions and to simulate other losses that might be attributed to heat exchange fouling.

Temperatures of approximately 300°F have been recorded in a nearby, deep, oil test well drilled in 1972. It is anticipated that producing temperature might be in excess of 300°F because the recorded temperatures were measured shortly after well completion. Temperatures near 300°F pose no problems to current start-of-the-art well material, pumps, and other components. Should temperatures higher than 350°F be encountered on a non-artesian basis, then well pump components may pose a problem. It has been estimated that if sufficient permeability is encountered, then production should range up to 500 to 1200 gallons per minute. For the purposes of this report, it was assumed that sufficient quantities of 350°F are present within the facility area. More specifically, it was assumed a well could be located within one-half mile of the water chiller complex.

A centralized geothermal air conditioning system is shown in Figure 1.

If the geothermal system is allowed to generate and store chilled water during the night, as is the case for the present system, the use of geothermal water is reduced dramatically.

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Figure 1. A centralized geothermal air conditioning system.

The chemical nature of the geothermal resource is totally unknown. It is, however, expected to be moderately saline (4,000-20,000 ppm). For estimating purposes, a plate-type heat exchanger was selected to isolate any possible harmful effects of the geothermal water from the vapor generators in the absorption water chillers. Because of the high temperatures involved, only insulated steel pipe has been considered between the well and heat exchanger and from the heat exchanger to the absorption chillers. Spent geothermal water from the heat exchangers could be used for providing domestic hot water before being discharged.

HEATING AND DOMESTIC WATER REQUIREMENTS

The demand for domestic hot water is shown in Table 3, recorded for the maximum flow:

TABLE 3. DOMESTIC HOT WATER DEMAND

<u>105°F</u> Domestic Hot Water Temperature			
	<u>Shift</u>	<u>Max gpm</u>	<u>Average</u>
	1	66.7	6.1
	2	12.5	1.2
	3	4.2	0.4
<u>130°F</u> Heating System Water Temperature			
	1	70.8	5.9
	2	13.3	1.1
	3	4.4	0.4

The total amount of 105°F and 130° water for average daily use is 21,630 gallons. If this water were provided by fossil fuel-heated ground water (55°F), the average hourly expenditure is nearly 500,000 Btu/hr. This moderately small load could be met with relative ease from the plate heat exchanger exit water. Figure 2 illustrates the design conditions.

Figure 2. System design for daily water use.

Piping

Steel pipe will be required to convey the high-temperature geothermal water to the heat exchanger and from the heat exchanger to the water chillers. Discharge lines from the heat exchanger and return lines from the water chillers could use an asbestos cement or fiberglass pipe material. However, for this report, the cost of an all-steel piping system was chosen for estimating purposes. Figure 3 shows the distances used in costing the piping material.

The piping system for the domestic hot water and heating system water was sized to handle a maximum of 70 gpm each with velocity flows of approximately 8 feet per second. All three circulation systems were assumed to be installed within the same trench work, thereby avoiding excessive installation costs. Aboveground service may be feasible if caution is taken for personnel safety and frost protection.

Discharge Possibilities

Discharge water temperature from the heat exchanger at the well site may be as high as 200°F. Under certain peak conditions for heating and domestic hot water, while experiencing below-peak cooling needs, the majority of water may be as low as 110°F. If more of the 200°F water could be used for other domestic use, heat purposes, or stored as hot water for off-peak use, the discharge water could be regulated to guarantee a constant low temperature. The potential to use the discharge water should be examined to its fullest extent because of its obvious benefit in a water-critical area. Many alternatives exist to use the discharge water directly, such as aquaculture, agriculture, wet lands use, or other low-temperature applications that have shown promising results from current research and development work.

Alternately, the discharge water could be reinjected into a shallow aquifer system. This alternative must ensure the protection of high-quality water in shallow water production aquifer. This can be accomplished using reasonable care and current technology. This alternative, however, can be relatively costly owing to additional wells required and pumping costs.

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Figure 3. Distances for water pipe runs.

WELL COSTS

Existing data, primarily the Exxon well located south of the proposed site, was used as the basis to establish well design criteria. Plant end-use requirements were used to design hole size and depth to accommodate needed flows and temperatures.

The well design approach was to minimize well costs by achieving an economic balance between minimum hole size required for production flows, and staying within hole size requirements for an optimum exploration hole. An optimum exploration hole size is 6 3/4 in. to 7 7/8 in. at the bottom. The minimal hole size for a production well is 8 3/4 in. Figure 4 shows a cross section of each well. Both wells were costed to allow for cost comparison. The smaller hole was estimated to cost \$1,894,000, as shown in Table 4. The larger production hole's estimated cost was \$2,061,000, as shown in Table 5. For such a minor cost difference (\$167,000), it is recommended to spend the additional money for a production hole. The larger hole will allow for full production potential, yet be large enough to set a production liner in the open hole if hole stability is needed.

RECOMMENDATIONS

The promising evidence of hydrothermal resources underlying or in close proximity to the development site suggests that the project continue through a life-cycle costing or other economic technique phase. It is recommended that a qualified architecture and engineering firm be employed to refine the cost estimate and produce a preliminary design. The chemical nature of the resource should be further defined, perhaps through a shallow well program or inference to the Exxon well. The potentials for discharge should also be examined to maximize the benefit arising from geothermal hot water. There are no known environmental or technical deterrents that would impede this project.

The total estimated cost for this project is shown in Table 6.

Figure 4. Cross sections of exploration and production holes.

TABLE 4. WELL COSTS FOR 7 7/8-IN. HOLE

Hardware	Costs (1979 dollars)
Mob/demob	\$ 250,000
Rig time--90 days @ \$7,000	630,000
Bits--3 x 15	
--7 x 10 5/8	
--20 x 7 7/8	47,000
Casing--40 ft x 16 in.	
--2500 x 11 3/4 (20/ft)	
--5000 x 8 7/8 (12/ft)	111,000
Cement	120,000
Casing hardware	7,000
Liner hanger	12,000
Wellhead	50,000
Mud logger	36,000
Mud	35,000
Welding, misc., transp.	10,000
Stabilization	20,000
Jars shock subs	7,000
Logging	45,000
Coring	15,000
Testing (three-day test)	25,000
Drilling supervision	36,000
	<u>\$1,456,700</u>
30% contingency	436,800
TOTAL	<u>\$1,893,500</u>

TABLE 5. WELL COSTS FOR 8 3/4-IN. HOLE

Hardware	Costs (1979 dollars)
Bits--3 in. x 17 1/2 in.	
--7 in. x 12 1/4 in.	
--20 in. x 8 3/4 in.	\$ 61,600
Casing--40 x 20 (35/ft)	
--2500 x 13 3/8 (25/ft)	
--5000 x 9 5/8 (16/ft)	250,000
Casing hardware	10,000
Cement	135,000
Liner hanger	15,000
All items not changed on Option 1	1,123,000
Drilling supervision	36,000
	<u>\$1,585,600</u>
30% contingency	475,680
<u>TOTAL</u>	<u>\$2,061,280</u>

TABLE 6. COSTS

Piping

Including installation costs, geothermal supply, and discharge lines @ 9 in., 5,280 ft	\$ 98,980
Water chiller supply and return lines @ 9 in., 5280 ft	183,375
Miscellaneous geothermal piping	7,000
Domestic water supply and return lines, 2 in., 5280 ft	58,400
Heating system supply and return lines, 2 in., 5280 ft	58,400
Valving and controls	115,000
Expansion tanks	<u>12,000</u>
SUBTOTAL	\$ 533,155

Heat Exchangers

Geothermal-to-water chiller main heat exchanger	\$ 109,400
Domestic water heat exchanger	2,385
Heating system heat exchanger	3,170
Installation	<u>6,000</u>
SUBTOTAL	\$ 120,955

Water Chillers

Four, 610-ton lithium bromide absorption units	\$ 320,000
Installation @ \$35/ton	85,400
Miscellaneous valves, controls	<u>41,500</u>
SUBTOTAL	\$ 446,900

Cooling Towers

4 units	\$ 76,800
Controls and valving	18,000
Installation @ \$10/ton	<u>24,400</u>
SUBTOTAL	\$ 119,200

TABLE 6. (continued)

<u>Pumps (including installation)</u>		
Production pump and wellhead equipment		\$ 137,500
Circulation pumps		27,500
Supply line discharge pump		25,000
Domestic water circulation pump		9,200
Heating system circulation pump		<u>9,200</u>
SUBTOTAL		\$ 208,400
<u>Wells</u>		
8-3/4 in. hole, 10,000 ft depth	SUBTOTAL	\$2,061,280
	TOTAL ESTIMATED COST ^a	\$3,489,890

a. Excluded from the above tabulations are costs associated with geophysical studies or exploration before well drilling as well as for costs for preliminary and final system design. Contingency and architecture and engineering fees have also not been included as the above costs reflect 1979 real dollar costs.