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BINARY GENERATING UNITS at KELLY HOT SPRINGS, CALIFORNIA

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DISCLAIMER

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INTRODUCTION

The Geothermal Floral Company is the owner of a property around Kelly Hot Spring which is located approximately two miles northeast of the town of Canby in Modoc County in northeastern California, just south of State Highway 299. The temperature and artesian flowrate of Kelly Hot Spring are reported 196°F and 330 gpm. This temperature is near the boiling point for the elevation of the area (4,350 feet). The quality of the water appears to be good with respect to deposition and corrosion (Gudmundsson, 1984).

Two deep wells have been drilled in the vicinity of Kelly Hot Spring. The first well, located one-quarter mile south of Kelly Hot Spring, was drilled in 1969 to a depth of 3,200 feet. Temperatures rose rapidly to about 1,600 feet. A major lost-circulation zone at that depth was followed by essentially adiabatic conditions to total depth. Maximum reported temperature was 110°C (230°F). This well was reported to produce about 20 gpm at completion. In 1974, another well was drilled to 3,396 feet about two miles to the east. A similar pattern of increasing temperature was observed with lost-circulation zone beginning at about 1,760 feet and going to total depth, accompanied by near-adiabatic temperature conditions. Maximum reported temperature in 1974 was 107°C (225°F) at hole bottom (Gudmundsson, 1984).

Temperature measurements in the second well made in 1977 showed a maximum of 115°C (239°F) at about 3,350 feet. There is therefore good accord between these two wells. This suggests the presence of an extensive, internally communicative, boiling water aquifer beneath several square miles at one-half to over one kilometer (1,640 to 3,280 feet) in depth. Wells completed in this depth interval are likely to produce liquid water in the temperature range 100°to 115°C (212° to 239°F, Gudmundsson, 1984).

On the basis of the above findings, the Ormat Turbines, Ltd. has submitted a proposal to the Geothermal Floral Company for one 600 kW binary generating unit and three 300 kW binary generating units (see Attachment). The output of the units is based on an 1,800 gpm supply of geothermal water at 220°F and 7,500 gpm of cooling water at 55°F.

This report presents the results of a study to determine the technical and economic feasibility of power generation at Kelly Hot Spring using binary power plants in accordance with the Ormat Turbines, Ltd. proposal.

SUMMARY AND CONCLUSIONS

Temperature measurements in the wells drilled in the area around Kelly Hot Spring in northeastern California indicate the presence of an extensive aquifer covering several square miles at 1,600-3,300 feet in depth. The water temperature in the aquifer is in the range of 212°to 239°F. No flow tests of wells in the area have been carried out.

A proposal from Ormat Turbines, Ltd. for a binary power plant generating 1,500 kW has been submitted to the owners of the area around Kelly Hot Spring. The proposal calls for a total of 1,800 gpm of geothermal fluid at 220°F and 7,500 gpm of cooling water at 55°F.

Assuming that the required geothermal fluid can be produced from three production wells, each drilled to a depth of 3,000 feet, an economic analysis of this project has been carried out. The results indicate that at 6.6% annual rate of interest, the project will return the initial capital investment of $5,400,000 in twenty years. This assumes full 25% investment tax credit (10% business, 15% energy) for capital investment costs other than drilling costs.

TECHNICAL DISCUSSION

Geothermal Water Supply

The surface features at Kelly Hot Spring, as reported in the literature, are typical for a low-to-moderate temperature geothermal system. There are apparently no sinter terraces, which would indicate reservoir temperatures of 300° to 400° F, and there are no fumaroles to indicate temperatures of over 400° F. The underground resource temperature estimated from the chemical composition of the water in Kelly Hot Spring are: (1) Na/K/Ca 203° F; (2) chalcedony 241° F; and (3) quartz 289° F. The quartz geothermometer applies mainly to high temperature systems. The NA/K/Ca geothermometer and the chalcedony geothermometer are therefore likely to apply for the Kelly Hot Spring resource. The predicted reservoir temperatures are then in the range from 203° to 241° F. Maximum temperatures 230° F and 239° F have been measured in the two deep wells in the area. There is, therefore, good agreement between predicted and measured reservoir temperatures (Gudmundsson, 1984).

The two wells in the area are 3,209 feet and 3,396 feet deep, drilled in 1969 and 1974 respectively. When the temperature of the second well was measured in August, 1979, it was 59° F at the surface, increasing linearly to about 212° F at 1,640 feet depth. From there to the well bottom, the temperature increased only by about 13° F. This kind of temperature profile is typical for geothermal reservoirs. The formation temperature below about 1,640 feet is dominated by fluid convection. The small temperature increase from 1,640 feet to bottom indicates good formation permeability and uniform reservoir properties. Wells completed in the depth interval from 1,650 feet to 3,300 feet are likely to produce water in the temperature range from 212° F to 239° F.

Upon completion of the first well, it was reported to produce about 20 gpm of water. This is not a high flow rate which possibly can be explained by the way the well was drilled. As previously mentioned, lost circulation was encountered in this well at about 1,600 feet. Below this depth, the well was drilled with lost circulation material added to the drilling mud. This restored circulations partially, but evidently much material was forced into the aquifer formations which may have plugged up water bearing channels. With careful drilling through the aquifer formations, it is not unlikely that considerably higher production rates can be obtained.

The flow rate from Kelly Hot Spring is high and the water temperature is near the boiling point for the elevations of the area (4,350 feet). The quality of the water appears to be good with respect to deposition and corrosion. The wells drilled in the area have shown that the resource is likely to be extensive. Although no flow measurements have been made of the two wells, there is every reason to believe that hot water production from the Kelly Hot Spring resource can be increased by drilling. The capacity of the resource can only be estimated by drilling and flow testing. It would seem reasonable to assume, however, that each successful well will flow artesian or could be pumped at a rate not less than the current hot spring flow rate. Increased water production from the reservoir is likely to decrease the flow from Kelly Hot Spring (Gudmundsson, 1984).

In the following analysis, it is assumed that the needed geothermal flow rate of 1,800 gpm is obtained by drilling three production wells. These wells will each be drilled to a depth of 3,000 feet with a cemented casing to a depth of 1,500 feet and a perforated liner hung from there to well bottom. Each well will be equipped with a downhole turbine pump in order to maintain the needed flow rate.

It is assumed that two reinjection wells will be needed in order to return the geothermal water to the aquifer. These will be of the same type as the production wells. It is assumed that the two reinjection wells will be required.

Cooling Water Supply

A shallow pond covering approximately forty-five acres is located near Kelly Hot Spring. This pond, which is formed by the discharge of the hot spring, is neither large enough nor cool enough to serve as a source of cooling water for a binary plant at Kelly Springs. A cooling tower will therefore have to be installed in order to achieve the necessary cooling.

An important factor in the selection of cooling towers is the approach, defined as the difference between the cold water temperature leaving the tower and the wet bulb temperature. As a generalization, the closer the approach is to the design wet bulb the more expensive the cooling tower is (Maze, 1967). Usually, an approach to the design wet bulb temperature of 5°F is the coldest water temperature that cooling tower manufacturers will guarantee.

The design wet bulb temperature for a cooling tower is usually defined as a value not exceeded over five per cent of the time during the summer months (June to September) in the area in question (Spencer and Stephani, 1978).

Figure 1 shows the distribution of design wet bulb temperatures in the United States according to the above definition. It is clear from the figure that the requirements of a cooling water temperature of 55°F cannot be met during the warmest part of the year. This means a reduction in power output from the binary plant during this time.

Figure 2 shows the frequency distribution of wet bulb temperatures in Reno, Nevada. From Figure 1, it appears that wet bulb conditions in northeastern California are not unlike those in Reno. Assuming that the Reno conditions can be applied to the Kelly Hot Spring area, it appears that the electrical energy output from the binary plant will be reduced by about 5% on an annual basis due to high wet bulb temperatures. During the warmest periods, however, when the wet bulb temperature may reach 65°F, the power from the plant may be expected to be reduced by about 25%.

<u>Available on-line energy from binary plant</u>

From the last section, it is found that the reductions in annual electrical energy generated by a binary plant at Kelly Hot Spring due to high wet bulb temperatures is on the order of 5%. Assuming a total down-time due to yearly maintenance of 10%, the total energy generated by a 1,500 kW plant is:

$$1,500 \times 0.95 \times 0.90 \times 8,760 = 11,234,700 \text{ kWh/year}$$

The power output from the binary units, 1,500 kW, represents net power, where the power requirements of the working fluid circulating pumps have already been deducted. On the other hand, other electrical equipment needed for the operation of the plant have not been taken into account. The power requirements of these are estimated as follows:

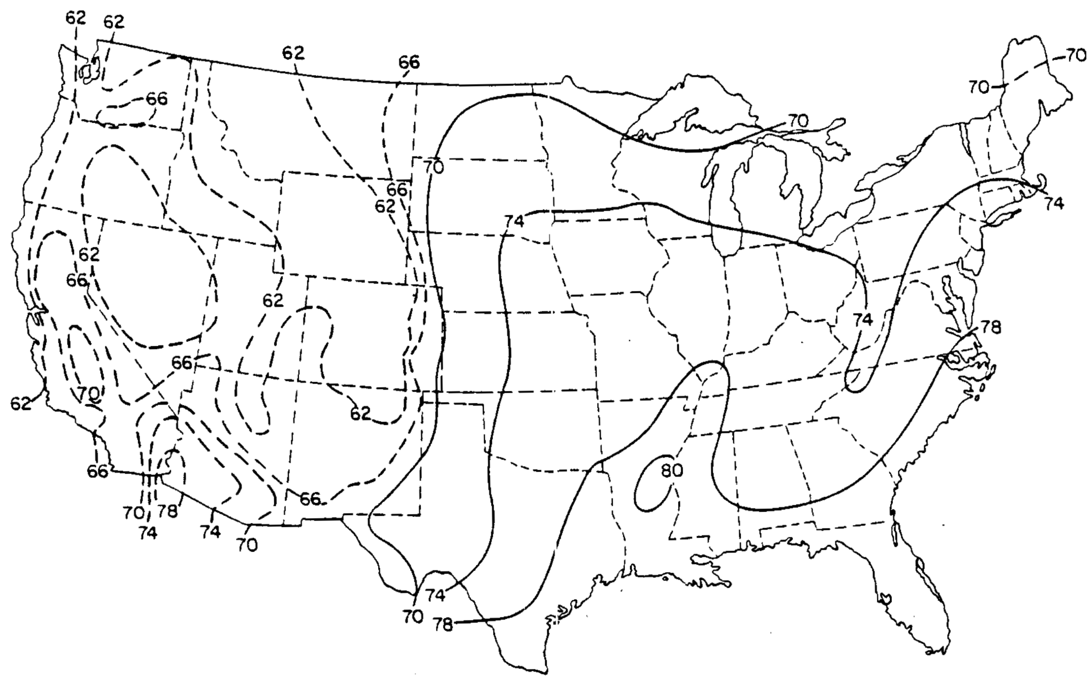

Figure 1. Design wet bulb temperature isolines in the United States (from Spencer and Stephani, 1978.)

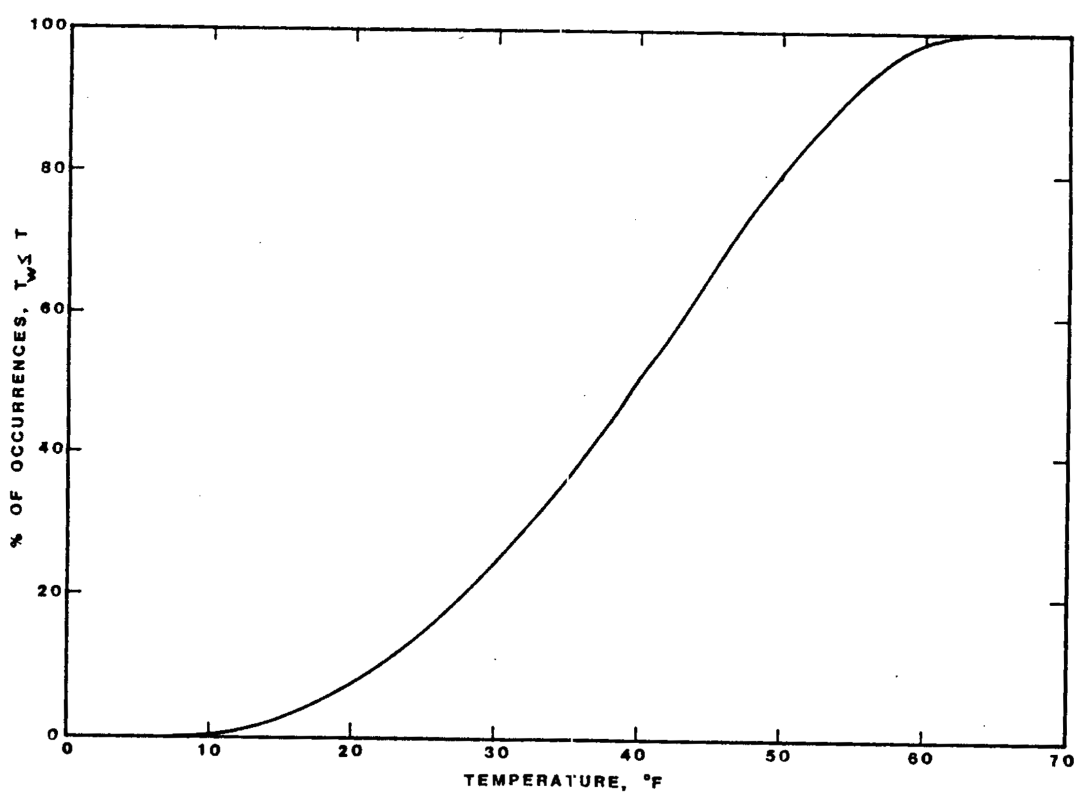

Figure 2. Frequency distribution of wet bulb temperatures in Reno, Nevada. (T_W = wet bulb temperature.)

Cooling water pumps	180	kW
Cooling tower fans	80	kW
Geothermal fluid pumps	255	kW
Total	515	kW

This power is unaffected by wet bulb temperature, resulting in an annual energy consumption of:

515 x 0.9 x 8,760 = 4,060,260 kWh/year

Available on-line energy is then about 7,175,000 kWh/year.

CAPITAL AND OPERATING COST ESTIMATES

Estimated capital and operating cost estimates of the binary plant at Kelly Hot Spring are shown in Table I. The total capital cost estimate is $5,400,000, of which drilling costs amount to approximately one-half.

ECONOMIC ANALYSIS

A life cycle cost analysis for the proposed binary plant at Kelly Hot Spring is presented in Table II. The analysis covers an assumed twenty years life of the plant. Several assumptions have been made in the analysis which are explained below.

Column 1 represents the electrical energy sales forecast. It is based on a flat rate of 9.0¢/kWh which is a reported average rate to small California producers under PG & E "Standard Offer No. 4." This rate is assumed to apply for a period of ten years after which time another flat rate of about 16.45¢/kWh is assumed. This increase is in accordance with the forecast figures recently published by the California Energy Commission (CEC, March, 1984) where the projected price rise of electricity from 1984 to 1994 is about 83%.

Columns 2 and 4 show the projected cost of insurance and maintenance, respectively. Both of these cost items are assumed to follow the general inflation rates according to the CEC forecast figures (CEC, March, 1984). These rates are the following:

Year	General Inflation
1984	1.0000
1985	1.0895
1986	1.1535

TABLE I

Capital and operating cost estimates for 1,500 kW binary plant at Kelly Hot Spring, California

Capital Cost Estimate

Binary generating units, 1 x 600 kW + 3 x 300 kW, as per Ormat offer of April 3, 1984	1,350,000
Installation and hookup of units	100,000
Production wells (3 x 3,000 ft. x $170/ft.)	1,530,000
Injection wells (2 x 3,000 ft. x $170/ft.)	1,020,000
Cooling tower	325,000
Well pumps	150,000
Various piping	200,000
Engineering - 0.5%	235,000
Sub-total	4,910,000
Contingency - 10%	490,000
Total capital cost	5,400,000

Operating Cost Estimate

Maintenance: Binary units	85,000
Cooling tower	11,000
Well pumps	9,000
Total Maintenance	105,000
Property taxes (1% excluding wells)	28,500
Insurance (1.5% excluding wells)	14,500
Total operating cost	148,000

TABLE II

Economic analysis of a 1,500 kw binary generating plant at Kelly Hot Spring, California. Discounted cash flow (column 13) is based on an annual rate of 6.615%

	1 Electrical Energy Sales	2 Insurance Binary System	3 Property Tax Binary System	4 Maint. Binary System	5 Depreciation	6 Net Operating Income	7 Depletion Allowance
Year zero cost	645750	14500	28500	105000			
Year							
1	645750	15798	28928	114398	570000	-83373	0
2	645750	16726	29361	121117	570000	-91454	0
3	645750	17707	29802	128226	570000	-99985	0
4	645750	18858	30249	136560	570000	-109917	0
5	645750	20084	30703	145437	570000	-120473	0
6	645750	21390	31163	154890	0	438307	96863
7	645750	22780	31631	164958	0	426382	96863
8	645750	24261	32105	175680	0	413704	96863
9	645750	25838	32587	187099	0	400226	96863
10	645750	27517	33075	199261	0	385897	96863
11	1180431	29306	33572	212213	0	905341	96863
12	1180431	31210	34075	226007	0	889139	177065
13	1180431	33239	34586	240697	0	871909	177065
14	1180431	35400	35105	256342	0	853584	177065
15	1180431	37701	35632	273005	0	834094	177065
16	1180431	40151	36166	290750	0	813364	177065
17	1180431	42761	36709	309649	0	791313	177065
18	1180431	45540	37259	329776	0	767856	177065
19	1180431	48501	37818	351211	0	742901	177065
20	1180431	51653	38385	374040	0	716353	177065
Total	18261810	606420	668910	4391314	2850000	9745166	2174757

Year	8 Net Income Before Taxes	9 Federal Income Tax	10 Net Income After Taxes	11 Add Tax Cr. Depreciation and Depletion	12 After Tax Cash Flow	13 After Tax Discounted Cash Flow	14 Cumulative After Tax Cash Flow	15 Cumulative After Tax Discounted Cash Flow
1	-83373	0	-83373	1282500	1199127	1124729	1199127	1124729
2	-91454	0	-91454	570000	478546	421007	1677673	1545736
3	-99985	0	-99985	570000	470015	387847	2147688	1933583
4	-109917	0	-109917	570000	460083	356096	2607771	2289679
5	-120473	0	-120473	570000	449527	326339	3057297	2616018
6	341445	157065	184380	96863	281243	191504	3338540	2807522
7	329519	151579	177940	96863	274803	175509	3613343	2983031
8	316842	145747	171095	96863	267957	160519	3881300	3143551
9	303364	139547	163817	96863	260679	146471	4141979	3290021
10	289034	132956	156079	96863	252941	133305	4394920	3423326
11	808479	371900	436578	96863	533441	263692	4928361	3687018
12	712074	327554	384520	177065	561585	260380	5489946	3947399
13	694844	319628	375216	177065	552280	240179	6042226	4187578
14	676519	311199	365320	177065	542385	221241	6584611	4408819
15	657030	302234	354796	177065	531861	203488	7116472	4612308
16	636299	292698	343602	177065	520666	186846	7637138	4799154
17	614248	282554	331694	177065	508759	171245	8145897	4970399
18	590791	271764	319027	177065	496092	156622	8641988	5127020
19	565836	260285	305552	177065	482616	142914	9124605	5269934
20	539288	248072	291215	177065	468280	130065	9592885	5400000
Total	7570409	3714781	3855628	5737257	9592885	5400000		

1987	1.2212
1988-2004	6.5% per year

Column 3 shows the property tax which is assumed to escalate at a rate of 1.5% per year.

Column 5 is straight line depreciation of the capital cost excluding the drilled production and injection wells. The depreciation period is five years.

Column 6 shows the net operating income before taxes not counting the depreciation allowance. Due to the accelerated rate of depreciation, this is negative for the first five years.

Column 7, the depletion allowance, is taken as the lower of either 15% of gross sales, column 1, or 50% of net operating income, column 6. For the first five years, therefore, the depletion allowance is zero.

Column 8 shows net income before taxes with depletion allowance deducted.

Column 9 shows the federal income tax of 46% of net income. For the first five years when the operation shows a loss, the income tax is zero. Net income after taxes is then shown in Column 10.

Column 11 shows the credits from the depreciation and depletion allowance columns (5 and 7) to be added to net income after taxes in order to evaluate the after tax cash flow, column 12. Included for the first year only is a business investment tax credit of 10% and an energy investment tax credit of 15% of the capital investment cost excluding the drilling costs, which totals $2,850,000. It is to be noted that if the investment tax credit is to be available, it must be applied against a tax liability generated by some other business activity since net income is negative during the early years.

Column 12 shows the cumulative after tax cash flow over the twenty year life cycle. It is seen that simple after tax payback takes about 11.8 years.

Column 13 shows the after tax discounted cash flow evaluated at an annual rate which returns the initial capital investment of $5,400,000 in twenty years. The rate of returns after taxes was found to be about 6.6%.

The foregoing analysis is based on several assumptions which make the results rather unreliable. One assumption which has a strong influence on the overall cost of the project is the number of wells needed for the production and injection of the 1,800 gpm of geothermal fluid. No flow tests of wells have been made in the area and nothing is known about the permeability of the reservoir. It is not at all unlikely that more than five wells will be needed which would have a strong and unfavorable influence on the overall economics.

Another factor of uncertainty is the investment tax credit which may or may not be available (column 11, year 1). If this credit is not allowed, the project will be very adversely affected. With the foregoing assumptions, the rate of return after taxes is only about 6.6% which is not very attractive at all.

REFERENCES

California Energy Commission, 1984: Preliminary Energy Commission Staff Price Forecast for California Utilities. Prepared by the Systems Assessment Office Staff, March, 1984.

Gudmundsson, J. S., 1984: Comments on the Kelly Hot Spring Geothermal Resource. Informal Report, Stanford University, California, June, 1984.

Maze, R. W., 1967: Practical Tips on Cooling Tower Sizing. Hydrocarbon Processing, Vol. 46, No. 2, pp. 123-126.

Spencer, J. R. and Stephani, R. M., 1978: Power Plant Heat Exchangers. In Section 9, Marks Standard Handbook for Mechanical Engineers, Theodore Baumeister, Editor-in-Chief. Eighth edition. McGraw-Hill Book Company, New York.

SWENSON
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AREA CODE 312—331-4000

April 3, 1984

Mr. Sal Pantano
Geothermal Floral
P.O. Box 190
Belmont, California 94002

Dear Mr. Pantano:

Thank you for your inquiry regarding power production from low temperature geothermal resource.

As we discussed, with 1800 gpm of 220° F. water we can generate approximately 1.5 MW, assuming 7500 gpm of cooling water is available at 55° F. The power plant can be put into operation in a relatively short time by using one 600 KW and three 300 KW units from our stock in the U.S.

As described in the technical bulletin, the units are skid-mounted. A stand-alone automatic control panel is also included for each unit. The budgetary price for the four units to generate 1.5 MW is approximately $1,350,000 (One Million Three Hundred Fifty Thousand Dollars).

I hope the above information is in accordance with your requirements. I am looking forward to working with you on this project.

Yours very truly,

SWENSON DIVISION

Anil Prasad

Anil Prasad
Ormat Sales Manager

AP:nd
Enc.