CHAPTER 3

PRELININARY EVALUATION OF AN ADVANCED BINARY POWER PLANT FOR BIG CREEK HOT SPRING

J. A. MICHELBACHER
T. W. LAWFORD
O. J. DEMUTH

EG&G IDAHO, INC.
P.O. BOX 1625, WCB, E3
IDAHO FALLS, ID 83415

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INTRODUCTION

The INEL has performed an engineering and economic feasibility study of the electric power generating potential of the Big Creek Hot Springs geothermal system in Lemhi County, Idaho. This study has been performed in cooperation with the University of Utah Research Institute (UURI) through the Technical Assistance Program. A plant size of 11 MWe net was considered with the power to be used by the nearby Blackbird Cobalt Mine and the town of Cobalt, Idaho. An advanced binary power generation cycle was determined to be the most efficient for this resource. Costs presented in this report are in second-quarter 1980 dollars.

SUMMARY

This preliminary evaluation of the Big Creek Hot Springs geothermal system is based upon electric power generation using an advanced binary cycle. Cycle optimization studies show a mixture of propane (95%) and hexane (5%) to be an effective working fluid for this plant. Due to the terrain in this area, this report proposes locating the power plant adjacent to Panther Creek where the geothermal fluid would be piped from the Big Creek Hot Springs area. Power would then be transmitted along Panther Creek approximately 13 miles to where it would tie into the Idaho power grid which supplies power to the Blackbird Mine and the town of Cobalt. This evaluation also assumes that by the use of directional drilling, multiple geothermal wells can be located on the same well pad.

Cost estimates were made for average well flow rates of 200,000 lb/hr and 400,000 lb/hr with an average resource temperature of 300°F (149°C). The results show that the cost of power at the lower flow rate would be about 160.2 mill/kWh and 122.2 mill/kWh at the higher flow rate. If a well life of 15 years is assumed, these costs would be increased by 15.5 mill/kWh and 8.6 mill/kWh respectively to cover the cost of replacement wells.

DISCUSSION

A. General

This report presents a preliminary engineering and economic study performed by the INEL for a geothermal power plant located at the Big Creek Hot Springs geothermal system in Lemhi County, Idaho. The proposed plant will produce 11 megawatts (net) of electricity which will be used to power operations at the Blackbird Cobalt Mine and supply additional power to the Town of Cobalt, Idaho.

B. Power Plant Performance

The resource temperature at Big Creek Hot Springs has been estimated to be approximately 300°F (149°C) by UURI. This temperature was arrived at by using a quartz conductive geothermometer. As shown in Figure 1, the net brine effectiveness (net power output per unit brine flow) at the anticipated temperature range of this resource is significantly higher for conventional binary systems than for dual flash steam systems. By utilizing mixtures of working fluids, an advanced binary cycle has been developed which has a net brine effectiveness approximately 40% greater than the conventional binary cycle at this resource temperature. This fluid is a mixture of propane (95%) and hexane (5%) and was selected as an optimum working fluid for the design temperature of the plant with the aid of the INEL computer code THERPP. Figure 2 is a pressure-enthalpy diagram of the working fluid cycle complete with the vapor dome for this mixture.

Figure 3 is a simplified power plant system diagram showing flow rates, temperatures, pressures and enthalpies for the geothermal fluid, working fluid, and cooling water. These parameters were used to evaluate the heater and condenser loads.

The heaters utilized for this system are of counterflow design with a heat transfer area of approximately 140,000 square feet. To minimize the physical size of these heaters, finned tubes were used. Three heaters 8 feet in diameter and 70 feet long will be required to meet the heat load requirements.

FIGURE 1

Net Brine Effectiveness

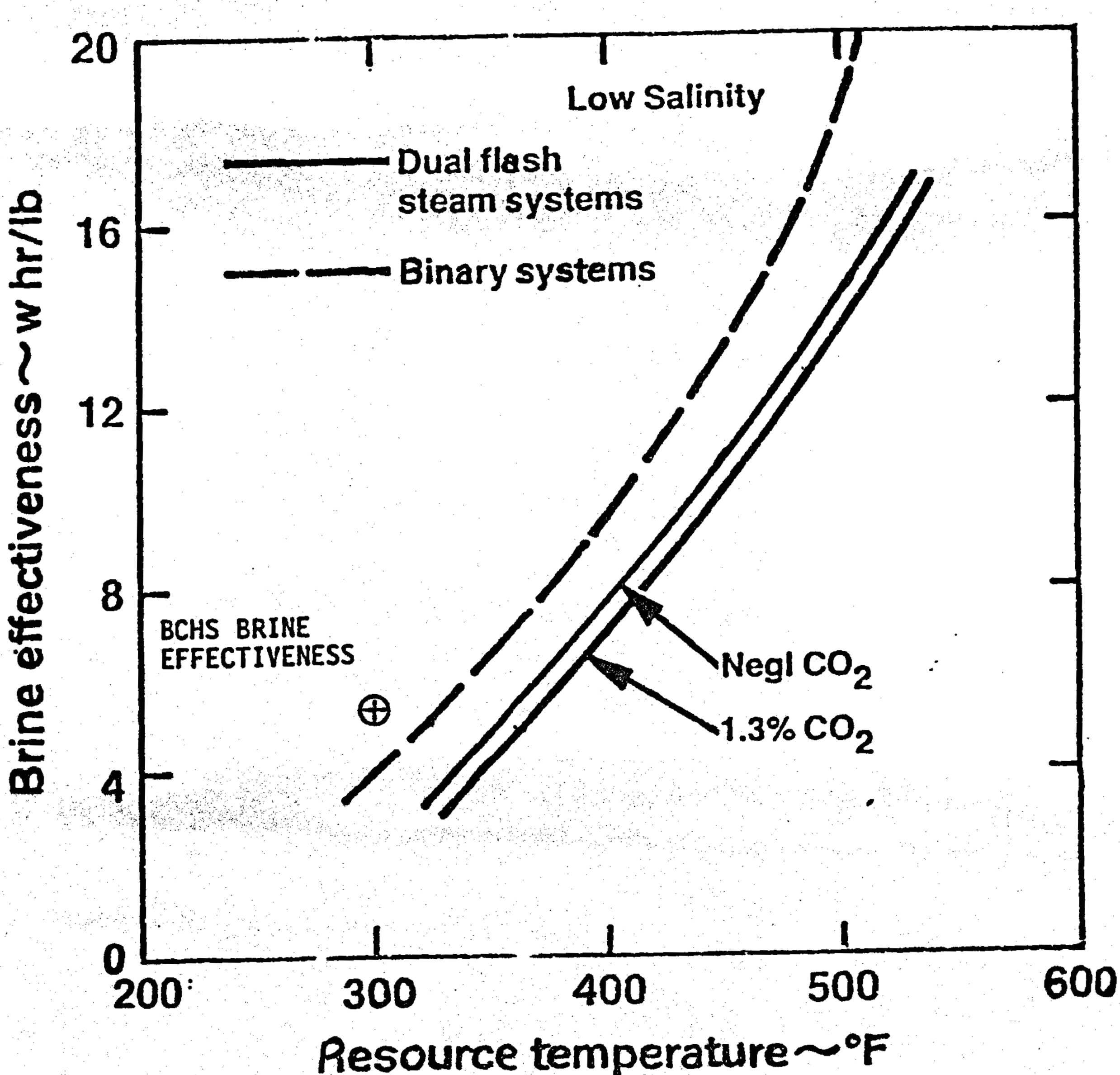

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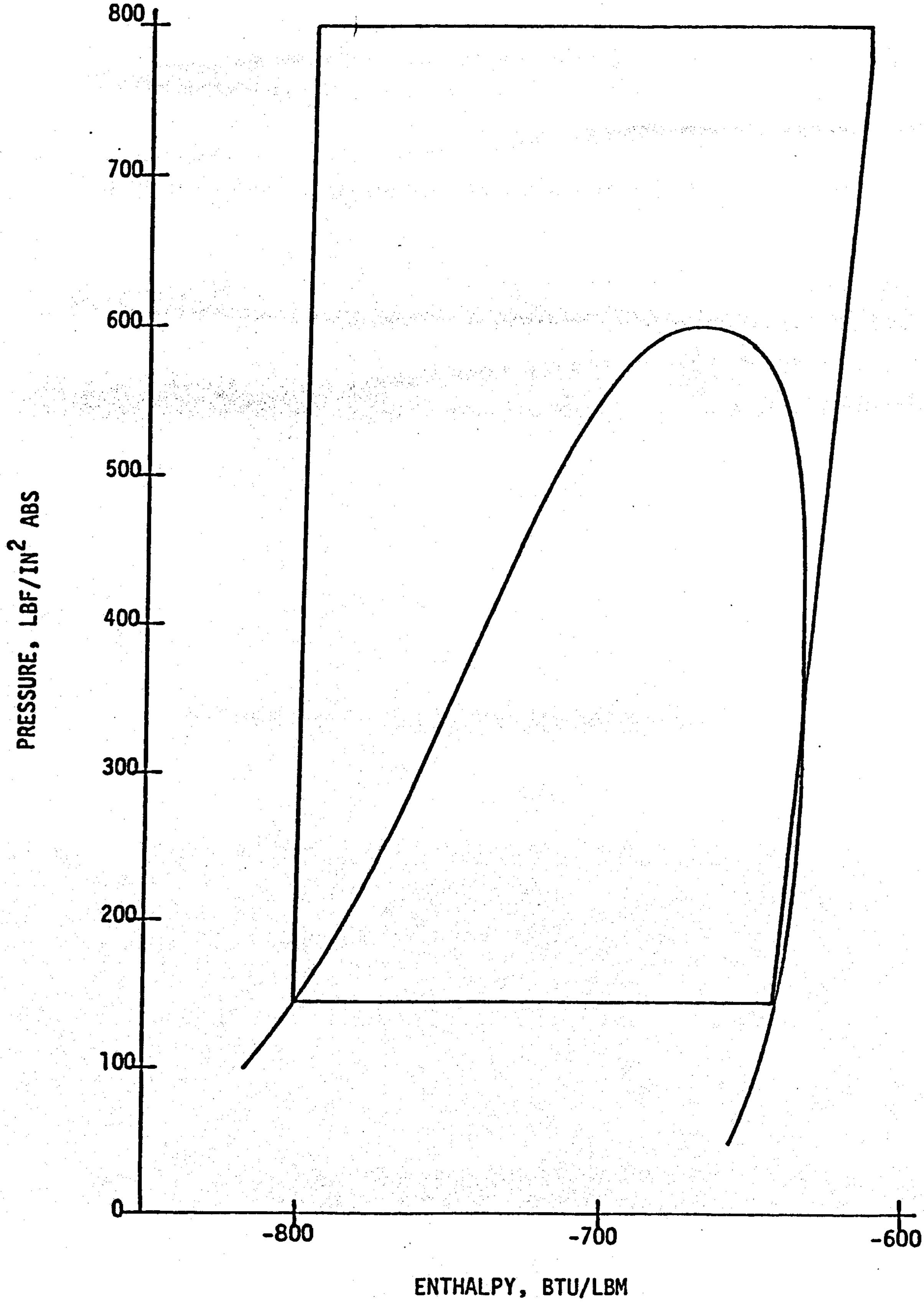
FIGURE 2. - Pressure - Enthalpy Diagram for Big Creek Hot Springs Working Fluid Cycle



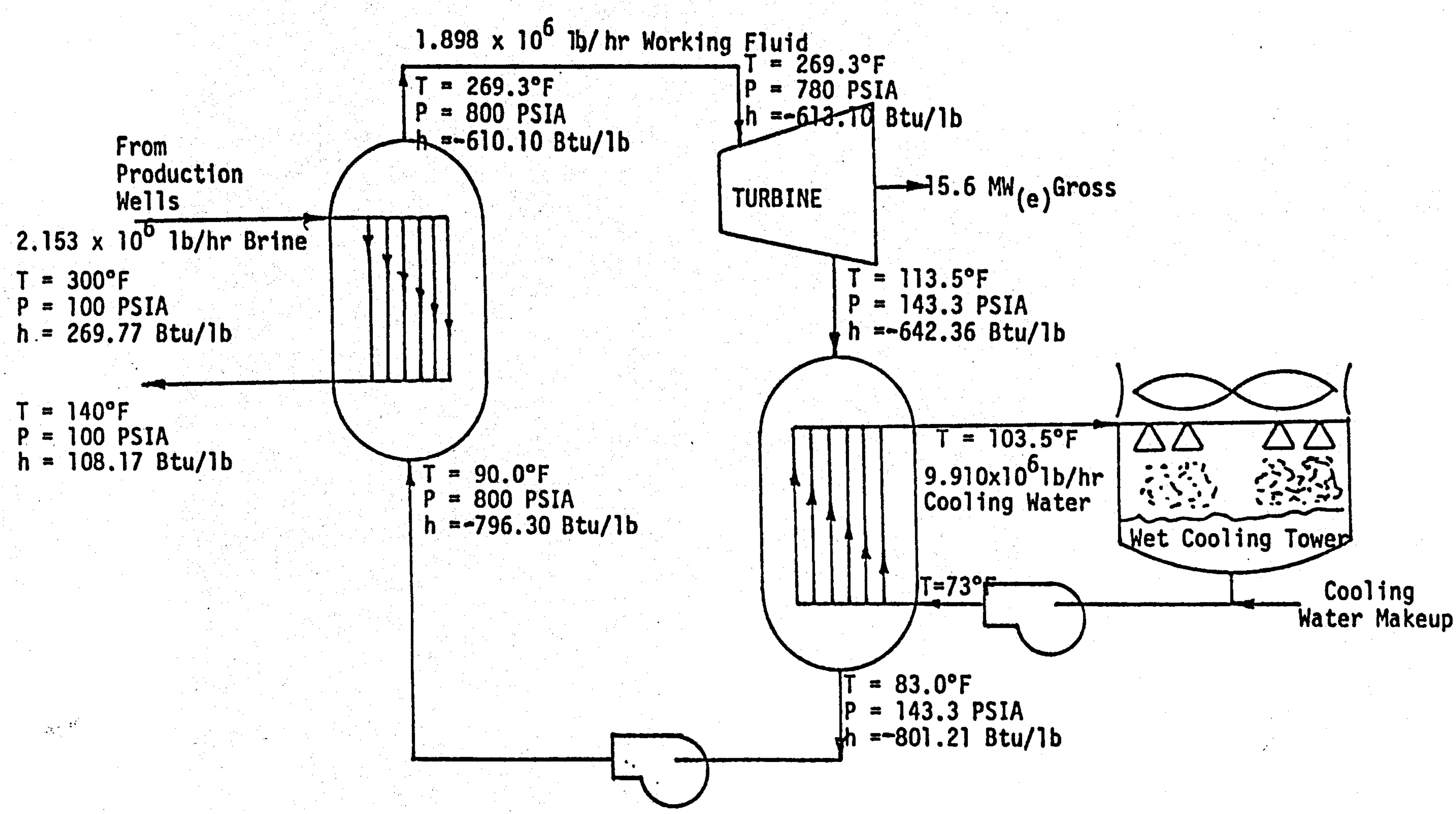


FIGURE 3. Proposed System Diagram for the Big Creek Hot Springs Geothermal System

The condensers specified are similar to the heaters in that they are also counterflow with finned tubes. Approximately 200,000 square feet of heat transfer area is required to condense the working fluid to the parameters shown on Figure 2. Two units are required with diameters of 16 feet and 12 feet, both being 70 feet long.

Due to the anticipated difficulty of constructing the power plant near the geothermal field, INEL proposes erecting the plant adjacent to Panther Creek and piping the brine from the well field to the power plant. A sketch of this plant illustrating the major components is shown in Figure 4.

The plant capital costs total $25,490,000 and are broken down in Table 1. Many of these costs were scaled from the Geothermal Loan Guarantee Program data base and are presented in second quarter 1980 dollars.

Plant O&M costs are listed in Table 2. The staff costs have been reduced on the assumption that many of the miscellaneous plant maintenance tasks can be absorbed by the Blackbird Mine staff.

Since nearby Panther Creek freezes over in the winter, INEL proposes drilling a fresh water well near the power plant to provide cooling water makeup.

C. Field System

The field system for the Big Creek Hot Springs geothermal system was costed for two average well flow rates; 200,000 lb/hr and 400,000 lb/hr. These costs were based on having multiple production wells (up to six) directionally drilled from each well pad. The required well depth was estimated by UURI to be 6000 feet. At the lower flow rate eleven production wells are required, while six will be necessary at the higher flow rate.

1. Heaters - 8' Dia. x 70' long
2. Turbine
3. Generator
4. Condensers - 12' & 16' Dia x 70' long
5. Condensate Tank - 10' Dia x 55' long

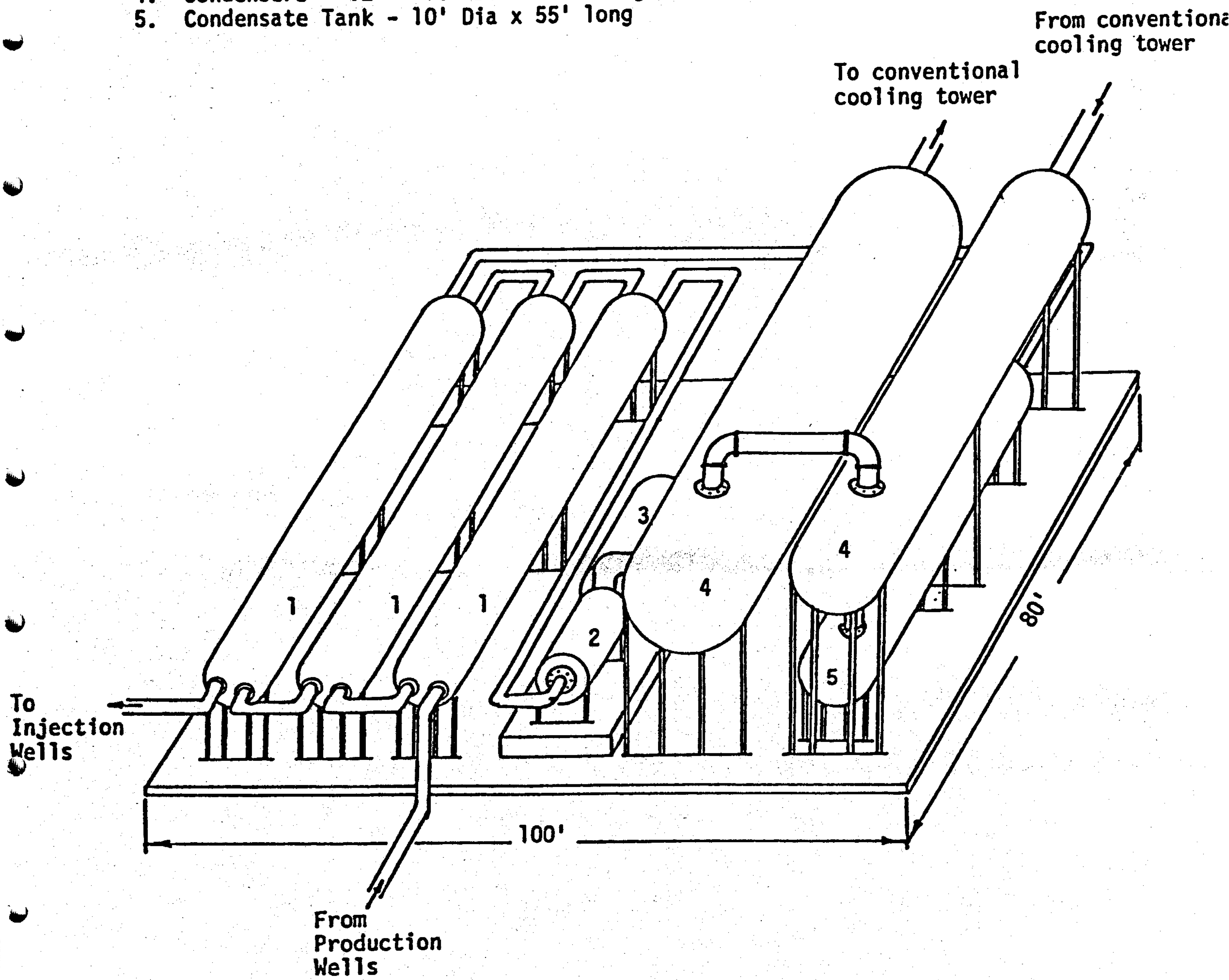


Figure 4. Process Area for Big Creek Hot Springs Geothermal Power Plant

Table 1. 11 MW(e) Net Binary Plant for Big Creek Hot Springs
(2nd Quarter 1980 $'s)

	Equipment	Labor	Total
Land & Land Rights			100,000
Structures & Improvements			
Plant Site Preparation			200,000
Foundations & Structures			1,000,000
Subtotal			1,300,000
Major Equipment			
Turbine Generator	2,550,000		
Condensers	3,000,000		
Cooling Water Piping	321,000		
Cooling Tower & Basin			447,100
Cooling Water Pumps	40,000		
Heat Exchangers	1,839,000		
Condensate Tanks	86,400		
Subtotal	7,836,400		
Construction & Small Equipment			
Crane	144,000		
Electrical & Switchgear	1,134,000		
I&C	1,000,000		
Working Fluid Piping & Valves	490,000		
Brine Piping & Valves	162,000		
Misc. Tanks & Piping	200,000		
Fire Protection System	150,000		
Misc. Mechanical Equipment	600,000		
Spare Parts & Tools	125,000		
Reinjection Pumps	0		
Reinjection Filters	370,000		
Feed Pumps	225,000		
Fresh Water Well			5,000
Subtotal	4,600,000		
Sales Tax @ 3%			373,100
Labor & Labor OH, 30% of Equip.		3,730,900	
Total Direct Costs, Excl. Land Rights			18,292,500
Contractor Markup & Constr. Mgt. (15%)			2,743,900
Contingency (10%)			2,103,600
Design			2,000,000
Plant Startup			250,000
TOTAL			25,490,000

Table 2. Annual Power Plant O&M Costs
(2nd Quarter 1980 $'s)

Staffing	293,333
4 Operators	
1 Laborer	
1 Superintendent	
Equipment Maintenance	216,468
Water Treatment	5,000
Miscellaneous	25,000
Total	539,801

Downhole pumps will be installed to assure the geothermal brine remains in the liquid state thus preventing any problems which could arise with two-phase flow in the production piping. This production piping is proposed to run approximately one mile from the well pads to the power plant located near Panther Creek. The size of this line is 20 inch NPS.

The field system costs for the previously mentioned flow rates are given in Table 3. Injection pumps are not included in these figures since the 800 foot elevation difference between the well field and power plant is assumed to provide sufficient head for injection. The injection wells will be located adjacent to the plant.

Field O&M costs are listed in Table 4. The staffing costs listed are reduced based on the assumption that many of the miscellaneous field maintenance tasks can be absorbed by the Blackbird Mine staff. This would, however, depend on who the field developer is and the working relationship maintained between the developer and the mine.

Average well life for this project is assumed to be 15 years, at which time the wells will have to be redrilled or replaced. The costs for these wells are listed in Table 4 as an average annual amount.

D. Transmission System

To transmit the power from the power plant to Blackbird Mine, it is proposed to run power line poles approximately 13 miles along Panther Creek to where the lines can tie into the Idaho power grid. The cost of this transmission system is estimated to be about $560,000. This is based on using 50 foot poles on 200 foot spans, with 1/0 stranded wire used to carry 24.9 kv at 255 amperes, 3 phase.

Table 3. 11 MW(e) Net Binary Field System Costs for Big Creek Hot Springs (2nd Quarter 1980 $'s)

	Average Well Flow Rate (lbm/hr)					
	200,000			400,000		
	Equip.	Labor	Total	Equip.	Labor	Total
Production Piping			1,075,236			786,346
Injection Piping			20,000			20,000
Production Wellhead "X-mas Trees"	709,544	212,863	922,407	387,024	116,107	503,131
Production Well Valves, I&C	279,323	83,797	363,120	152,358	45,707	198,065
Injection Well Valves, I&C	205,560	61,668	267,228	123,336	37,001	160,337
Downhole Pumps			1,058,200			876,000
Sales Tax (3% of materials)			66,381			41,872
Contractor Markup & Constr. Mgt. (15%)			565,886			387,863
Contingency (10%)			433,846			297,361
Design (5%)			238,615			163,549
Well Cost (at $1.296 x 10^6/well)			20,736,000			11,664,000
TOTAL			25,746,919			15,098,524

Table 4. Annual Field System O&M Costs
(2nd Quarter 1980 $'s)

	Average Well Flow Rate (lbm/hr)	
	200,000	400,000
Staffing	213,333	213,333
1 Roustabout 1 Foreman 1/2 Mechanical Engineer 1/2 Production Engineer		
Surface Equipment Maintenance	100,218	68,690
Production Well Maintenance	264,000	144,000
Injection Well Maintenance	281,500	168,900
Subtotal	859,051	594,923
Production Well Replacement	979,000	534,000
Injection Well Redrilling	215,000	129,000
Total	2,053,051	1,257,923

E. Summary

Table 5 summarizes the total cost of power in mills per kilowatt-hour. These prices are based on a 30 year plant life with an annual operating factor of 80%. The total fixed cost of capital on the plant was taken as 17%, while the field cost of capital was assumed to be 25%. A comparison of these costs with the costs of alternative energy sources will yield the economic feasibility of this study.

Table 5. Price of Power (mill/kw-h)

	Average Well Flow Rate (lbm/hr)	
	200,000	400,000
Field System Capital Costs	83.6	49.0
Field O&M Costs	11.1	7.7
Plant Capital Costs	56.7	56.7
Plant O&M Costs	7.0	7.0
Transmission Line Costs	1.8	1.8
Well Replacement/Redrilling	15.5	8.6
Total	175.7	130.8