GEOTHERMAL COMMERCIAL POWER PLANT STUDY

MASTER

Monthly Progress Report

for Period January 29, 1977 to February 25, 1977

Prepared for

THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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1 SUMMARY OF WORK ACCOMPLISHED

The major effort was concentrated on Task 10, Plant Operating Modes. Conceptual designs and capital cost estimates were completed for the six different Heber power plants in this study. The six plants involve two types of operating modes, "constant geothermal fluid flow rate" and "constant power output," each for net capacities of 50, 100, and 200 MWe. Conceptual designs were completed for the six plants by modifying and scaling-up the base case design described in the last monthly progress report, dated March 8, 1977. The capital costs for all six plants were estimated in fourth-quarter 1976 dollars.

Work is proceeding on a schedule that assumes the four-week time extension and additional funding discussed in the monthly progress report dated January 31, 1977 will be granted by ERDA. The initial request for this extension and funding was transmitted to ERDA on February 16, 1977. A follow-up inquiry requesting that we be advised of ERDA's determination by April 30, 1977 was sent on April 7, 1977.

2 DISCUSSION OF WORK ACCOMPLISHED

2.1 Task 10 - PLANT OPERATING MODES

Curves of required brine flow rate for the 50, 100, and 200 MWe plants that employ the "constant power output" operating mode were included in the last monthly progress report as Figure 6. These curves formed the bases for the conceptual designs of these plants. The curves show that the brine flow rates are greatest for the last (30th) year of plant operation. Gross power outputs necessary to produce 50, 100, and 200 MWe net are also greatest in year 30. Since equipment such as flash tanks, pumps, condensers, the cooling tower and piping must be sized for the greatest flow rates, and the turbine-generator for the greatest gross power output, year 30 was used as the basis for design for the three plants employing the "constant power output" operating mode. Figure 1 is a Flow Diagram for the 50 MWe (net) plant, which illustrates the conceptual design for the "constant power output" operating mode. This plant consists of the same equipment items and arrangement as the base

case design, but the equipment is larger as necessary to accommodate increased flow rates and additional gross power.

Curves illustrating the net power output as a function of time for 50 MWe equivalent units that make up the 50, 100, and 200 MWe equivalent plants employing the "constant brine flow rate" operating mode are shown in Figure 2. The conceptual designs for these plants were based on these curves. The curves shown in Figure 2 were developed by Bechtel using the Chevron temperature decline curves that were included in the last monthly progress report.

As brine temperature declines over the lifetime of the plants designed for the "constant brine flow rate" operating mode, the net power outputs from the 50, 100, and 200 MWe equivalent plants, decrease. Consequently, gross power outputs are greatest in the first year of plant operation, and the turbine-generator must be selected for the conditions that occur in this year. Steam and cooling water flow rates which affect the size of other plant equipment, will also be greatest in the first year of plant operation. Therefore, year 1 was selected as the design year for these plants. The conceptual design for the plants employing the "constant brine flow rate" operating mode is illustrated by Figure 3, which is a Flow Diagram for the 50 MWe (net) plant.

Additional aspects of the conceptual designs for both operating modes are included in Tables 1 and 2. Table 1 compares the gross power output from the 50 MWe base case plant to that of the 50 MWe units making up the six other plant designs. Table 2 shows the specific net energy (watthour per pound of brine) in year 1 and in year 30 for all plant designs. It is seen that in year 1 the specific net energy is highest and nearly the same for all plants, but it falls off in year 30 as brine temperature declines. It is the lowest in year 30 for the 200 MWe plants which cause the brine temperature to decrease at the fastest rate and to the lowest level.

Capital cost estimates were developed for 50, 100, and 200 MWe plants using both operating modes. This was accomplished by appropriately

POWER OUTPUT VERSUS TIME CONSTANT BRINE FLOW RATE OPERATING MODE

Figure 2

Figure 3

TABLE 1
GROSS POWER OUTPUT
GEOTHERMAL POWER PLANT
HEBER, CALIFORNIA

	Gross Power Output (MWe)
Base Case (50 MWe)	57.6
Constant Power (Year 30)	
50 MWe Unit for 50 MWe Plant	58.4
50 MWe Unit for 100 MWe Plant	59.0
50 MWe Unit for 200 MWe Plant	60.6
Constant Brine Flow Rate (Year 1)	
50 MWe Unit for 50 MWe Plant	64.1
50 MWe Unit for 100 MWe Plant	67.8
50 MWe Unit for 200 MWe Plant	74.9

TABLE 2
SPECIFIC NET ENERGY
GEOTHERMAL POWER PLANT
HEBER, CALIFORNIA

	Brine Flow Rate (10 ⁶ lb/hr)		Net Power (MWe)		Specific Net Energy (Wh/lb Brine)	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Base Case	10.1	10.1	50	50	4.95	4.95
Constant Power						
50 MWe Unit for 50 MWe Plant	10.2	12.0	50	50	4.90	4.17
50 MWe Unit for 100 MWe Plant	10.2	13.4	50	50	4.90	3.73
50 MWe Unit for 200 MWe Plant	10.3	17.0	50	50	4.85	2.94
Contant Brine Flow Rate						
50 MWe Unit for 50 MWe Plant	11.3	11.3	55.7	47.0	4.93	4.16
50 MWe Unit for 100 MWe Plant	11.9	11.9	58.9	45.3	4.95	3.81
50 MWe Unit for 200 MWe Plant	13.1	13.1	65.2	41.5	4.93	3.17

revising the base case equipment list and piping list and cost estimating the revised lists. Two estimates were made for each of the six plants, one for the high cost turbine-generator (General Electric) and the other for the low cost turbine-generator (Mitsubishi). The resulting estimates are shown in Table 3 for the 50 MWe plant designed for "constant power output," and in Table 4 for the 50 MWe plant designed for "constant brine flow rate." Table 5 summarizes the capital cost estimates for all cases. As expected, capital cost increases for both operating modes as plant capacity increases. It is important to note, however, that the capital cost of the plants designed for "constant brine flow rate" are greater than plants of the same capacity designed for "constant power output." The increase in capital cost for the "constant brine flow rate" operating mode, caused by the necessity to design for increased gross power output in year 1 is greater than the increase for the "constant power output" mode, caused by the requirement to design for increased flow rates in year 30.

3 FUTURE PLANS

The next effort will concentrate on Task 12, Energy Production Cost. The "lower limit" geothermal fuel price will be developed, based on the capital and O&M cost of the well field owned and operated by a utility company. The well field capital cost includes the cost of production and reinjection wells, pipelines to the power plant, and related equipment. Plant capital and O&M costs will then be combined with the geothermal fuel costs, using the net present value technique, to estimate levelized electric energy production costs in terms of mills per kilowatt hour.

4 FINANCIAL STATUS

Total estimated contract cost		\$413,633
Previous expenditures	\$347,720	
Estimated expenditures this period	15,870	
Cumulative expenditures to date		<u>\$363,590</u>
Funds remaining		\$ 50,073

Table 3

CONCEPTUAL CAPITAL COST ESTIMATE SUMMARY
 50 MWe (NET) GEOTHERMAL POWER PLANT
 HEBER, CALIFORNIA

CONSTANT POWER OUTPUT OPERATING MODE

	Installed Cost (1,000)	
	High Turb-Gen Cost	Low Turb-Gen Cost
Field Construction		
Mechanical Equipment	15,805	11,480
Turbine-Generator	10,370	6,040
Flash Tanks	400	400
Condenser	850	850
Cooling Tower	1,290	1,290
Pumps and Drives	2,250	2,250
Auxiliary Systems	645	645
Piping and Instrumentation	4,860	4,860
Piping, Valves and Insulation	3,600	3,600
Instrumentation and Controls	1,260	1,260
Electrical	3,215	3,210
Distribution Equipment	1,580	1,580
Cable and Raceways	1,085	1,085
Lighting and Miscellaneous	550	550
Civil/Structural	3,790	3,790
Turbine Building	1,950	1,950
Site Improvements	470	470
Concrete and Earthwork	1,370	1,370
Field Construction Cost	27,670	23,340
Engineering Services	3,320	2,810
Allowance for Uncertainty	5,010	5,250
Total Installed Cost	36,000	31,400

Fourth Quarter 1976

Table 4

CONCEPTUAL CAPITAL COST ESTIMATE SUMMARY
50 MWe (NET) GEOTHERMAL POWER PLANT
HEBER, CALIFORNIA

CONSTANT BRINE FLOW RATE OPERATING MODE

	Installed Cost (1,000)	
	High Turb-Gen Cost	Low Turb-Gen Cost
Field Construction		
Mechanical Equipment	16,920	12,150
Turbine-Generator	11,370	6,600
Flash Tanks	420	420
Condenser	880	880
Cooling Tower	1,415	1,415
Pumps and Drives	2,195	2,195
Auxiliary Systems	640	640
Piping and Instrumentation	4,770	4,770
Piping, Valves and Insulation	3,540	3,540
Instrumentation and Controls	1,230	1,230
Electrical	3,250	3,250
Distribution Equipment	1,615	1,615
Cable and Raceways	1,085	1,085
Lighting and Miscellaneous	550	550
Civil/Structural	3,890	3,890
Turbine Building	1,980	1,980
Site Improvements	470	470
Concrete and Earthwork	1,440	1,440
Field Construction Cost	28,830	24,060
Engineering Services	3,470	2,870
Allowance for Uncertainty	5,200	5,510
Total Installed Cost	37,500	32,300

Fourth Quarter 1976

Table 5
CONCEPTUAL CAPITAL COST ESTIMATE
FLASHED STEAM POWER PLANT
HEBER, CALIFORNIA

	HIGH TURB-GEN COST		LOW TURB-GEN COST	
	\$1,000	\$/KWe(NET)	\$1,000	\$/KWe(NET)
BASE CASE	35,000	700	30,400	608
CONSTANT POWER				
50 MWe UNIT FOR 50 MWe PLANT	36,000	720	31,400	628
50 MWe UNIT FOR 100 MWe PLANT	36,500	730	31,800	636
50 MWe UNIT FOR 200 MWe PLANT	38,200	764	33,400	668
CONSTANT BRINE FLOW RATE				
50 MWe UNIT FOR 50 MWe PLANT	37,500	750	32,300	646
50 MWe UNIT FOR 100 MWe PLANT	38,500	770	33,100	662
50 MWe UNIT FOR 200 MWe PLANT	41,400	828	35,400	708

FOURTH QUARTER 1976