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Heat Rejection From Geothermal Power Plants

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Final Report
November 1979

MASTER

Prepared by
R. W. Beck and Associates
Denver, Colorado

ELECTRIC POWER RESEARCH INSTITUTE

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ABSTRACT

Comprehensive computer programs are developed for purposes of determining cooling makeup water requirements and electricity production costs for evaporative (wet) and dry/wet-peaking cooling towers, which are the principal cooling technologies for rejecting the heat from hydrothermal power plants. Such information can be used to determine the incremental cost of reducing the water consumption of the cooling system, or, conversely, what cost would be incurred at a site if only a certain quantity of water were available, thus requiring the supplemental use of dry cooling systems.

Parametric economic analyses were performed for both flash steam and binary conversion processes for various combinations of resource temperatures, climatological types, hydrothermal "fuel" costs, and cooling system makeup water costs. Results of these analyses are presented in a number of curves showing relative busbar cost of electricity as a function of relative amount of cooling makeup water required. These curves show that use of wet/dry cooling systems can cut makeup water requirements by factors of about 2 to 4 at the cost of an additional 10% to 25% in the busbar price of electricity.

Turbine-generator performance curves are constructed for a range of condensing conditions for both the flash steam and hydrocarbon binary-cycle turbines. Estimates of hydrothermal resources in the western United States are also given.

EPRI PERSPECTIVE

PROJECT DESCRIPTION

Because a major portion of the U. S. hydrothermal resources are located in the arid and semiarid western states, the availability of water for geothermal power plant cooling could become a critical constraint on the growth of geothermal energy utilization. The contract for Research Project (RP) 927-1 was issued to provide a detailed study of the problem of waste heat rejection under conditions relevant to commercial use of geothermal resources in water deficient areas. Although this study focused on geothermal power generation, the problem of cooling water supply in arid regions is germane to other types of power plants, and the data derived in this Final Report should be of use in other EPRI projects and in utility planning.

PROJECT OBJECTIVES

EPRI awarded the contract in order to obtain a comparative analysis of alternate heat rejection systems, taking into account the variability of geothermal resources, regional climatic differences, geologic conditions, water availability, and power conversion options. The many possible combinations of these factors required development of computational models for use in parametric analyses. From these analyses, specific correlations can be derived for plants such as the binary cycle power plant proposed for Heber in the Imperial Valley and for binary and direct flash power plants at other resources having development potential in the next 10-year period.

PROJECT RESULTS

High penalties in both capital cost and decreased power output make totally dry cooling systems an unacceptably expensive option for geothermal heat rejection. Use of a dry/wet-peaking cooling system can greatly reduce cooling water consumption at some penalty in the busbar electricity cost. The penalty is in the 10 to 20% range when consumptive use of cooling water is cut by half. Greater reductions in cooling water use, e.g. cutting back to only one fifth of the water used by a purely evaporative (wet) system, can be achieved at a busbar cost penalty ranging from 15 to 35%. Busbar costs of electricity depend much more on resource temperature and production costs (e.g., wells) than on costs of cooling water and cooling systems. When compared on the same 182°C (360°F) resource, binary power plants require about 17% more cooling water than flash plants because the binary plants can use more of the low temperature heat available from the resource.

Vasel Roberts, Program Manager
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PURPOSE OF STUDY

The objectives of this study were (1) to identify the makeup water sources and demand for geothermal power production and (2) to develop analytical techniques and perform a comparative analysis of the waste heat rejection options for geothermal power plants, thereby determining how water consumption may be reduced. The results of this study will be used to identify options that are best suited for geothermal waste heat rejection by region, resource type, and conversion technology.

In this study, consideration is given to hydrothermal reservoirs with temperatures between 150°C and 246°C, because these offer potential for the development of commercial power generation facilities. Most of the known hydrothermal resources are located in the western United States, where water resources are scarce, highly allocated, or influenced by regional institutional and legal considerations.

Wet, wet/dry, and dry cooling towers appear to be the principal cooling technologies for rejecting the waste heat from hydrothermal power plants. Comprehensive computer programs have been developed for this project for purposes of determining cooling water makeup requirements and energy production costs for the aforementioned cooling technologies. Parametric economic analyses have been performed for both flash steam and binary conversion processes for various

combinations of resource temperatures, climatological types, hydrothermal "fuel costs", and cooling system makeup water costs.

PARAMETRIC ANALYSES PERFORMED

Specifically, the parametric analyses performed for this study assumed the following range of values:

- Hydrothermal resource temperature: 150 C (300 F), 182 C (360 F), and 246 C (475 F)
- Hydrothermal power plant conversion process: flash steam and binary
- Climatological type: High Mountain, Pacific Northwest, Basin and Range, and Hot Desert
- Cooling system type: mechanical-draft wet towers and mechanical-draft direct dry/wet peaking towers
- Annual fixed-charge rate: 15 percent
- Hydrothermal "fuel cost": $\$0.50/10^6$ Btu and $\$1.00/10^6$ Btu
- Makeup water cost: $0.10/Kgal, $1.00/Kgal, and $2.50/Kgal (includes acquisition, transportation, treatment, and disposal costs)

By selectively analyzing various combinations of values for these parameters, it is possible to compare the busbar energy production costs and makeup water requirements for hydrothermal power plants equipped with alternative cooling tower systems under different site, design, and economic conditions.

The results of the analyses are presented in the form of curves representing relative busbar energy production costs as a function of percentage water use for a range of fuel and makeup water costs at the four sites. Zero percent water consumption represents a plant with dry cooling towers only, whereas 100 percent water consumption represents a plant with evaporative (wet) cooling towers only. The points between zero and 100 percent represent plants having different size combinations of dry and wet cooling towers, with a higher value of water consumption indicating a combination of a smaller dry tower with a larger wet tower. From such curves, the decision-maker can determine the incremental cost of reducing the water consumption of the cooling system, or, conversely, what cost would be incurred at a site if only a certain quantity of water were available, thereby requiring the supplemental use of dry cooling systems.

INFORMATION OBTAINABLE FROM COMPUTER PROGRAMS

The computer programs which were developed to economically optimize and evaluate mechanical-draft evaporative and direct dry/wet peaking cooling tower systems provide the following information for each combination of resource temperature, conversion process, climatic condition, fuel cost, fixed-charge rate, and makeup water cost considered:

- Gross annual base generation and auxiliary energy requirements
- Annual makeup water requirements
- Annual plant capital and operating costs
- Annual hydrothermal "fuel" and operating costs
- Annual makeup water and operating costs
- Total annual capital and operating costs
- Busbar energy production costs
- Busbar component cost breakdown
- Summary of pertinent cooling tower and condenser design data
- Cost breakdown for cooling tower, condenser, circulating water facilities, controls, engineering and contingencies, interest during construction, and conversion plant
- Annual turbine operation profile

- Annual plant generation profile
- Distribution of heat load between wet and dry towers for the dry/wet peaking tower

RESULTS OF STUDY

Conclusions

Several key results were obtained from analysis of the range of values calculated in the parametric studies performed under this contract. The main observations are:

- Busbar energy production costs are very sensitive to hydrothermal resource temperature and hydrothermal "fuel cost" and less sensitive to climatological type and makeup water cost. All other parameters remaining constant, busbar energy production costs for 150°C (300°F) resources are generally on the order of 80 percent higher than for 246°C (475°F) resources. Likewise, an increase in "fuel cost" from \$0.50 to \$1.00/10^6 Btu will result in an increase in busbar costs on the order of 50 percent. However, an increase in water cost from \$0.10 to \$2.50/Kgal will result in an increase in busbar costs of only about 15 percent. The differences in busbar costs for the four sites are typically on the order of 5 percent.
- Turbine-generator design significantly determines the overall plant performance and economics of both the binary and flash steam conversion systems. Direct comparisons between binary and flash steam systems for 150°C (300°F) and 246°C (475°F) resources were not possible in this study since optimum binary fluid choices and turbine designs are not yet available.
- Analyses indicate that binary systems yield slightly lower busbar energy production costs than flash steam systems for the 182°C (360°F) resource temperature, although makeup water requirements are higher than for flash steam systems. Higher heat rejection for the binary system relative to the flash system accounts for the higher makeup water requirements.
- No computer analyses were performed for the radial hydrocarbon turbine design for the binary conversion process (turbine performance data were not available in time for this study). An examination of the radial turbine performance characteristics which were furnished by a manufacturer indicates that the busbar energy production cost and cooling system makeup water requirements should not differ significantly from those of the axial hydrocarbon turbine unless there are significant differences in capital or operating costs between the two types of turbines.

- On the basis of the turbine performance data available for this study, cooling system makeup water requirements for evaporative cooling towers serving flash steam systems are approximately 24-27 percent higher for 150°C (300°F) resources than for 182°C (360°F) resources, and approximately 29-30 percent lower for 246°C (475°F) resources than for 182°C (360°F) resources. Makeup water requirements for evaporative cooling systems serving binary systems are approximately 17-21 percent higher than for flash steam systems for 182°C (360°F) resource temperatures.

- For the range of fuel and makeup water costs considered, an all-dry cooling tower system does not appear to be economically competitive with an evaporative cooling tower system. However, the addition of a relatively small evaporative peaking tower to the dry tower (such as 95 percent dry/5 percent wet) will substantially reduce the busbar cost penalty incurred by an all-dry system. As the cost of makeup water increases, the relative difference in busbar cost between an all-dry or a dry/wet peaking tower and an evaporative tower decreases significantly.

- For low water costs ($0.10/Kgal), the penalty in busbar cost for saving approximately 60 percent water by use of a dry/wet peaking cooling tower is on the order of 7-15 percent for non-desert sites and 9-25 percent for desert sites. However, for higher water costs ($2.50/Kgal), the penalty decreases to approximately 1-4 percent for non-desert sites and 2-10 percent for desert sites. The economic penalty for saving more water increases as additional dry cooling is used. Therefore, the use of dry/wet peaking towers may be feasible for hydrothermal power plants under certain site, plant design, and economic conditions, as well as social and environmental constraints.

- Busbar energy production costs and cooling system makeup water requirements as estimated in this study for given plant design and economic constraints do not vary significantly for non-desert sites. However, busbar costs are approximately 2-6 percent higher and makeup water requirements are approximately 6-17 percent higher for desert sites.

- Several methods for accounting for costs associated with loss of generating capacity were considered in this study. Busbar energy production costs are slightly lower for the method which does not penalize for loss of capacity during operation at high ambient temperature conditions than for the other methods. However, typical differences in cost for these alternative methods are on the order of a few percent.

- Direct dry towers resulted in lower busbar energy production costs than indirect dry towers for the generating units with the sizes evaluated in this report. Differences in cost are typically on the order of a few percent of the total busbar cost, so that this conclusion could change if relative capital costs of the two systems are different from those assumed.

- For study purposes, the design back pressure value does not significantly affect the relative estimated busbar energy production cost or cooling system makeup water requirements. In the actual design of a hydrothermal power plant, however, the design back pressure is an important consideration.

Accuracy of Results

The accuracy with which cost estimates can be made for new energy conversion technologies is directly related to the history and experience of the industries developing the technologies. In the case of hydrothermal power plants, capital cost estimates are subject to inaccuracies resulting from a lack of cost trends, which can be established only after several power plants have been designed and constructed. Moreover, site-specific costs due to local labor and materials cost differences or physical site conditions will also markedly affect plant costs for any actual installation.

The accuracy with which the computer programs developed for this study simulate actual power plant performance is limited primarily by the accuracy or applicability of the turbine performance data, climatological data, and capital cost data. Estimates of makeup water requirements are based upon rigorous procedures adopted by the Cooling Tower Institute and therefore are limited primarily by the accuracy or applicability of the turbine performance and climatological data. Therefore, as data are refined, the accuracy of estimating energy production costs and makeup water requirements can also be refined.

Limitations of Study

The results of the parametric analyses presented in this report represent a wide range of variables and assumptions which affect the performance and economics of hydrothermal power plants. However, since geothermal energy is still in the development stage, necessary data are not yet available for many aspects of the power plant design, e.g. the performance of binary turbine-generators for many resource conditions.

The binary turbine data used in the analyses performed are based upon the Elliott turbine design for a 182°C (360°F) resource and therefore do not represent optimum hydrocarbon working fluid choices or turbine designs for either 150°C (300°F) or 246°C (475°F) resources. By comparison, the flash steam turbine data used in the analyses are based upon well-established turbine performance estimating methods and therefore are considered to be valid for all three temperatures investigated.

Recommendations for Subsequent Studies

In addition to the need for binary turbine-generation performance data for a range of hydrothermal resource temperatures, our analyses indicate that the following studies are warranted:

- Analyses of alternative hydrocarbon turbine designs should be performed before any major decision is made regarding either the selection of a hydrocarbon turbine or the selection of one conversion process over another.
- The actual operation of hydrothermal power plants in conjunction with other conventional power plants on the utility grid should be evaluated. Forced outage rate, planned outage for scheduled maintenance, and summer and winter capacity of the hydrothermal plant should be investigated with respect to operating economics.

- Because of the high fuel costs and cooling system auxiliary energy requirements associated with hydrothermal plants, natural-draft cooling systems may be more economical than mechanical-draft systems at many locations and should therefore be evaluated in subsequent studies. The choice between mechanical-draft and natural-draft cooling towers is usually based on economics, although in some instances environmental considerations could favor the use of natural-draft towers.

Section 1

INTRODUCTION

The relatively low temperatures of geothermal resources result in thermal efficiencies of 10-15 percent in power conversion cycles. If conventional evaporative cooling methods are to be used, large quantities of cooling water will be required. However, most of the known resources are located in the western United States where water resources are scarce, highly allocated, or influenced by regional institutional and legal considerations.

The primary objectives of this study, therefore, were (1) to identify the makeup water requirements for geothermal power production and (2) to develop analytical techniques and perform a comparative analysis of the waste heat rejection options for geothermal power plants to determine how water consumption may be reduced. The results of this study will be used to identify options that are best suited for geothermal waste heat rejection by region, resource type, and conversion technology.

Section 2

DEVELOPMENT OF CRITERIA FOR PARAMETRIC EVALUATIONS OF COOLING SYSTEMS FOR HYDROTHERMAL POWER PLANTS*

INTRODUCTION

In order to make meaningful economic evaluations of alternative cooling systems for hydrothermal power plants, several parameters are involved in the determination of energy production costs and makeup water requirements. The parameters analyzed in this study include the following:

- Temperature of hydrothermal resource
- Hydrothermal power plant conversion process
- Climatological characteristics which affect cooling system performance
- Cooling system type, performance, and cost
- Availability and cost of makeup water
- Hydrothermal fluid production cost
- Financial parameters

By selectively analyzing various combinations of values for these parameters, it is possible to compare the electrical energy production costs and makeup water requirements for hydrothermal power plants equipped with alternative heat rejection systems under different site, design, and economic conditions.

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*Some technical data contained in Section 2 were prepared for this project by Dr. G. V. Keller and Dr. L. T. Grose, faculty members at the Colorado School of Mines.

HYDROTHERMAL RESOURCES IN THE WESTERN UNITED STATES*

Of the three basic types of geothermal resources in the world -- hydrothermal (wet and dry steam), hot dry rock, and geopressurized zones -- hydrothermal resources appear to offer the greatest potential for immediate development. Hydrothermal reservoirs, which consist of high-temperature water under pressure, are fairly common in the western United States. Hot dry rock systems, although more abundant, have not yet been evaluated beyond the preliminary research stage. Geopressurized zones are also being examined through research and exploratory efforts, but preliminary indications are that considerable technological effort will be required before the resources can be developed on a commercial basis.

The eleven western states are characterized by many phenomena which suggest anomalously high heat concentrations at shallow depths in the earth's crust. Subsurface heat flow in the western states is significantly higher than in the rest of the contiguous United States, and more than a thousand thermal springs have been found. Tensional tectonic activity is widespread and of young geological age, much of it manifest in historic seismic activity; and recent volcanism is widespread. Many basins are filled with large volumes of water-soaked layers, some of which are thermally insulated. The presence of all these phenomena in the western states suggests that the region has considerable potential for high-temperature hydrothermal energy development.

Hydrothermal resources are generally classified according to a number of different characteristics such as volcanism, resource occurrence, nature of

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*The information provided in this subsection is based upon work performed in conjunction with this study by Dr. G. V. Keller and Dr. L. T. Grose of the Colorado School of Mines.

hydrothermal fluids, and mechanism of heat entrapment. In order to delineate those regions having potential for electrical energy production, nine geothermal regions have been defined in Figure 2-1 according to a combination of geological features and upper mantle and crustal processes. For the purpose of this report, however, only hydrothermal systems that have sufficiently high temperature (>150 C (302 F)) for electrical energy production are considered. The classification used herein is based on estimated reservoir base temperatures as follows:

- Low temperature: 150-200 C (302-392 F)
- Intermediate temperature: 201-250 C (393-482 F)
- High temperature: >250 C (>482 F)

The approach used in this report to estimate hydrothermal reserves (as described in Appendix A) is based upon the statistical data available from heat flow determinations which have been made throughout the continental United States. Assuming that the heat flow determinations are randomly distributed, these data can be used to estimate the hydrothermal resource base in each of the nine regions. The recoverable energy from hydrothermal sources in each region can then be estimated as a function of heat flow by using conventional methods of estimating hydrothermal fluid production, electrical energy production from hydrothermal fluid, and the area assumed to be available for hydrothermal development. By estimating the electrical energy which might be produced by a region, the electrical production capacity for the region can be estimated for a nominal 30-year facility lifetime, as shown in Table 2-1. It is recognized that the schedule for actual development will depend upon the economic balance between hydrothermal power and other competing sources of power generation.

In order to analyze plant performance for various resource conditions, resource temperatures of 150 C (302 F), 182 C (360 F), and 246 C (475 F) have been selected for the parametric analyses. These values not only provide a range of temperatures but also are representative of several hydrothermal resources which have been discovered to date (Raft River, Heber, and Valles Caldera).

TABLE 2-1

ESTIMATES OF NOMINAL 30-YEAR ELECTRICAL PRODUCTION CAPACITY
FOR THE MAJOR HYDROTHERMAL REGIONS AS A FUNCTION OF HEAT FLOW

Hydrothermal Region	MWe (3-4 hfu)	MWe (4-5 hfu)	MWe (>5 hfu)	MWe Total
Central California Coast Range	1,450	1,740	850	4,040
Cascade Range	200	120	30	350
Snake River Plain	2,050	3,420	3,000	8,470
Northwestern Basin and Range	5,600	7,560	3,780	16,940
Central Basin and Range	150	70	20	240
Eastern Basin and Range	880	620	160	1,660
Salton-Imperial Valley	480	800	700	1,980
Southern Basin and Range	960	420	90	1,470
Rio Grande Rift System	1,840	2,050	1,100	4,990
TOTAL	13,610	16,800	9,730	40,140

(Note: Discussion of hfu is given in Appendix A.)

HYDROTHERMAL PLANT CONVERSION PROCESSES

A number of processes have been devised for converting the thermal energy of water-dominated geothermal resources into electrical energy. The principal conversion processes are the flash steam process, the binary process, and the hybrid process, which is a combination of the flash and binary processes. As further described in Section 3, these processes operate on the principle of producing a vapor either directly from the hydrothermal resource (flash steam process) or by transfer of energy from the hydrothermal resource to a suitable working fluid (binary process). The vapor is then expanded through a turbine or expander to produce mechanical work which, in turn, is used to drive an electrical generator. In this report, both the flash steam and the binary processes are analyzed.

CLIMATOLOGY AND COOLING SYSTEM PERFORMANCE

Climatological parameters not only determine the availability of water within a region but also affect power plant cooling system performance. For instance, in a dry cooling tower, higher ambient dry-bulb temperatures increase the turbine back pressure, which results in poorer fuel economy and loss of generating capability. The full range of annual ambient air temperatures at the site affect the fuel economy, but it is the maximum temperatures which have the more significant economic effect. The maximum temperature, in combination with the cooling system design parameters and the turbine characteristics, sets the maximum loss of generating capability which would be experienced during the year and is a major factor in determining the economically optimum design of a dry cooling tower system. Section 4 further describes the effect of climate upon cooling system design and performance.

The wet-bulb temperature likewise is an important parameter in the design and performance of evaporative-type cooling tower systems, since the wet-bulb temperature of the air is the lowest temperature to which the water circulating through the tower can be theoretically cooled. The design wet-bulb temperature of the air for a specific site is generally selected as that wet-bulb temperature which is exceeded no more than a small percentage of the time.

Makeup water requirements are also directly related to site wet-bulb temperature profiles, since the difference between the temperature of the hot circulating water and the ambient wet-bulb temperature is the driving force for evaporation in a wet cooling system. Because this temperature difference is greater in the summer, evaporation rates are higher during summer weather. Convective heat transfer, by comparison, is a function of the difference between the temperature of the hot circulating water and the ambient dry-bulb temperature. Greater temperature differences usually occur in the winter, with consequent increases in convective heat transfer.

Saturation deficit is defined as the quantity of water vapor required to saturate the ambient air. If the ambient wet-bulb temperature is high and the relative humidity is low, the evaporation rate in a wet cooling system is high and the convective heat transfer rate is low (high saturation deficit). On the other hand, if the ambient wet-bulb temperature is low and the relative humidity is high, the evaporation rate will be reduced and the convective heat transfer rate will be increased (low saturation deficit).

Additionally, as site elevation increases, the capital cost of the cooling system and the required fan horsepower tend to increase, since the reduced air density makes it necessary to move a volume of air greater than that required at a lower elevation through the cooling system in order to achieve the same mass flow rate. In other words, a tower designed to meet a certain duty at a lower elevation may not be capable of meeting that same duty at a higher elevation. This effect is somewhat offset, however, by the fact that air temperatures are generally lower at high elevations. Evaporation rates also increase with elevation due to the lower atmospheric pressures at higher elevations.

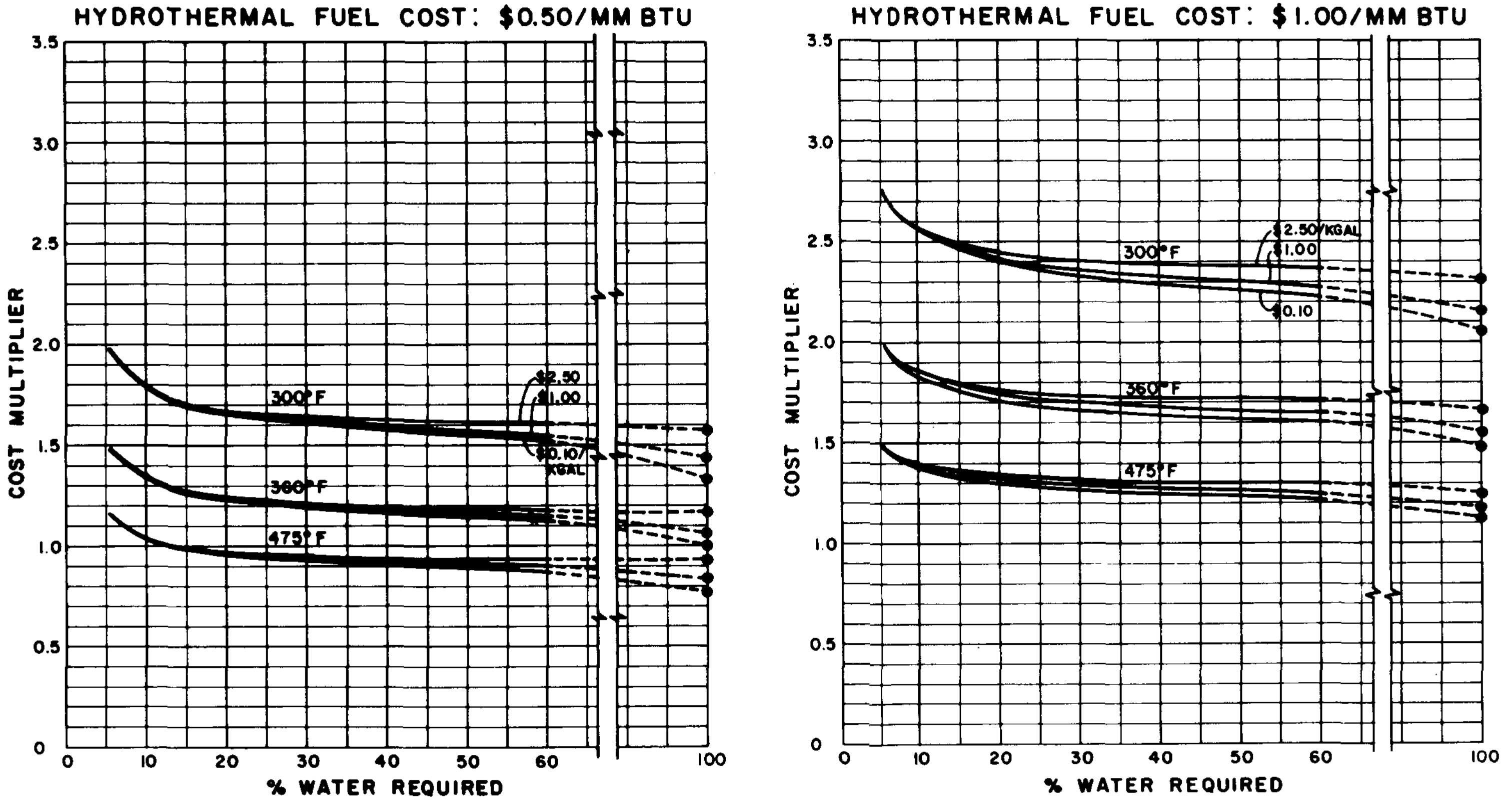
APPENDIX A

DESCRIPTION OF HYDROTHERMAL RESOURCES IN THE WESTERN UNITED STATES

Note: Technical data contained in this section were prepared for this project by G. V. Keller and L. T. Grose of the Colorado School of Mines.

FIGURE 5-10

BUSBAR ENERGY PRODUCTION COST MULTIPLIERS
FOR DRY/WET PEAKING COOLING TOWERS
FOR 150°C (300°F), 182°C (360°F) AND 246°C (475°F) FLASH AT HOT DESERT SITE



NOTE: PERCENT WATER IS BASED UPON MAKEUP WATER REQUIREMENT FOR EVAPORATIVE TOWER

Approximate extreme meteorological parameters for the selected major hydrothermal sites in the western United States (shown in Figure 2-1) are presented in Table 2-2. For purposes of parametric analyses, however, the following four types of sites represent an adequate range of dry-bulb and wet-bulb temperature variations, elevation, and geographical location insofar as the analysis of cooling systems for hydrothermal plants is concerned:

- Hot Desert (Data source: Heber, California)
- Basin and Range (Data source: Reno, Nevada)
- Pacific Northwest (Data source: Medford, Oregon)
- High Mountain (Data source: Valles Caldera, New Mexico)

Maximum, 2½ percent summer, and average dry-bulb and wet-bulb temperatures for the four sites are given in Table 2-3. Hourly climatological data in the form of dry-bulb temperature distributions for distinct categories of relative humidity were obtained from published sources for each type of site and are shown in Appendix B. This type of data is useful in analyzing the performance of alternative cooling systems under all conditions experienced during a typical year.

COOLING SYSTEM TYPES

Because of the relatively low temperatures of hydrothermal resources, the thermal efficiencies of hydrothermal conversion cycles are quite low, on the order of 10 percent. Thus, the waste heat rejection from the turbine exhaust flow of a hydrothermal power plant typically will be 20,000 to 30,000 Btu/kWh of electrical generation at design conditions, compared to approximately 5000 Btu/kWh for a modern fossil-fueled plant. If conventional evaporative cooling methods are to be used for geothermal power plants, large quantities of cooling water will be required.

Table 2-2

APPROXIMATE EXTREME METEOROLOGICAL PARAMETERS FOR SELECTED HYDROTHERMAL SITES

	Hydrothermal Site	Hydrothermal Region	Barometric Pressure mm Hg	Barometric Pressure (in. Hg)	1% Summer Dry-Bulb Temperature C	1% Summer Dry-Bulb Temperature (F)	1% Summer Wet-Bulb Temperature C	1% Summer Wet-Bulb Temperature (F)	99% Winter Dry-Bulb Temperature C	99% Winter Dry-Bulb Temperature (F)
1.	Geysers-Clear Lake, CA	I	705	(27.8)	34	(94)	22	(72)	-3	(26)
2.	Surprise Valley, CA	IV	640	(25.2)	32	(89)	17	(63)	-17	(1)
3.	Gerlach and Fly Ranch, NV	IV	655	(25.8)	34	(93)	17	(63)	-14	(7)
4.	Brady's Hot Springs, NV	IV	640	(25.2)	34	(93)	17	(63)	-14	(7)
5.	Steamboat Springs, NV	IV	630	(24.8)	34	(93)	17	(63)	-14	(7)
6.	Long Valley, CA	IV	585	(23.0)	38	(100)	18	(64)	-9	(16)
7.	Coso Hot Springs, CA	IV	640	(25.2)	40	(104)	20	(68)	-8	(18)
8.	Beowawe, NV	IV	630	(24.8)	34	(94)	18	(64)	-25	(-13)
9.	Raft River, ID	IV	615	(24.2)	34	(94)	18	(65)	-22	(-8)
10.	Roosevelt Hot Springs, UT	VI	610	(24.0)	34	(94)	18	(65)	18	(-1)
11.	Imperial Valley, CA	VII	760	(29.9)	46	(114)	27	(81)	-2	(29)
12.	Valles Caldera, NM	IX	545	(21.5)	33	(92)	18	(64)	-20	(-4)

Table 2-3

CLIMATOLOGICAL PARAMETERS FOR SITES SELECTED FOR PARAMETRIC ANALYSIS

	Maximum Temperature		2½% Summer Temperature		Average Temperature		Elevation
	Dry-Bulb	Wet-Bulb	Dry-Bulb	Wet-Bulb	Dry-Bulb	Wet-Bulb	
Type of Site	C (F)	C (F)	C (F)	C (F)	C (F)	C (F)	M (Ft)
Hot Desert	49 (120)	33 (92)	43 (110)	27 (80)	23 (73)	14 (57)	0 (0)
Basin and Range	39 (102)	21 (69)	33 (92)	17 (62)	10 (50)	4 (40)	1300 (1400)
Pacific Northwest	42 (107)	25 (76)	34 (94)	20 (68)	12 (53)	10 (46)	400 (1300)
High Mountain	36 (97)	21 (70)	31 (87)	16 (61)	8 (47)	3 (37)	2700 (8800)

As further described in Sections 3 and 4, wet, wet-dry, and dry cooling towers were the principal cooling systems considered in this study for rejecting the waste heat from a hydrothermal power plant. Once-through cooling, cooling ponds, and spray ponds are other cooling system alternatives, although they do not have as universal application as cooling towers for hydrothermal power plants.

If sufficient surface water or groundwater is available, or if the hydrothermal fluid can be used for cooling tower makeup, the conventional wet cooling tower can be used. Dry cooling towers, which transfer the waste heat from a power plant directly to the atmosphere by means of air-cooled, finned-tube heat exchangers without consumptive use of water, afford greater flexibility in power plant siting than other methods of waste heat rejection. This can be an especially important factor in considering the development of hydrothermal power plants. However, the low available energy of hydrothermal resources, which results in a rapid deterioration of turbine-generator performance as the condensing temperature increases above the design value, will have a significant effect on the relative economics of all-dry cooling tower systems for such applications.

By combining wet and dry cooling methods in a single system, the makeup water requirements associated with all-wet systems may be reduced significantly, usually with a considerably smaller increase in electrical energy production costs than would result from the use of an all-dry system. With this type of cooling combination the wet tower provides the additional cooling capacity required to maintain a relatively low back pressure, thus reducing the amount of generating capacity lost during high ambient air temperature operation.

WATER RESOURCE CONSIDERATIONS

The location and quantity of water for cooling system makeup is of fundamental importance to both the siting and design of power generation facilities. While conventional power plants are generally located in the proximity of surface water or groundwater resources, hydrothermal plants must be located at the production reservoirs, which may or may not be located in the vicinity of sufficient cooling water resources. Furthermore, since the majority of hydrothermal resources occur in arid climates, it is reasonable to assume that the availability of water for cooling system makeup may be of concern in many of the areas of hydrothermal interest. In many western areas, water resources are scarce, highly allocated, or influenced by regional institutional and legal considerations. Consequently, large quantities of water may have to be imported to the hydrothermal site, or special design provisions must be made which will reduce or eliminate the need for cooling system makeup water.

Availability of Water

The availability of water for various uses in the western United States is closely related to the climatic conditions which exist in the various regions. Moreover, the climatic types which would require the greatest amount of cooling system makeup water as a result of evaporation typically have the smallest amount of potentially available water.

The patterns of precipitation in the western states are extremely complex and variable as a result of predominant physiographic features, such as mountain ranges, which tend to inhibit and redirect the flow of moist air. Heaviest precipitation usually occurs in the vicinity of mountain ranges, especially on the windward slope. Moreover, maximum precipitation usually occurs in the winter, so that water storage reservoirs are required for irrigation and other purposes.

The average annual precipitation in the western United States ranges from approximately 12 to more than 200 cm (5 to more than 80 inches) per year, with corresponding surface runoff ranging from approximately 1 to 200 cm (1 to 80 inches) per year. Hence, the availability of surface water for various uses from precipitation and resultant runoff may be quite high in the humid regions, although it is generally very low in the more arid regions.

In many regions of the western states, groundwater resources are hydrologically related to surface water resources and therefore are also dependent upon patterns of precipitation. The use of groundwater resources in some areas may not be feasible since increased use may further deplete already dwindling reservoirs. The use of geothermal fluids may be feasible at some sites, depending upon their chemical composition and the necessity to reinject fluids to prevent subsidence or maintain reservoir integrity.

Institutional and Legal Considerations

Since water is a scarce resource in most of the western United States, a large number of institutions and regulatory bodies have been established to provide for equitable distribution. The availability of water for use by hydrothermal plants may therefore be limited or influenced by constraints associated with water rights and state and federal allocation policies.

Included in allocation policies are international agreements, interstate compacts, and federal and Indian claims to water rights. In addition, individual states have enacted legislation to exercise control over the acquisition and use of water within the state, and many states exercise control over the use of groundwater as well. The appropriation system of water allocation is predominant in the western states. The major feature of this system is the concept of "first in time, first in right"; that is, the right of the earliest appropriator supersedes all other claims. Appropriation by other appropriators is possible only if water is available in excess of that claimed by the earlier appropriators. During periods of water shortages, some appropriators may not be entitled to any water.

The appropriation system has been replaced by a permit system in most of the western states. This system, based primarily on the appropriation law, is essentially an administrative change which gives the state engineer or board of water rights the authority to grant or deny applications for water rights.

Cost of Water

The cost of water for power plant makeup is highly dependent upon the general availability and quality of the source of water. For instance, the unit cost of water (i.e. cost per gallon, acre-foot, etc.) may be relatively high for those sites where the water is either in short supply or highly allocated. Similarly, the transportation of water from a remote source, or the treatment of poor quality water, may result in a relatively high makeup water cost. The determination of exact costs of makeup water for the various regions of the western states would be a labyrinthian exercise. However, by performing analyses for a range of water costs, parametric economic evaluations of cooling systems can be made without extensive hydrological studies on a site-specific basis. The cost of water in this study is assumed to include acquisition, transportation, treatment, and disposal.

HYDROTHERMAL RESOURCE COSTS

In the optimization and evaluation of alternative heat rejection systems for hydrothermal power plant applications, it was assumed that the hydrothermal resource will be purchased by the utility from a producer who will provide the resource at the plant site. Therefore, the costs of developing, producing, and supplying the hydrothermal resource were considered to be included in the fuel cost rather than being treated separately in the economic analysis. Hydrothermal fuel cost is further described in Sections 3 and 4.

ECONOMIC PARAMETERS

In analyzing waste heat rejection systems for hydrothermal power plants, the following factors should be considered:

- Size of cooling system
- Capital cost
- Annual fixed-charge rate
- Ambient air temperature and durations
- Resource cost
- Turbine-generator performance
- Auxiliary energy requirements
- Replacement capacity and energy costs
- Makeup water costs
- Operation and maintenance costs

Computer models which consider the above factors were used to perform optimization and economic analyses of waste heat rejection systems for the various resources (high, intermediate, and low temperature) for both the flash steam and binary conversion processes. These models are described in detail in Section 4.

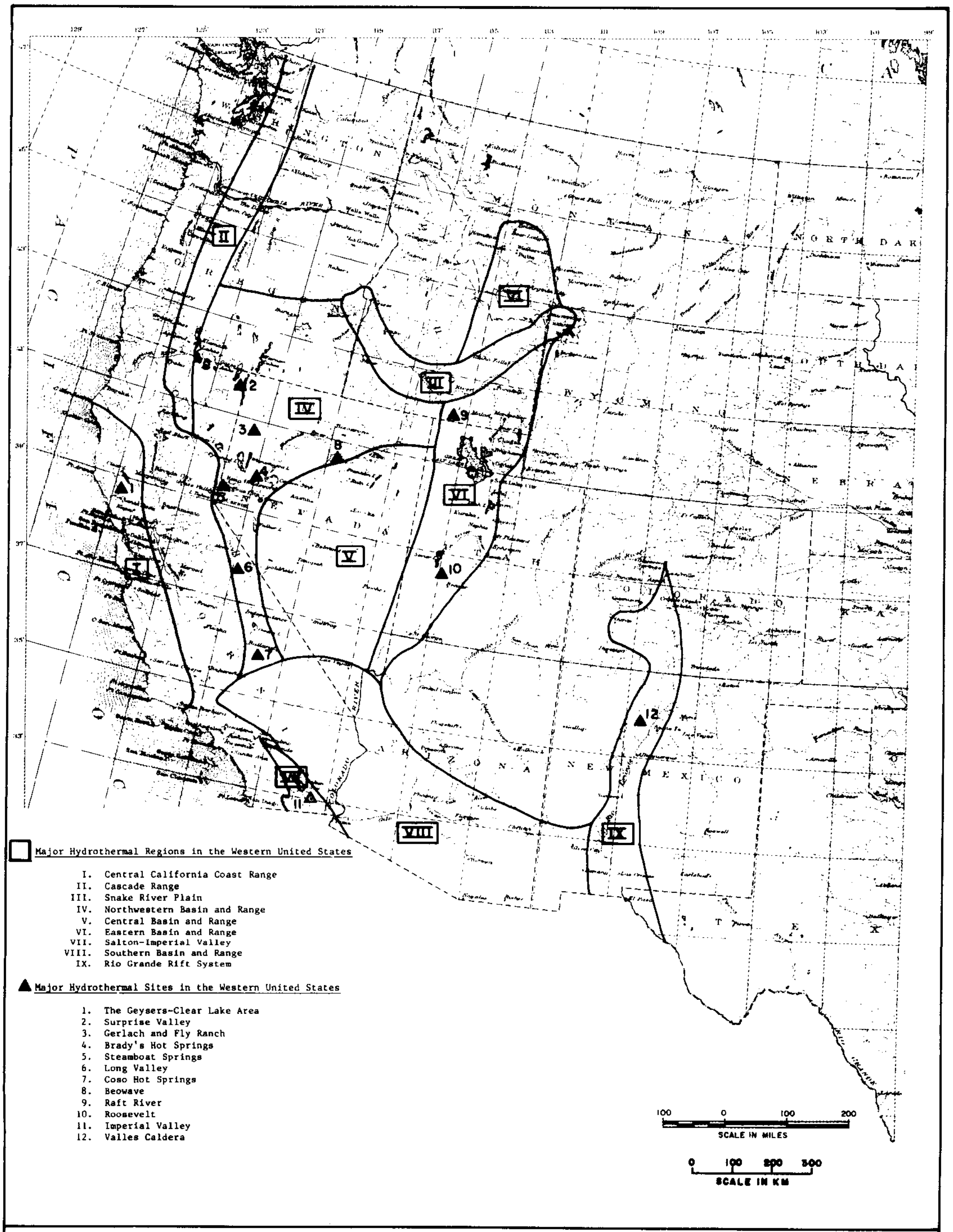


FIGURE 2-1
SELECTED MAJOR HYDROTHERMAL REGIONS AND SITES IN THE WESTERN UNITED STATES

Section 3

COMBINED PERFORMANCE OF HYDROTHERMAL CONVERSION PROCESSES AND COOLING TOWER SYSTEMS

GENERAL

In evaluating alternative cooling tower systems for power plants, an understanding of the combined performance of the turbine-generator and cooling tower is essential. The complex relationships which exist between the tower and the turbine must first be determined in order to predict the performance of a combination of turbine-generator and cooling tower system.

The three major factors given consideration in this part of the study were:

- Hydrothermal Conversion System
- Turbine-Generator System
- Cooling Tower System

The conversion system includes the hydrothermal heat exchanger for the binary system and the flash tanks and moisture separators for the flash steam system. The turbine-generator system assumed for this study includes the hydrocarbon turbine and generator for the binary system and the steam turbine and generator for the flash steam system. The cooling tower system includes the cooling tower or towers, condenser, and circulating water facilities.

HYDROTHERMAL CONVERSION SYSTEM

Binary Conversion Process

A binary conversion system utilizes a heat exchanger which transfers heat from the hot hydrothermal fluid to a secondary working fluid such as a hydrocarbon. The unique fluid properties of commercial isobutane, for example, permit much higher working pressures than possible with steam at the same temperature, thereby increasing overall turbine efficiency. Also, due to the low specific volume of commercial isobutane as compared to steam, the hydrocarbon turbine is physically smaller than the steam turbine and has a lower capital cost.

For the sites and resource temperatures considered in this study, the following assumptions were made regarding the binary conversion process:

- In order to prevent fouling of reinjection facilities, the geothermal supplier has established a minimum reinjection temperature of 71 C (160 F). Therefore, maximum energy is extracted from the hydrothermal fluid when the temperature of the hydrothermal fluid leaving the heat exchanger is 71 C (160 F).
- "Fuel cost" is based upon the amount of energy extracted, that is, cost per pound per hour of hydrothermal fluid pumped. Minimum fuel cost will occur when the spent hydrothermal fluid is reinjected at 71 C (160 F).

In evaluating the heat exchanger performance of the binary conversion system, two basic equations were used:

$$(1)\quad Q = UA\ \overline{\Delta T}$$

where Q = Heat transferred by heat exchanger (Btu/hr)

U = Heat transfer coefficient of heat exchanger (Btu/hr-ft^2-$^\circ$F)

A = Surface area of heat exchanger (ft^2)

$\overline{\Delta T}$ = Average incremental temperature difference across heat exchanger (^{o}F)

and (2) $Q = \dot{m}_h C_P (T_{in} - T_{out})$ or $Q = \dot{m}_i (h_{out} - h_{in})$

where Q = Heat transferred by heat exchanger (Btu/hr)

$\dot{m}_h$ = Mass flow rate of hydrothermal fluid (lbs/hr)

C_P = Specific heat of hydrothermal fluid (Btu/lb-^{o}F)

T_{in} = Hydrothermal resource temperature (^{o}F)

T_{out} = Hydrothermal fluid return temperature (^{o}F)

$\dot{m}_i$ = Mass flow rate of isobutane (lbs/hr)

h_{in} = Enthalpy of isobutane entering heat exchanger (Btu/lb)

h_{out} = Enthalpy of isobutane leaving heat exchanger (Btu/lb)

It was assumed that the heat transfer coefficient U would remain constant for the expected temperature conditions. Because heat exchanger surface area A is geometrically fixed, the ratio $Q/\overline{\Delta T}$ would be constant also, thereby enabling calculations to be made over the expected range of condensing temperatures of the hydrocarbon turbine. Using equations (1) and (2) (assuming C_P = 1.0 Btu/lb-^{o}F), T_{out} can be calculated for the range of condensing temperatures. This method of evaluating heat exchanger performance falls well within the accuracy limits of this study and, in addition, simplifies calculations considerably.

Figure 3-1 illustrates the heat exchanger temperature profiles for the 150 C (300 F), 182 C (360 F), and 246 C (475 F) resources. Since the hydrocarbon turbine cycle was assumed to be the same for all three resource temperatures, a single temperature profile curve for commercial isobutane is given.

The binary cycle using commercial isobutane was designed specifically for a 182 C (360 F) hydrothermal resource. Thus, when used with a 246 C (475 F) resource, the binary cycle using commercial isobutane does not take full advantage of the high resource temperature. In the case of the 150 C (300 F) resource, the heat exchanger experiences pinch point problems, as shown in Figure 3-1, which prevent a low hydrothermal fluid return temperature. This significantly increases fuel requirements and fuel cost and makes the 150 C (300 F) supercritical isobutane cycle a poor design choice as well.

An earlier study performed by the Ben Holt Company of Pasadena, California (EPRI ER-301) showed that subcritical isobutane cycles or supercritical cycles using 50 percent propane and 50 percent isobutane would be better suited for the 150 C (300 F) resource temperature. The 50 percent propane/50 percent isobutane supercritical cycle would also be well suited to the 150 C (300 F) resource temperature, but performance data for a turbine operating with this mixture were not available at the time this study was performed.

Flash Steam Conversion Process

A flash steam conversion process utilizes the thermodynamic flashing principle to convert a portion of the hot hydrothermal fluid into usable steam to drive a steam turbine. The percent of hot hydrothermal fluid that flashes to steam ranges from about 10 percent for the 150 C (300 F) resource to about 25 percent for the 246 C (475 F) resource. Each resource temperature operates at different flash pressures, as shown in Table 3-1.

TABLE 3-1

FLASH PRESSURES ASSUMED FOR HYDROTHERMAL FLASH STEAM CONVERSION PROCESSES

Resource Temperature °C (°F)	First Stage Flash Pressure kP (psia)	Second Stage Flash Pressure kP (psia)
150 C (300 F)	290 (42)	110 (16)
182 C (360 F)	379 (55)	138 (20)
246 C (475 F)	1055 (153)	232 (33.7)

The pressures shown are those used by the Ben Holt Company in EPRI Research Project 580, Topical Report 2, November 1976. The Ben Holt Company indicated that these pressures are the optimum combination for each resource temperature for minimizing the hydrothermal fluid flow from the resource.

A significant fuel cost penalty for the flash steam conversion system is incurred since the hydrothermal fluid is flashed at above atmospheric pressure in order to prevent leakage of air into the system. Therefore, the spent hydrothermal fluid, even when mixed with cool condensate, will always be at a temperature above 93 C (200 F) and could reach temperatures as high as 116 C (240 F), depending on resource temperature and ambient air temperatures. The high return temperature of the spent hydrothermal fluid represents a consistent penalty of 40 to 80 Btu/lb of fluid with respect to the 71 C (160 F) minimum return temperature limitation. This results in an increase in required hydrothermal fluid of 25 percent for the 246 C (475 F) resource and 50 percent for the 150 C (300 F) resource to generate the same amount of energy. Apart from flashing at lower-than-atmospheric pressures, which is not recommended, little can be done to reduce this penalty.

TURBINE-GENERATOR SYSTEM

Hydrocarbon Turbine

The turbine used for the binary analysis was an Elliott tandem-compound two-flow hydrocarbon turbine rated at 65.0 MWe at 586 kP (85 psia) exhaust pressure with commercial isobutane as the working fluid. Constant turbine inlet conditions of 379 kP (550 psia) and 143 C (290 F) upstream of the throttle valve were assumed. In order to maintain constant turbine inlet conditions with varying condensing temperature (a requirement due to limited turbine performance data), it was necessary to vary the flow of hydrothermal fluid through the heat exchanger to compensate for the effect due to the changing temperature of the isobutane entering the heat exchanger from the condenser. This operation would probably require a more sophisticated control system to function properly. The Elliott Company has also established a limit on turbine-generator output of 69.55 MWe, a 7 percent over-limit of the generator. Although considered in the computer analyses, the generator output limit was not shown in representing the turbine-generator performance in the curves of this section.

Figure 3-2 compares the performance of the Elliott axial-flow turbine with the performance of the Rotoflow radial-flow turbine. Both curves are for 3792 kP (550 psia), 143 C (290 F) throttle conditions and approximately 3,900,000 kg/hr (8,700,000 lb/hr) of commercial isobutane. Although computer analyses of the radial turbine were not performed in this study, it was assumed that the axial turbine evaluation is representative of what the radial turbine would have produced, had the required data been available. This is due to the fact that the performance of both turbines is comparable near the turbine design point. Therefore, except for differences in capital or operating costs, the evaluated busbar costs should be comparable for both the axial and radial turbine designs.

Flash Steam Turbine

The turbine used for the flash steam analyses was a General Electric tandem-compound four-flow steam turbine rated at 55.0 MWe at 14 kP (4 inches Hg) exhaust pressure. Turbine inlet conditions, as shown in Table 3-2, were assumed to be constant for a specific resource temperature.

TABLE 3-2

STEAM TURBINE INLET CONDITIONS FOR
HYDROTHERMAL FLASH STEAM CONVERSION PROCESSES

Resource Temperature ^{o}C (^{o}F)	First Stage Turbine Inlet Pressure kP (psia)	Second Stage Turbine Inlet Pressure kP (psia)
150 (300)	269 (39.1)	103 (14.9)
182 (360)	353 (51.2)	128 (18.6)
246 (475)	981 (142.3)	216 (31.3)

Different turbine inlet pressures require different turbine designs, so that the 150 C (300 F) resource temperature, having the lowest flash pressures, requires the largest steam turbine due to the higher specific volume of the low pressure steam. Performance of the steam turbine for all three resource temperatures is illustrated in Figure 3-3. The curves shown were calculated using established General Electric steam turbine performance estimating methods.

Gross Heat Rate

Gross heat rate, illustrated in Figures 3-4 and 3-5, is defined in this study as the heat input into the cycle by the hydrothermal fluid divided by the gross energy output, and is expressed in Btu/kWh. The single curve for the binary case is representative of all three resource temperatures studied. Conversely, the flash steam cycle gross heat rate is unique for each resource temperature. Gross heat rate for the binary system was calculated from the Elliott hydrocarbon turbine performance data, and gross heat rate for the flash steam system was calculated from the General Electric steam turbine performance data.

Cost Heat Rate

The cost heat rates shown in Figures 3-6 and 3-7 form the basis for fuel cost evaluation in this study. Cost heat rate is defined as the hydrothermal heat energy charged to the plant divided by the gross energy output, and is expressed in Btu/kWh. The 246 C (475 F) resource, when referenced to the established minimum hydrothermal fluid return temperature of 71 C (160 F), provides 315 Btu/lb of available heat. Likewise, the 182 C (360 F) resource provides 200 Btu/lb, and the 150 C (300 F) resource provides 140 Btu/lb, assuming the hydrothermal fluid has a specific heat of 1.0 Btu/lb-^{o}F. Therefore, if the cost of hydrothermal fluid is \$0.50/10^6 Btu, the cost of 1000 pounds of hydrothermal fluid is \$0.16 for the 246 C (475 F) resource, \$0.10 for the 182 C (360 F) resource, and \$0.07 for the 150 C (300 F) resource. However, because the plant hydrothermal fluid requirement increases with decreasing resource temperature, the net result is that overall fuel cost in mills/kWh is higher with a lower temperature resource. If the evaluation were made on the basis of equal cost per 1000 pounds for all three resources, relative busbar costs among the three resources would increase, but would not affect the conclusions of this study.

Figure 3-6 illustrates cost heat rate for the binary case. It should be emphasized that the curves shown for the 150 C (300 F) and 246 C (475 F) resources reflect high fuel costs due to the use of a non-optimum hydrocarbon working fluid (commercial isobutane) as previously explained. With optimized binary designs, one would expect to see a more even spread between the curves as in Figure 3-7, which reflects optimum designs for the flash steam cases.

COMBINED PERFORMANCE OF HYDROTHERMAL CONVERSION SYSTEMS WITH COOLING TOWERS

Figures 3-8 and 3-9 show turbine heat rejection for the binary cases and the flash steam cases, respectively. These curves are important in the design of the cooling tower system. For a given cooling tower, increased heat rejection results in a higher exhaust pressure, poorer plant performance, and, in the case of a wet tower, higher evaporative losses.

Figures 3-10 through 3-16 demonstrate combined performance of a binary turbine and a cooling tower. To avoid confusion and an excessive number of curves, similar illustrations were not included in the report for the flash steam cases, since the figures included for the binary cases are representative of the flash steam cases as well.

Figure 3-10 shows performance curves for an 11 C (20 F) ITD mechanical-draft direct dry cooling tower with the heat rejection curve for the binary turbine superimposed, and demonstrates combined performance of the binary turbine with a dry cooling tower. At a given ambient air temperature, using an 11 C (20 F) ITD tower, the binary turbine will have a unique heat rejection and condensing temperature. The condensing temperature is the sum of the ambient air temperature plus the tower ITD at the point of design tower heat rejection. This holds true for direct dry towers with any ITD. Figures 3-11 and 3-12 show progressively smaller direct dry towers with a 33 C (60 F) ITD and 56 C (100 F) ITD, assuming the same design heat rejection as the 11 C (20 F) ITD tower. Tower performance is shown only over a range of ambient air temperatures sufficent to include the Elliott turbine heat rejection curve.

Figure 3-13 illustrates the combined performance a wet cooling tower with a design wet-bulb temperature of 21 C (70 F) serving a binary turbine. From this graph, it can be shown that a 6 C (10 F) change in wet-bulb temperature, for example, has only about half the effect on condensing temperature with a wet tower that the same change in ambient air temperature has on condensing temperature with a direct dry tower. Under ambient temperature conditions where a dry tower would lose significant capability, a wet tower would perform with very little loss in capability. Figures 3-14 and 3-15 illustrate this point by demonstrating performance of the binary turbine with a dry and wet tower, respectively. For example, assume that the site has an average ambient air temperature of 12 C (53 F) and an average wet-bulb temperature of 8 C (46 F), and that the maximum ambient air temperature is 42 C (107 F) and maximum wet-bulb temperature is 23 C (73 F). Using Figure 3-15, at an 8 C (46 F) wet-bulb temperature, the gross generator output of the binary turbine would be 68.5 MW. At the maximum wet-bulb temperature of 23 C (73 F), the gross generator output would be 59 MW, a loss in capability of 9.5 MW. Using Figure 3-14, assuming a 33 C (60 F) ITD dry tower and an ambient air temperature of 12 C (53 F), the gross generator output would be 63.0 MW. At the maximum ambient air temperature of 42 C (107 F), the gross generator output would be 31.5 MW, a loss of 31.5 MW.

It is extremely cumbersome to exactly represent the performance of a wet/dry system in the form of a graphic illustration, since performance would have to be represented as a function of both wet-bulb temperature and dry-bulb temperature simultaneously. Figure 3-16, which represents only an approximation of a typical case, shows the gross generator output curve and the net generator output curve (gross output less auxiliary power) for the binary turbine. Operation of the dry/wet peaking cooling tower is described in Section 4.

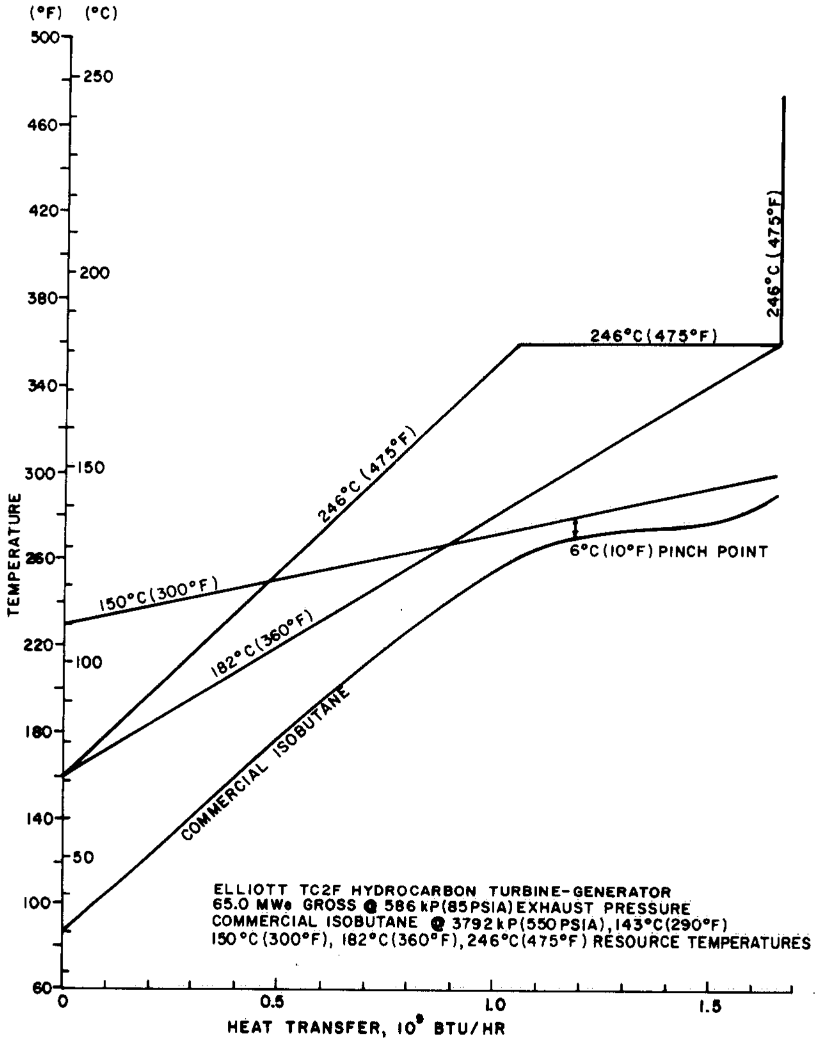
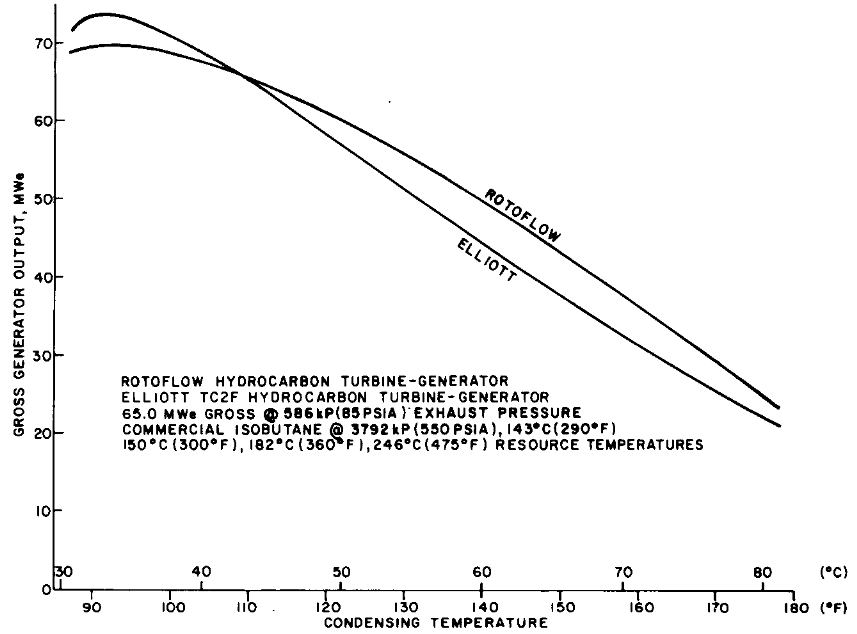
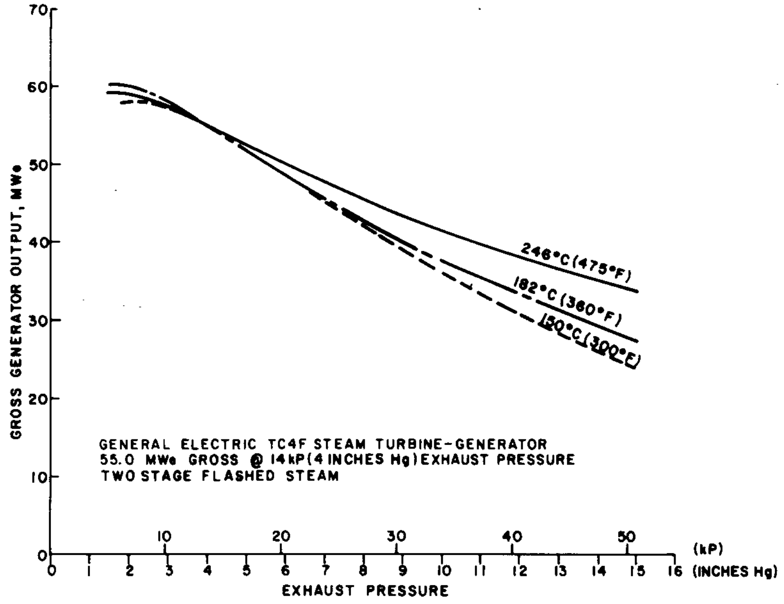


FIGURE 3-1 TEMPERATURE PROFILES OF HYDROTHERMAL HEAT EXCHANGERS



ROTOFLOW HYDROCARBON TURBINE-GENERATOR
ELLIOTT TC2F HYDROCARBON TURBINE-GENERATOR
65.0 MWe GROSS @ 586kP(85PSIA) EXHAUST PRESSURE
COMMERCIAL ISOBUTANE @ 3792kP(550PSIA), 143°C(290°F)
150°C(300°F), 182°C(360°F), 246°C(475°F) RESOURCE TEMPERATURES

FIGURE 3-2 TURBINE-GENERATOR PERFORMANCE - BINARY



GENERAL ELECTRIC TC4F STEAM TURBINE-GENERATOR
55.0 MWe GROSS @ 14kP(4 INCHES Hg) EXHAUST PRESSURE
TWO STAGE FLASHED STEAM

FIGURE 3-3 TURBINE-GENERATOR PERFORMANCE-FLASHED STEAM

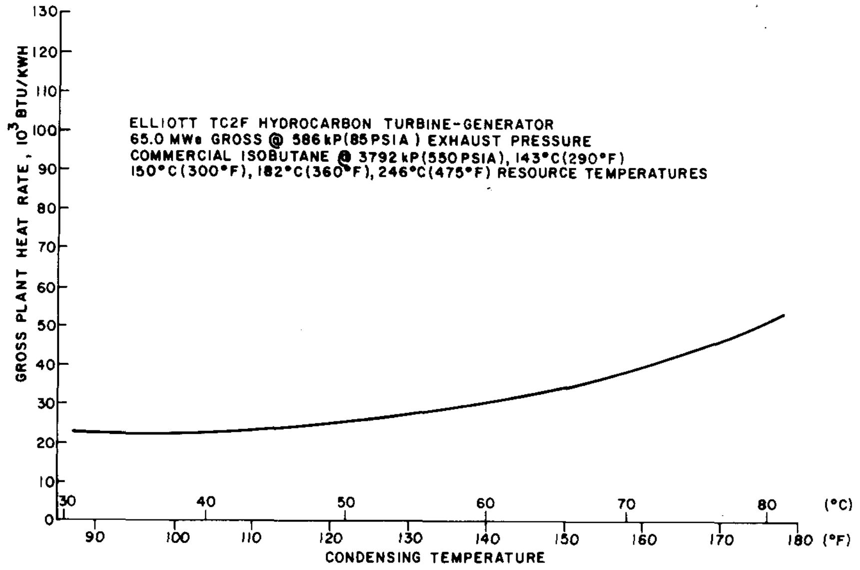


FIGURE 3-4 GROSS PLANT HEAT RATE – BINARY

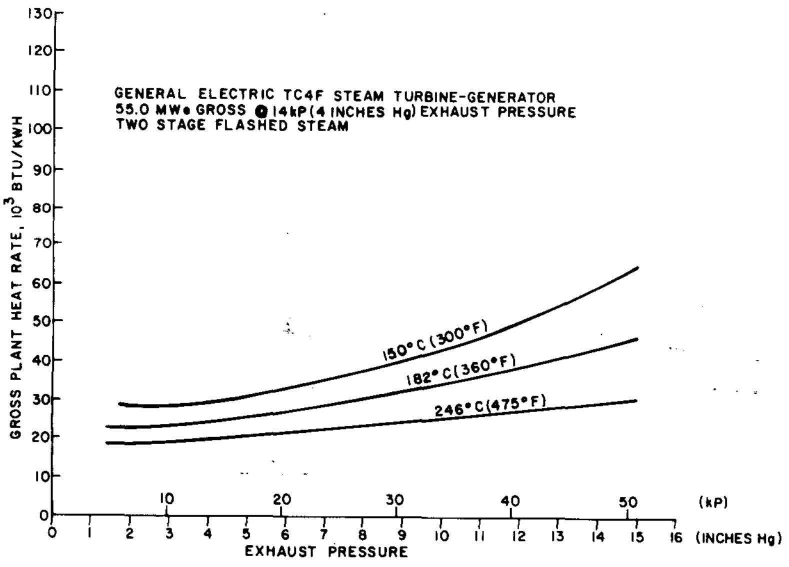


FIGURE 3-5 GROSS PLANT HEAT RATE–FLASHED STEAM

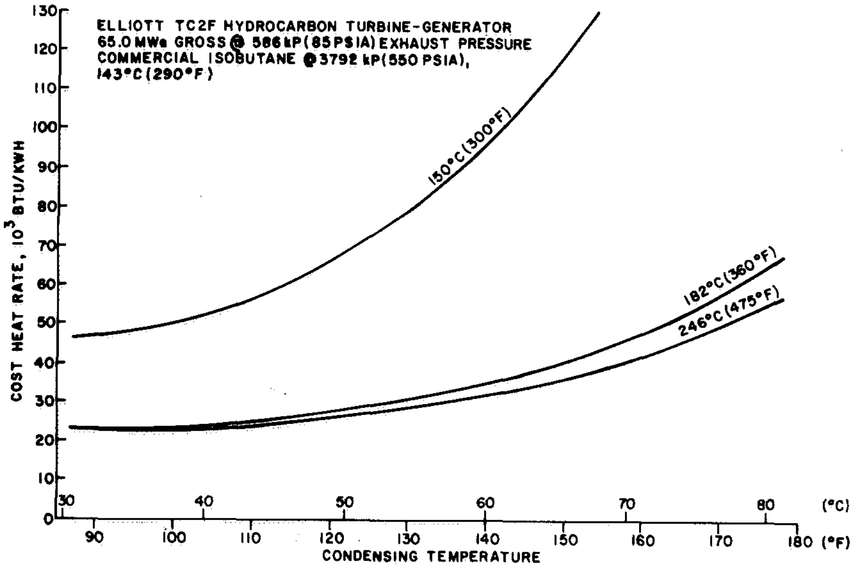


FIGURE 3-6 COST HEAT RATE – BINARY

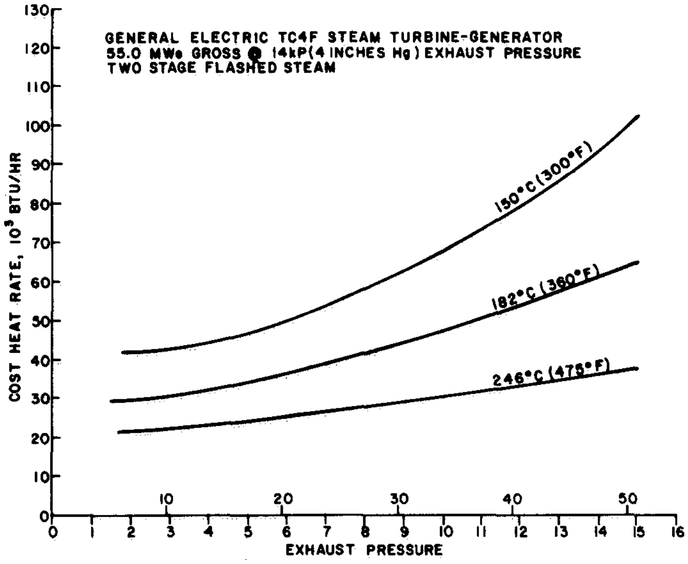


FIGURE 3-7 COST HEAT RATE – FLASHED STEAM

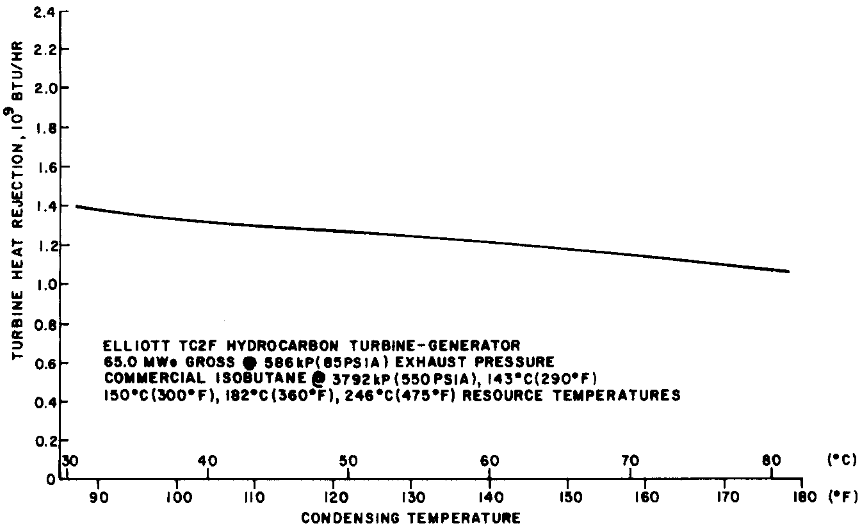


FIGURE 3-8 TURBINE HEAT REJECTION — BINARY

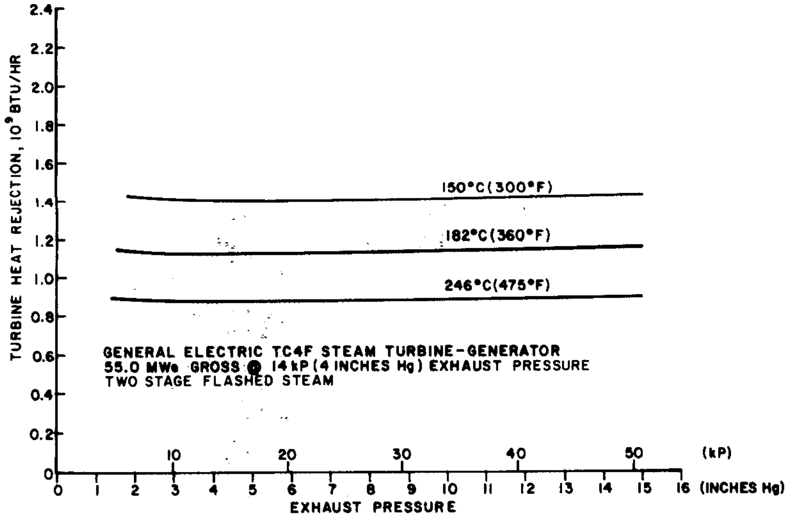


FIGURE 3-9 TURBINE HEAT REJECTION - FLASHED STEAM

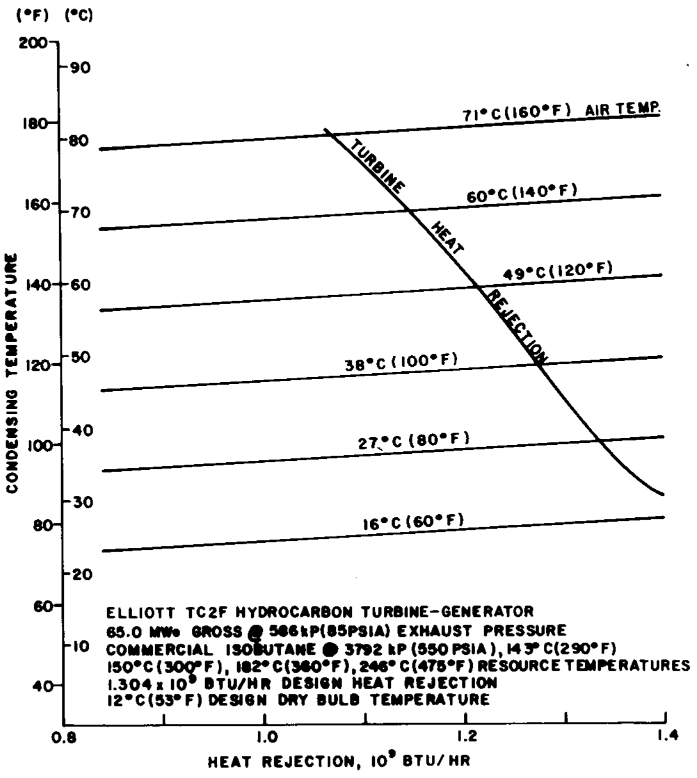


FIGURE 3-10 PERFORMANCE OF AN 11°C (20°F) ITD MECHANICAL-DRAFT DIRECT DRY COOLING TOWER

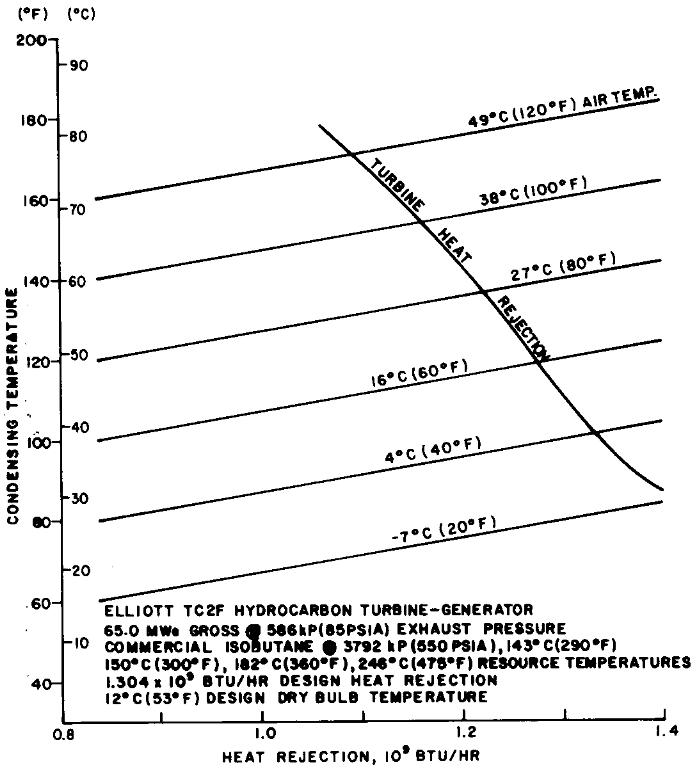


FIGURE 3-11 PERFORMANCE OF A 33°C (60°F) ITD MECHANICAL-DRAFT DIRECT DRY COOLING TOWER

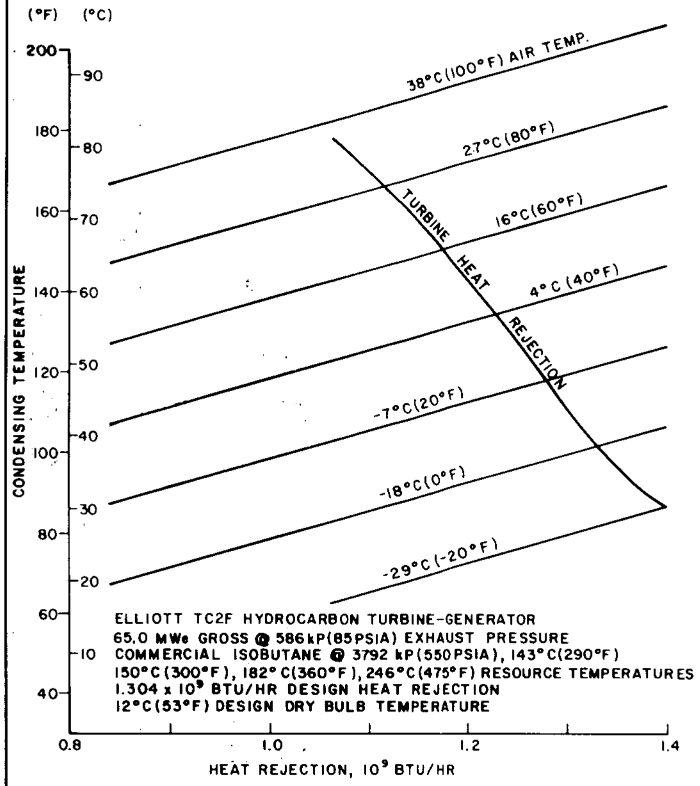


FIGURE 3-12 PERFORMANCE OF A 56°C (100°F) ITD MECHANICAL-DRAFT DIRECT DRY COOLING TOWER

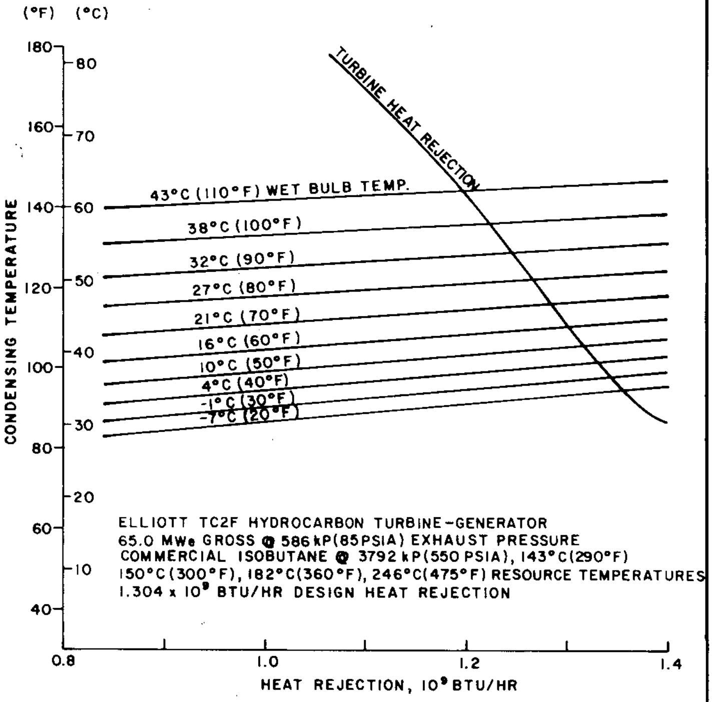


FIGURE 3-13 PERFORMANCE OF A 21°C (70°F) DESIGN WET BULB MECHANICAL-DRAFT WET COOLING TOWER

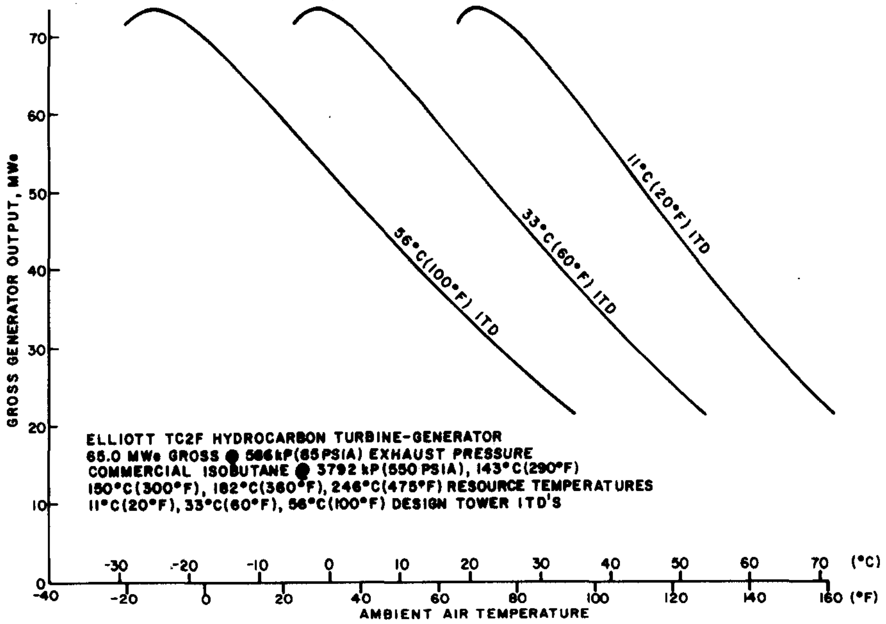


FIGURE 3-14 COMBINED PERFORMANCE OF ELLIOTT TURBINE WITH A MECHANICAL-DRAFT DIRECT DRY COOLING TOWER

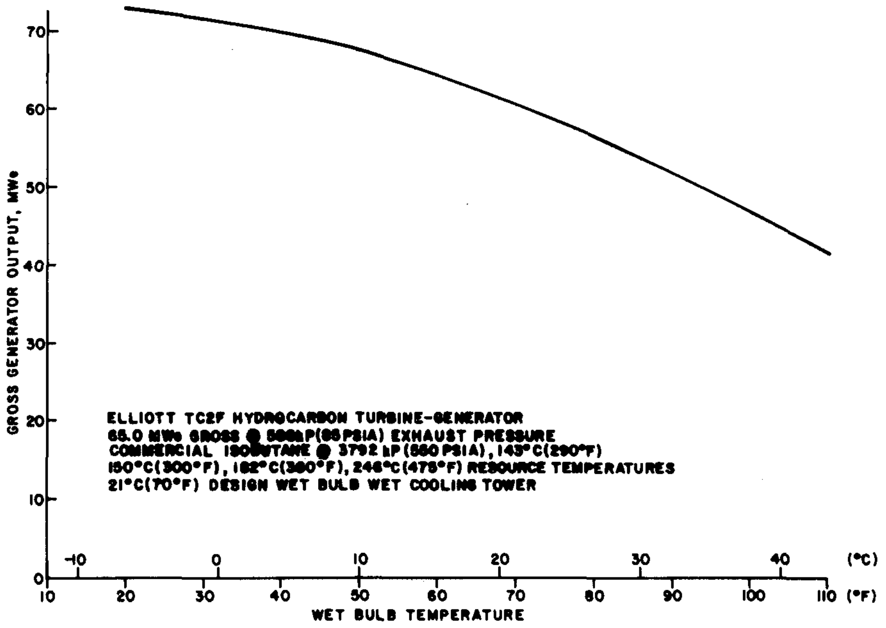


FIGURE 3-15 COMBINED PERFORMANCE OF ELLIOTT TURBINE WITH A MECHANICAL-DRAFT WET COOLING TOWER

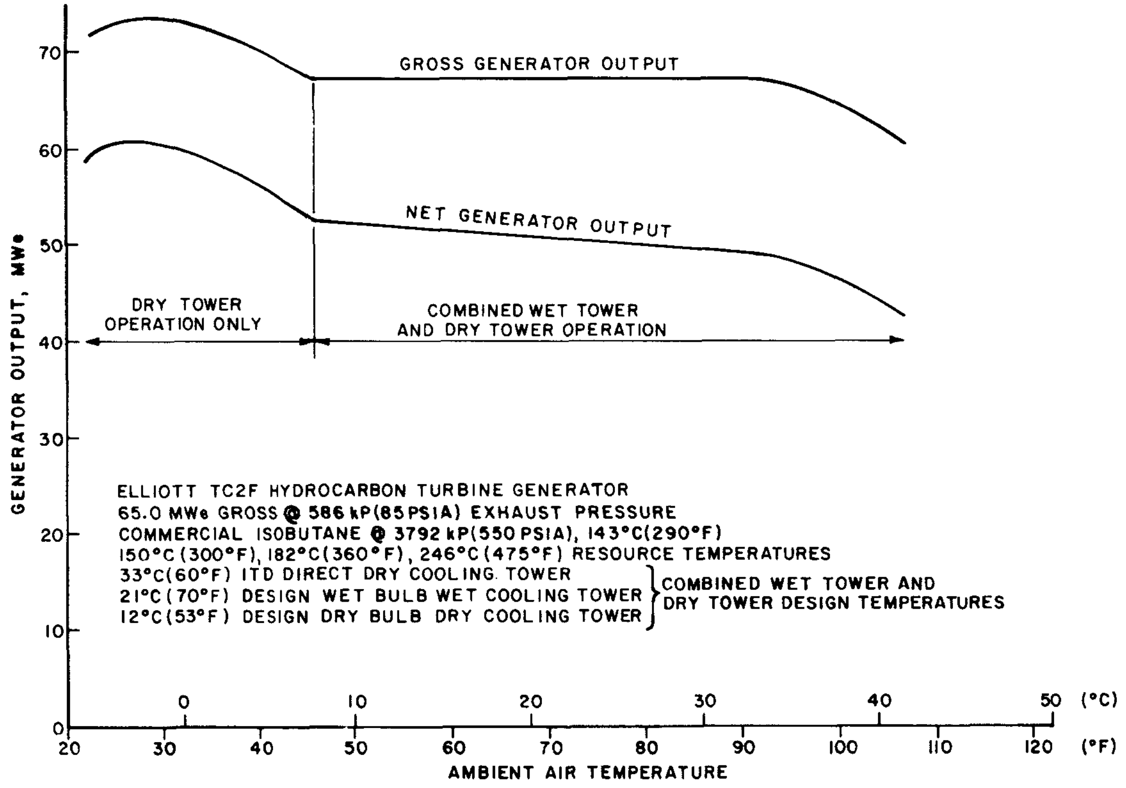


FIGURE 3-16 TYPICAL COMBINED PERFORMANCE OF ELLIOTT TURBINE WITH A MECHANICAL-DRAFT DIRECT WET-DRY COOLING SYSTEM

Section 4

OPTIMIZATION AND EVALUATION OF ALTERNATIVE HEAT REJECTION SYSTEMS FOR HYDROTHERMAL POWER PLANTS

GENERAL METHODOLOGY

In order to make economic evaluations of alternative heat rejection systems for hydrothermal power plant applications, the design of each candidate heat rejection system should be optimized for each set of site, plant, and operating conditions to be considered. The optimum design for the heat rejection system will be that which results in the lowest net electrical energy production costs. The optimum system, associated costs, and water requirements can then be determined by comparing the results of the optimization analyses for the various types of heat rejection systems.

The pertinent design variables to be optimized relate primarily to the physical size of the heat exchange components of the system. These variables include (1) the cooling range and approach in an evaporative cooling tower and (2) the initial temperature difference (ITD) between the temperature of the warm circulating water entering an indirect dry tower, or the condensing temperature of the turbine cycle working fluid in a direct dry tower, and the temperature of the ambient air entering the tower. In general, the capital cost of a heat rejection system increases, and system performance, turbine-generator performance, and operating economy improve as the sizes of the heat exchange components increase.

The required sizes and installed capital costs of the various system components are determined for the given site and plant design conditions. The cumulative annual combined performance of the heat rejection system design and turbine-generator are then determined based upon an assumed operating mode and duration of ambient temperatures. Evaluated annual capital and operating costs, penalties, and credits can then be determined. Net electrical energy production costs on a kilowatt-hour basis are determined by dividing total annual net evaluated costs by annual net electrical generation.

Turbine-generators rated at different turbine exhaust conditions and/or having different performance characteristics should also be investigated, since the generating capability will vary for different heat rejection system designs. Therefore, in order to make comparisons among heat rejection systems, the performance obtained in each case should be measured against an assumed reference system as described hereinafter.

The above procedure is then repeated for other combinations of values for the system design variables. The optimum design of the heat rejection system is then determined from a comparison of the net electrical energy production costs calculated for the various designs considered. By performing similar analyses for various types of heat rejection systems, the economically optimum type and design of heat rejection system can be determined.

COSTS AFFECTED BY TYPE OR DESIGN OF HEAT REJECTION SYSTEM

Heat Rejection System Capital Cost

The heat rejection system capital cost includes equipment, materials, and installation or erection costs for all components and facilities from the turbine exhaust flange outward. This would include condensers, towers, circulating water facilities, storage facilities, controls, and any other components required by a particular type of heat rejection system.

Appropriate allowances for engineering and contingencies, escalation, and interest during construction are also included in the estimated capital cost. Annual operation and maintenance costs are also typically calculated as a percentage of total heat rejection system capital cost.

Hydrothermal Energy Conversion System Capital Cost

The hydrothermal energy conversion system includes the heat exchangers, fluid circulating facilities, piping, turbine-generator, controls, and any other equipment directly involved in the conversion of the thermal energy of the hydrothermal resource into electrical energy. The optimum turbine-generator design and design condensing temperature may be affected by the type of heat rejection system and may also affect the overall design and total capital cost of the conversion system. In addition, conversion system and heat rejection system auxiliary power requirements will also affect the required size and capital cost of the conversion system. Appropriate allowances for indirect costs are also included in the estimated capital cost of the conversion system.

Annual Hydrothermal Resource Cost

Lower conversion cycle efficiencies of turbines designed for high condensing temperature operation, as compared with those designed for lower condensing temperatures, will result in greater annual hydrothermal resource requirements and costs for the same electrical energy production. Conversion cycle efficiency and annual hydrothermal resource requirements and costs will therefore depend upon the type of conversion process being considered.

Annual Cooling Water Makeup Cost

Conventional evaporative heat rejection methods require considerable quantities of cooling water makeup to replace losses due to evaporation, blowdown, and drift. Makeup requirements and costs are dependent upon cooling system design and can be significantly reduced by use of wet/dry cooling tower systems and essentially eliminated with dry cooling towers.

Costs Associated With Loss of Generating Capability

The generating capability of a hydrothermal turbine-generator decreases significantly with increasing turbine exhaust pressure, or condensing temperature, which increases with ambient temperature. Traditional approaches to analyzing heat rejection systems have assumed that either the conversion system and/or the heat rejection system must be sized to meet the electrical load demand under high ambient temperature conditions or provisions must be made for replacing losses associated with the reduced capability of the generating unit under high ambient temperature conditions. Alternatively, the conversion system and heat rejection system can be designed without provisions for sizing to meet a demand or for replacing losses.

Sizing the Conversion System. Sizing the conversion system, including the turbine-generator, to meet the desired electrical load demand at the highest condensing temperature expected will result in a high capital cost plant with excess generating capacity under the more favorable operating conditions which will exist during the remainder of the year. No provision is made for installing replacement capacity, and therefore no penalties are assessed. The reasonableness of this approach will depend upon the following considerations:

- Whether or not a market or need exists for the excess generation

- Whether or not the hydrothermal resource flow rate can be varied, thereby conserving the resource under favorable operating conditions
- The economic trade-off between the high capital cost of the conversion system and the potential income or savings associated with the available excess generating capability.

Sizing the Heat Rejection System. An alternative method of analysis is to size the heat rejection system so that high condensing temperatures will be avoided during high ambient temperature operation. This would result in greater cooling capacity than required under lower ambient temperature conditions. This might be a reasonable approach for evaporative-type heat rejection systems, since the variation in turbine-generator performance due to ambient conditions generally is limited to a relatively narrow range. This approach is not likely to be feasible for dry cooling systems, however, since the performance of a dry tower is nearly a linear function of ambient dry-bulb temperature, which typically varies over a wide range throughout the year at most sites. Thus, a dry tower system designed on the basis of the maximum ambient dry-bulb temperature occurring at a given site would be very large and costly and would have a much greater cooling capacity at low ambient temperatures than could be effectively utilized by a hydrothermal generating unit. The required size of the dry tower can be reduced significantly, however, by combining it with a wet peaking tower.

Replacement of Losses. Alternatively, the hydrothermal energy conversion and heat rejection systems can be designed on the basis of ambient conditions which will prevail over a greater part of the year, with capacity losses resulting from the reduced generating capability at higher temperatures being replaced from other sources. The required peaking capacity and replacement generation could be provided by gas turbines or other peaking units, or could be purchased from other utility systems which have excess generating capacity available.

No Sizing or Replacement of Losses. Since geothermal energy is normally considered to be a base load energy alternative, a "take-what-you-get" type of operating mode may also be reasonable. In this type of mode, the conversion system and heat rejection system are not sized to meet a demand, and replacement capacity and energy are not provided. Rather, it is assumed that the plant is utilized strictly for energy production and not for satisfying capacity requirements, although at least some measure of generating capacity can be considered as available for the system.

FACTORS WHICH INFLUENCE THE OPTIMIZATION AND COMPARATIVE EVALUATIONS OF ALTERNATIVE HEAT REJECTION SYSTEMS

Optimization of a heat rejection system essentially represents a trade-off between annual costs associated with constructing, owning, operating, and maintaining the system and annual costs related to the performance of the system. The optimum selection of a heat rejection system also includes consideration of the effects of each type of heat rejection system on the evaluated capital costs and operating economy of the hydrothermal energy conversion system.

Capital Cost of Heat Rejection System

The capital cost of a heat rejection system increases with the size of the system and is a major factor in determining the optimum design. The capital costs of optimum-sized dry and wet/dry cooling tower systems typically are higher than for evaporative-type systems for a given application.

Capital Cost of Hydrothermal Energy Conversion System

The size and capital cost of the hydrothermal energy conversion system are functions of the turbine-generator design, turbine cycle conversion efficiency, and the auxiliary power requirements of the conversion and heat rejection systems.

Efficient turbine-generator designs are likely to be relatively expensive but will reduce the operating cost by providing better turbine-cycle conversion efficiencies. Cycle efficiency improves with decreasing turbine exhaust pressure, or condensing temperature, and thus favors a larger size of heat rejection system. In a binary system, plant output and performance deteriorate as the hydrocarbon turbine operates off the design point. However, auxiliary power requirements increase with the size of the heat rejection system, thereby increasing the required size, auxiliary power requirements, and capital cost of the hydrothermal energy conversion system.

Annual Operation and Maintenance Costs

Annual operation and maintenance costs typically are calculated as percentages of the installed capital costs and increase with the size of the energy conversion and heat rejection systems. Estimates of capital costs will therefore affect estimates of operation and maintenance costs in the analyses.

Turbine-Generator Performance Characteristics

In addition to affecting the size and capital cost of the hydrothermal energy conversion system, the turbine-generator performance characteristics will also determine the design heat load on the heat rejection system. Turbine-generator performance will also determine both the annual net electrical generation produced by the hydrothermal unit, assuming a constant geothermal fluid flow, and the peaking capacity and replacement generation requirements.

The optimization of the heat rejection system, particularly in the case of dry towers, may also be affected by the performance characteristics of the turbine-generator at low exhaust pressures or condensing temperatures. At the back pressure at which the exhaust flow from a steam turbine has reached sonic velocity, further decreases in turbine exhaust pressure fail to produce any additional improvement in turbine-generator performance. For a hydrocarbon turbine, efficiency falls off sharply and performance deteriorates below a specific blade path pressure ratio. Therefore, the turbine-generator may be unable to effectively utilize the cooling capacity of a large heat rejection system under low ambient temperature conditions.

Ambient Air Temperatures

As mentioned in Section 2, the performance of dry cooling tower systems is nearly a linear function of ambient dry-bulb temperature, whereas the performance of evaporative-type heat rejection systems is affected primarily by the ambient wet-bulb temperature and, to a lesser extent, the ambient dry-bulb temperature. Wet-bulb temperatures generally do not vary over as great a range as dry-bulb temperatures. Since the approach to the wet-bulb temperature decreases as wet-bulb temperature increases, the performance of an evaporative-type heat rejection system generally is not as adversely affected by increases in ambient temperature as that of a dry system. At low ambient temperatures the performance of a dry cooling system may exceed that of an evaporative system. Thus, the most favorable applications for dry cooling systems are where average and maximum ambient temperatures are relatively low. High ambient temperatures will greatly increase the optimum size of a dry cooling system and will favor the use of evaporative-type heat rejection systems. The penalties associated with the use of dry cooling systems for high ambient temperature applications can be reduced significantly, however, by combining a dry tower with a wet peaking tower.

The entire range of ambient air temperatures occurring at a site affect the annual electrical generation and the replacement energy requirements of the plant. However, for a utility with a summer peak electrical demand, the maximum ambient temperature generally determines the peaking capacity requirements or, alternatively, the size of the generating plant if peaking capacity is not to be provided.

Cost of Replacement Capacity

Although the cost of capacity required to replace the loss of generating capability suffered at high ambient temperatures is a capital cost item, it results from a consideration of the performance of the heat rejection system. Therefore, an increase in the cost of peaking capacity will tend to increase the optimum size of the heat rejection system.

Cost of Replacement Energy

An increase in the cost of replacement energy required to meet the electrical load demand when the hydrothermal generating unit cannot do so will favor a larger heat rejection system and a turbine-generator design whose performance is less affected by increases in exhaust pressure or condensing temperature.

Annual Fixed-Charge Rate

The annual fixed-charge rate is the percentage rate applied to the capital costs of the hydrothermal energy conversion system, the heat rejection system, and the installed peaking capacity to determine the annual costs of the following items:

- Interest, or cost of money
- Depreciation, or amortization
- Interim replacements
- Insurance, or payments in lieu of insurance
- Taxes, or payments in lieu of taxes

By increasing the annual fixed-charge rate, the significance of capital costs in the economic analyses also increases.

Unit Hydrothermal Resource Costs

For this study, it has been assumed that the hydrothermal resource will be purchased by the utility from a producer who will provide the resource at the plant site. Therefore, the costs of developing, producing, and supplying the hydrothermal resource will be considered to be included in the fuel cost rather than being determined separately in the economic analyses. An increase in the unit cost of the hydrothermal resource will favor conversion system (including the turbine-generator) and heat rejection system designs which maximize the overall conversion efficiency, i.e., larger, higher capital cost heat rejection systems.

It has also been assumed that the utility will purchase geothermal heat on a cost per million Btu basis calculated as a function of the difference between the initial resource temperature and a set minimum return temperature designed to prevent scaling in the reinjection wells. Therefore, depending upon the initial temperature of the resource, the utility would pay for a set number of Btu per pound of resource, regardless of return temperature.

Unit Water Costs

The cost of cooling water makeup is assumed to include the base cost of the water plus the cost of supplying and treating it. Higher unit water costs will improve the comparative economics of wet/dry and dry cooling tower systems.

DESCRIPTION OF COMPUTER PROGRAMS

The foregoing pages describe the general approach incorporated in the computer programs which have been developed for optimizing and evaluating cooling tower systems for hydrothermal plants. Input data are read into the programs at the time of execution from three separate data files. These files contain the following types of data:

- Site-specific data, such as ambient temperature duration data
- Characteristic performance data for the turbine-generator design being considered
- Input data applicable to a particular analysis, such as the ranges of unit input energy and makeup water costs to be considered; the source and costs of peaking capacity and replacement generation, if provided; the assumed annual operating profile; and the scheduled startup date for the plant

Basic design, characteristic performance, and unit capital cost data applicable to the various components of the cooling tower systems are incorporated in the programs in DATA statements.

The performance of a cooling tower system design is determined by use of applicable characteristic tower performance equations. For example, dry cooling towers are sized on the basis of performance data supplied by manufacturers of such equipment. Performance equations adopted by the Cooling Tower Institute are used to determine the performance and size of an evaporative cooling tower for given design conditions. Steam surface condensers are designed according to Heat Exchange Institute (HEI) standards, whereas hydrocarbon condensers are designed on the basis of manufacturer-supplied information. Other components of the heat rejection system, such as pumps and piping, are sized in accordance with established power plant design practice. The wet/dry program assumes that the turbine exhaust flow is directed to two separate condensers, one served by a wet tower and the other served by a dry tower.

The capital costs of major equipment items (towers, condensers, pumps, etc.) are determined from manufacturers' quotations and pricing guides. Construction costs are estimated on the basis of published information, manufacturers' installation and erection cost estimates, and construction cost data compiled by R. W. Beck and Associates from previous design and construction engineering jobs. Capital cost data incorporated in the computer programs are based on national average material costs and labor rates and a given base year. Adjustments can be made for annual escalation rates, construction cost indices applicable to the given site, the projected length of the construction period, and the scheduled startup date for the plant.

The wet/dry cooling tower program assumes that the wet tower will be used only as a peaking tower to prevent the condensing temperature from exceeding a specified maximum value when the dry tower alone could not maintain the specified condensing pressure or temperature. This operating mode results in the minimum water consumption for the wet/dry system. For instance, if the dry cooling tower is able to carry the full heat load without exceeding the specified maximum operating back pressure at a given ambient air temperature, only the dry tower is used. When the minimum back pressure operating condition is reached, dry tower fan power is reduced by switching fans to half-speed or by taking fans out of service in order to reduce auxiliary energy requirements. When ambient temperatures increase to the point where the dry tower alone is not able to maintain the specified maximum operating back pressure, wet tower capacity is activated as required to maintain that back pressure. If additional wet cooling were added at this point, the back pressure would decrease, with resulting improvement in turbine-generator performance. However, this mode of operating the wet/dry cooling system to achieve optimum fuel economy is not considered, since the purpose of the wet/dry cooling tower program is to determine the amount of water which can be saved.

The annual combined performance of the turbine-generator and heat rejection system is evaluated on essentially an hour-by-hour basis over the annual range of ambient temperature conditions normally expected to occur at the given site.

The computer programs are structured to use weather data as published in the Decennial Census of United States Climate - Summary of Hourly Observations.

A list of the information which can be obtained from the computer programs is presented in Section 5.

Section 5

PARAMETRIC EVALUATIONS OF COOLING SYSTEMS FOR HYDROTHERMAL POWER PLANTS

RANGE OF PARAMETERS CONSIDERED IN ANALYSES

In order to make meaningful economic evaluations of alternative cooling systems for hydrothermal power plants, numerous parameters should be analyzed to determine busbar energy production costs and makeup water requirements. A detailed discussion of these parameters is provided in Section 2, and the computer programs which have been developed to perform the evaluations are described in Section 4.

Specifically, the parametric analyses performed for this study assumed the following range of values:

- Hydrothermal resource temperature: 150 C (300 F), 182 C (360 F), and 246 C (475 F)
- Hydrothermal power plant conversion process: Flash steam and binary
- Climatological type: High Mountain, Pacific Northwest, Basin and Range, and Hot Desert
- Cooling system type: Mechanical-draft wet towers and mechanical-draft direct dry/wet peaking towers
- Annual fixed-charge rate: 15 percent
- Hydrothermal "fuel cost": $\$0.50/10^6$ Btu and $\$1.00/10^6$ Btu
- Makeup water cost: $0.10/Kgal, $1.00/Kgal, and $2.50/Kgal (includes acquisition, transportation, treatment, and disposal costs)

By selectively analyzing various combinations of values for these parameters, it is possible to compare the busbar energy production costs and makeup water requirements for hydrothermal power plants equipped with alternative cooling tower systems under different site, design, and economic conditions.

The following assumptions were made for all cases considered:

- Nominal electrical output of flash steam plant: 55 MWe gross and 50 MWe net
- Nominal electrical output of binary plant: 65 MWe gross and 50 MWe net
- Scheduled commercial startup date: 1980
- Annual hours of operation: 6500
- Capital costs described in Appendix C
- 4.5 cycles of concentration of circulating water in the evaporative cooling tower

PRELIMINARY ANALYSES PERFORMED

Loss of Generating Capability

As described in Section 4, several methods may be used for accounting for costs associated with the loss of generating capability during periods of high ambient temperature. Preliminary analyses were performed in order to determine the magnitude of the differences in busbar energy production cost for the following three methods of accounting for loss:

- Sizing the conversion system
- Replacement of losses
- No sizing or replacement of losses

In all of the preliminary cases considered, busbar costs were slightly lower when no penalty was assessed for capacity and energy losses, i.e., designing the plant for certain ambient temperature conditions and then "taking what you get". Typical differences in cost were on the order of a few mills/kWh, equivalent to a few percent of the total busbar cost. The parametric analyses presented in this report were therefore performed assuming that no penalty was assessed for loss of capability.

Direct Versus Indirect Dry Towers

Preliminary computer analyses were performed for dry/wet peaking cooling tower systems for both direct and indirect dry towers. In all of the preliminary cases considered, the use of direct dry towers resulted in lower busbar energy production costs than indirect dry towers. The primary reason for the improvement in economics with a direct dry cooling system is the fact that the direct dry towers do not have the thermodynamic loss associated with the surface condenser used with the indirect dry cooling system. Because of the long duration of high ambient dry-bulb temperatures at the sites considered in this study, the elimination of the surface condenser TTD has a marked effect on the tower size and performance. Typical differences in cost were on the order of a few mills/kWh, or a few percent of the total busbar cost. The parametric analyses presented in this report were therefore performed assuming direct dry towers.

Effect of Turbine Design Back Pressure

Preliminary computer analyses were performed for a range of design back pressures for the wet tower and design maximum operating back pressures for the dry/wet peaking tower in order to determine optimum back pressure design values for each case considered. For most cases, the range was 80-95 psia for the binary systems and 3-4.5 in. Hg for the flash steam systems.

Binary and flash steam systems served by evaporative cooling towers generally optimized at different design back pressures for each resource temperature considered at each site. The results presented in this report for the binary systems are based upon the corresponding optimum back pressure values. However, since makeup water requirements for the flash systems change slightly with different design back pressures, design back pressures which optimized for the majority of the cases at a particular site were selected as representative of that site for all resource temperatures.

If busbar energy production cost is plotted as a function of makeup water requirement for a dry/wet peaking cooling tower for several different design maximum operating back pressures, a family of curves is produced as illustrated in Figure 5-1. In actual practice, a "least-cost curve" can be constructed from the family of curves so that the design back pressure which results in the lowest busbar cost for a given quantity of makeup water would be selected. However, in order to facilitate the reduction of data for the dry/wet peaking cases, the family of curves was simply "averaged" for both the binary and flash steam cases. As subsequently described, the results of this study are presented in terms of a base case and a set of cost multipliers to be used for related cases. Therefore, averaging does not significantly affect the accuracy of the results.

RESULTS OF PARAMETRIC ANALYSES

Information Obtainable from Computer Programs

The computer programs which were developed to economically optimize and evaluate mechanical-draft evaporative and direct dry/wet peaking cooling tower systems provide the following information for each combination of resource temperature, conversion process, climatic condition, fuel cost, fixed charge rate, and makeup water cost considered:

- Gross annual base generation and auxiliary energy requirements
- Annual makeup water requirements
- Annual plant capital and operating costs
- Annual geothermal energy and operating costs
- Annual makeup water and operating costs
- Total annual capital and operating costs
- Busbar energy production costs, exclusive of site-specific costs due to site inaccessibility, local labor and materials variability, pollution control measures, transmission line facilities, and taxes
- Busbar component cost breakdown
- Summary of pertinent cooling tower and condenser design data
- Cost breakdown for cooling tower, condenser, circulating water facilities, controls, engineering and contingencies, interest during construction, and conversion plant
- Annual turbine operation profile
- Annual plant generation profile
- Distribution of heat load between wet and dry towers for the dry/wet peaking tower

Sample computer output for the mechanical-draft evaporative cooling tower program is given in Appendix D, while sample output for the mechanical-draft direct dry/wet peaking cooling tower program is given in Appendix E. (Computer printouts for all the cases analyzed are available for inspection at the EPRI offices.)

Results of Analyses of Evaporative Cooling Systems

Analyses of mechanical-draft evaporative cooling towers for both binary and flash steam systems were performed for 150 C (300 F), 182 C (360 F), and 246 C

(475 F) resources for the sites, fuel costs, and makeup water costs previously described. Because of the large number of cases studied, the results of the analyses have been condensed for the text of this report.

As discussed in Section 3, the binary turbine data used in the analyses are based upon the Elliott turbine design optimized for a 182 C (360 F) resource and therefore do not represent optimum hydrocarbon fluid choices or turbine designs for either 150 C (300 F) or 246 C (475 F) resources. For this reason, the results of the binary analyses for 150 C (300 F) and 246 C (475 F) are presented in Appendix F rather than in the text of this report. By comparison, the flash steam turbine data used in the analyses are based upon well-established turbine designs and therefore are considered to be valid for all three temperatures investigated.

The approach used in this report to portray results of the computer analyses is to define a base case and establish a set of cost multipliers. This approach was possible since varying such parameters as fuel cost and water cost did not noticeably affect makeup water requirements. Therefore, for a given resource temperature and climatological type, the busbar energy production costs could be expressed as multiples of each other, which simplified the presentation of the results considerably.

For binary systems, the base case was selected as the busbar energy production cost of a 182 C (360 F) binary system with an evaporative cooling tower using a fuel cost of $\$0.50/10^6$ Btu and a makeup water cost of \$0.10/Kgal. For flash systems, the base case was selected as the busbar energy production cost of a 182 C (360 F) flash steam system with an evaporative cooling tower using a fuel cost of $\$0.50/10^6$ Btu and a makeup water cost of \$0.10/Kgal. Busbar costs for other resource temperatures, fuel costs, and makeup water costs may be determined by multiplying the base cost by an appropriate multiplier. Definitions of cost cost multipliers for evaporative cooling towers are shown in Table 5-1, while the base cases for binary and flash steam systems for evaporative cooling towers are shown in Table 5-2. Cost multipliers for the 182 C (360 F) binary cases are listed in Table 5-3, and cost multipliers for the flash steam cases are plotted according to resource temperature in Figure 5-2 for the different sites. Table 5-4 provides a list of conversion factors used in the parametric analyses.

The cost multipliers presented in Table 5-3 (binary) and Figure 5-2 (flash steam system) apply to all four sites considered. This is primarily due to the fact that the various cases analyzed for a particular site were referenced to the 182 C (360 F) case for $\$0.50/10^6$ Btu fuel cost and \$0.10/Kgal water cost at that same site. Another fact worth noting is that there is little difference in the base case busbar energy production costs and cooling tower makeup water requirements shown in Table 5-2 for the three non-desert sites considered. Cooling tower makeup water requirements and busbar costs were slightly higher for the Hot Desert site than the other sites due to higher ambient temperatures.

In order to illustrate the use of the cost multiplier concept, the following sample calculations are presented for both binary and flash steam systems using evaporative cooling towers.

Sample Calculation. Find the makeup water requirement and busbar energy production cost (exclusive of site-specific factors) for a 182 C (360 F) binary system served by a mechanical-draft evaporative cooling tower at a High Mountain site assuming that fuel costs $\$1.00/10^6$ Btu and water costs \$1.00/Kgal. From Table 5-3, the appropriate cost multiplier is 1.57. From Table 5-2, the water consumption and base cost (for a 360 F resource at $\$0.50/10^6$ Btu and \$0.10/Kgal) are 3003 acre-feet per year and 31.08 mills/kWh. The busbar energy production cost for this example is therefore 1.57 x 31.08, or 48.80 mills/kWh.

Table 5-1

DEFINITION OF COST MULTIPLIERS FOR EVAPORATIVE COOLING TOWERS

Binary

$$\text{cost multiplier} = \frac{\text{Mills/kWh at site for } 360^{o}\text{, FC, WC}}{\text{Mills/kWh at site for } 360^{o} \text{ Binary, \$0.50/10}^{6} \text{ Btu, \$0.10/Kgal}}$$

Flash

$$\text{cost multiplier} = \frac{\text{Mills/kWh at site for T, FC, WC}}{\text{Mills/kWh at site for } 360^{o} \text{ Flash, \$0.50/10}^{6} \text{ Btu, \$0.10/Kgal}}$$

where T = temperature of the resource
FC = Fuel cost in $\$/10^6$ Btu
WC = Water cost in \$/Kgal ($K = 10^3$)

Table 5-2

BASE CASES FOR BUSBAR ENERGY PRODUCTION COST AND WATER CONSUMPTION FOR EVAPORATIVE AND DRY/WET PEAKING COOLING TOWERS

Binary

360 F binary case using $\$0.50/10^6$ Btu fuel cost and \$0.10/Kgal water cost:

Site	Mills/kWh	Acre-Feet 360 F
Pacific Northwest	31.65	2871
Basin and Range	31.22	2931
High Mountain	31.08	3003
Hot Desert	33.02	3355

Flash

360 F flash case using $\$0.50/10^6$ Btu fuel cost and \$0.10/Kgal water cost:

Site	Mills/kWh	Acre-Feet		
		300 F	360 F	475 F
Pacific Northwest	33.68	3083	2454	1909
Basin and Range	33.47	3154	2496	1942
High Mountain	33.42	3244	2564	1995
Hot Desert	34.31	3447	2774	2135

(Note: Based upon 50 MWe net plant sizes operating 6500 hours per year.)

Table 5-3

BUSBAR ENERGY PRODUCTION COST MULTIPLIERS FOR 182 C (360 F) BINARY SYSTEMS USING EVAPORATIVE COOLING TOWERS

Site	Fuel Cost, $\$/10^6$ Btu	Water Cost, $/Kgal	Cost Multiplier
(All Sites)	0.50	0.10	1.00
		1.00	1.08
		2.50	1.21
	1.00	0.10	1.48
		1.00	1.57
		2.50	1.70

Table 5-4

TABLE OF USEFUL CONVERSION FACTORS FOR PARAMETRIC ANALYSIS

300 F = 150 C

360 F = 182 C

475 F = 246 C

1 acre-foot = 325,851 gallons

1 acre-foot = 1233 cubic meters

$0.10/Kgal = $ 32/acre-foot

$1.00/Kgal = $325/acre-foot

$2.50/Kgal = $814/acre-foot

$K = 10^3$

Sample Calculation. Find the makeup water requirement and busbar energy production cost (exclusive of site-specific factors) for a 246 C (475 F) flash steam system served by a mechanical-draft evaporative cooling tower at a Basin and Range site assuming that fuel costs $\$0.50/10^6$ Btu and water costs \$2.50/Kgal. From Figure 5-2, the appropriate cost multiplier is 0.91. From Table 5-2, the water consumption and base cost (for a 360 F resource at $\$0.50/10^6$ Btu and \$0.10/Kgal) are 1942 acre-feet per year and 33.47 mills/kWh. The busbar energy production cost for this example is therefore 0.91 x 33.47, or 30.46 mills/kWh.

Results of Analyses of Dry/Wet Peaking Cooling Systems

Analyses of mechanical-draft direct dry/wet peaking cooling towers for both binary and flash steam systems were also performed for 150 C (300 F), 182 C (360 F), and 246 C (475 F) resources for the sites, fuel costs, and makeup water costs previously described. Because of the large number of cases studied, the results of the analyses have similarly been condensed for the text of this report. The results of the binary systems for 150 C (300 F) and 246 C (475 F) resources are not included in the text of this report for the reasons previously cited.

The same approach is used to portray results of the computer analyses for dry/wet peaking cooling towers -- that is, to define a base case and establish a set of cost multipliers to be used for related cases. For binary systems, the base case was selected as the busbar energy production cost of a 182 C (360 F) binary system with an evaporative cooling tower using a fuel cost of $\$0.50/10^6$ Btu and a water cost of \$0.10/Kgal. For flash steam systems, the base case was selected as the busbar energy production cost of a 182 C (360 F) flash steam system with an evaporative cooling tower using a fuel cost of $\$0.50/10^6$ Btu and a water cost of \$0.10/Kgal. Busbar costs for different resource temperatures, fuel costs, and makeup water costs may be determined by multiplying the base cost by an appropriate multiplier. Definitions of cost multipliers for dry/wet peaking cooling towers are shown in Table 5-5, while the base cases for binary and flash steam systems for dry/wet peaking cooling towers are shown in Table 5-2.

Cost multipliers for the 182 C (360 F) binary cases are plotted as a function of percent water requirement in Figures 5-3 through 5-6 for the sites considered, and cost multipliers for the flash steam cases for all resource temperatures considered are similarly plotted in Figures 5-7 through 5-10. Appendix G contains tabulations of the multipliers used for plotting both the binary and flash steam curves.

Zero percent water consumption represents a plant with dry cooling towers only, whereas 100 percent water consumption represents a plant with evaporative (wet) cooling towers only. The points between zero and 100 percent represent plants having different size combinations of dry and wet cooling towers, with a higher value of water consumption indicating a combination of a smaller dry tower with a larger wet tower. From such a graph, the decision-maker can determine the incremental cost of reducing the water consumption of the cooling system, or, conversely, what cost would be incurred at a site if only a certain quantity of water were available, thereby requiring the supplemental use of dry cooling systems.

Sample Calculation. Find the makeup water requirement and busbar energy production cost (exclusive of site-specific factors) for a 246 C (475 F) flash steam system served by a mechanical-draft dry/wet peaking cooling tower designed to use only 10 percent of the water required by an evaporative cooling tower at a Basin and Range site assuming that fuel costs $\$0.50/10^6$ Btu and water costs \$2.50/Kgal. From Figure 5-7, the appropriate cost multiplier is 0.95. From Table 5-2, the water consumption and base cost (for a 360 F resource served by

Table 5-5

DEFINITION OF COST MULTIPLIERS AND WATER PERCENTAGES FOR DRY/WET PEAKING COOLING TOWERS

Binary

$$\%\ \text{water consumption} = \frac{\text{Acre-feet required at site for wet/dry}}{\text{Acre-feet required at site for wet}}$$

$$\text{cost multiplier} = \frac{\text{Mills/kWh at site for wet/dry for } 360^{\circ}\text{, FC, WC}}{\text{Mills/kWh at site for wet for } 360^{\circ}\text{ Binary, \$0.50/}10^{6}\text{Btu, \$0.10/Kgal}}$$

Flash

$$\%\ \text{water consumption} = \frac{\text{Acre-feet required at site for wet/dry}}{\text{Acre-feet required at site for T for wet}}$$

$$\text{cost multiplier} = \frac{\text{Mills/kWh at site for wet/dry for T, FC, WC}}{\text{Mills/kWh at site for wet for } 360^{\circ}\text{ Flash, \$0.50/}10^{6}\text{Btu, \$0.10/Kgal}}$$

where T = Temperature of the resource

FC = Fuel cost in \$/10^6 Btu

WC = Water cost in \$/Kgal

an evaporative cooling tower at $0.50/10^6 Btu and $0.10/Kgal) are 1942 acre-feet per year and 33.47 mills/kWh. The busbar energy production cost for this example is therefore 0.95 x 33.47, or 31.80 mills/kWh. The water requirement is 0.1 x 1942, or 194 acre-feet per year. Similarly, using 3 percent and 47 percent of the water required for an evaporative cooling tower results in busbar costs of 37.6 mills/kWh and 30.8 mills/kWh, respectively. As previously shown in a sample calculation, the evaporative cooling tower results in a busbar cost of 30.46 mills/kWh and requires 1942 acre-feet per year.

The penalty in busbar cost for using only 10 percent of the water can also be computed directly from Figure 5-7 by determining a ratio of the busbar cost of 10 percent water use (10 percent evaporative tower and 90 percent dry tower) to 100 percent water use (100 percent evaporative tower), or 0.95/0.91 = 1.04. Therefore, saving 90 percent of the water required by an evaporative tower will increase busbar cost by approximately 4 percent and result in a cost of (0.95/0.91) x 30.46, or 31.80 mills/kWh.

Sample Calculation. Find the makeup water requirement and busbar energy production cost (exclusive of site-specific factors) for a 182 C (360 F) binary system served by a mechanical-draft dry/wet peaking cooling tower designed to use only 10 percent of the water required by an evaporative cooling tower at a High Mountain site assuming that fuel costs $1.00/10^6 Btu and water costs $1.00/Kgal. From Figure 5-5, the appropriate cost multiplier is 1.69. From Table 5-2, the water consumption and base cost (for a 360 F resource served by an evaporative cooling tower at $0.50/10^6 Btu and $0.10/Kgal) are 3003 acre-feet per year and 31.08 mills/kWh. The busbar energy production cost for this example is therefore 1.69 x 31.08, or 52.53 mills/kWh. The water requirement is 0.1 x 3003, or 300 acre-feet per year. Similarly, using 3 percent and 47 percent of the water required for an evaporative cooling tower results in busbar costs of 60.6 mills/

kWh and 51.3 mills/kWh, respectively. As previously shown in a sample calculation, the evaporative cooling tower results in a busbar cost of 48.80 mills/kWh and requires 3003 acre-feet per year.

The penalty in busbar cost for using only 10 percent of the water can also be computed directly from Figure 5-5 by determining a ratio of the busbar cost of 10 percent water use (10 percent evaporative tower and 90 percent dry tower) to 100 percent water use (100 percent evaporative tower), or 1.69/1.57 = 1.08. Therefore, saving 90 percent of the water required by an evaporative tower will increase busbar cost by approximately 8 percent and result in a cost of (1.69/1.57) x 48.8, or 52.53 mills/kWh.

Conclusions

Several conclusions may be drawn based upon the range of values analyzed in the parametric analyses performed in this study:

- Busbar energy production costs are very sensitive to hydrothermal resource temperature and hydrothermal "fuel cost" and less sensitive to climatologial type and makeup water cost. All other parameters remaining constant, busbar energy production costs for 150 C (300 F) resources are generally on the order of 80 percent higher than for 246 C (475 F) resources. Likewise, an increase in "fuel cost" from \$0.50 to \$1.00/10^6 Btu will result in an increase in busbar costs on the order of 50 percent. However, an increase in water cost from \$0.10 to \$2.50/Kgal will result in an increase in busbar costs of only about 15 percent. The differences in busbar costs for the four sites are typically on the order of 5 percent.
- Turbine-generator design significantly determines the overall plant performance and economics of both the binary and flash steam conversion systems. Direct comparisons between binary and flash steam systems for 150 C (300 F) and 246 C (475 F) resources were not possible in this study since optimum binary fluid choices and turbine designs are not yet available.
- Analyses indicate that binary systems yield slightly lower busbar energy production costs than flash steam systems for the 182 C (360 F) resource temperature, although makeup water requirements are higher than for flash steam systems. Higher heat rejection

for the binary system relative to the flash system accounts for the higher makeup water requirements.

- No computer analyses were performed for the radial hydrocarbon turbine design for the binary conversion process (turbine performance data were not available in time for this study). An examination of the radial turbine performance characteristics which were furnished by a manufacturer indicates that the busbar energy production cost and cooling system makeup water requirements should not differ significantly from those of the axial hydrocarbon turbine unless there are significant differences in capital or operating costs between the two types of turbines.

- On the basis of the turbine performance data available for this study, cooling system makeup water requirements for evaporative cooling towers serving flash steam systems are approximately 24-27 percent higher for 150 C (300 F) resources than for 182 C (360 F) resources, and approximately 29-30 percent lower for 246 C (475 F) resources than for 182 C (360 F) resources. Makeup water requirements for evaporative cooling systems serving binary systems are approximately 17-21 percent higher than for flash steam systems for 182 C (360 F) resource temperatures.

- For the range of fuel and makeup water costs considered, an all-dry cooling tower system does not appear to be economically competitive with an evaporative cooling tower system. However, the addition of a relatively small evaporative peaking tower to the dry tower (such as 95 percent dry/5 percent wet) will substantially reduce the busbar cost penalty incurred by an all-dry system. As the cost of makeup water increases, the relative difference in busbar cost between an all-dry or dry/wet peaking tower and an evaporative tower decreases significantly.

- For low water costs ($0.10/Kgal), the penalty in busbar cost for saving approximately 60 percent water by use of a dry/wet peaking cooling tower is on the order of 7-15 percent for non-desert sites and 9-25 percent for desert sites. However, for higher water costs ($2.50/Kgal), the penalty decreases to approximately 1-4 percent for non-desert sites and 2-10 percent for desert sites. The economic penalty for saving more water increases as additional dry cooling is used. Therefore, the use of dry/wet peaking towers may be feasible for hydrothermal power plants under certain site, plant design, and economic conditions as well as social and environmental constraints.

- Busbar energy production costs and cooling system makeup water requirements as estimated in this study for given plant design and economic constraints do not vary significantly for non-desert sites. However, busbar costs are approximately 2-6 percent higher and makeup water requirements are approximately 6-17 percent higher for desert sites.

- Several methods for accounting for costs associated with loss of generating capacity were considered in this study. Busbar energy production costs are slightly lower for the method which does not penalize for loss of capacity during operation at high ambient temperature conditions than for the other methods. However, typical differences in cost for these alternative methods are on the order of a few percent.

- Direct dry towers resulted in lower busbar energy production costs than indirect dry towers for the generating units with the sizes evaluated in this report. Differences in cost are typically on the order of a few percent of the total busbar cost, so that this conclusion could change if relative capital costs of the two systems are different from those assumed.
- For study purposes, the design back pressure value does not significantly affect the relative estimated busbar energy production cost or cooling system makeup water requirements. In the actual design of a hydrothermal power plant, however, the design back pressure is an important consideration.

Recommendations for Subsequent Studies

In addition to the need for binary turbine-generation performance data for a range of hydrothermal resource temperatures, our analyses indicate that the following studies are warranted:

- Analyses of alternative hydrocarbon turbine designs should be performed before any major decision is made regarding either the selection of a hydrocarbon turbine or the selection of one conversion process over another.
- The actual operation of hydrothermal power plants in conjunction with other conventional power plants on the utility grid should be evaluated. Forced outage rate, planned outage for scheduled maintenance, and summer and winter capacity of the hydrothermal plant should be investigated with respect to operating economics.
- Because of the high fuel costs and cooling system auxiliary energy requirements associated with hydrothermal plants, natural-draft cooling systems may be more economical than mechanical-draft systems at many locations and should therefore be evaluated in subsequent studies. The choice between mechanical-draft and natural-draft cooling towers is usually based on economics, although in some instances environmental considerations could favor the use of natural-draft towers.

Accuracy of Results

The accuracy with which cost estimates can be made for new energy conversion technologies is directly related to the history and experience of the industries developing the technologies. In the case of hydrothermal power plants, capital cost estimates are subject to inaccuracies resulting from a lack of cost trends, which can be established only after several power plants have been designed and constructed. Moreover, site-specific costs due to local labor and materials cost differences or physical site conditions will also markedly affect plant costs for any actual installation.

The accuracy with which the computer programs developed for this study simulate actual power plant performance is limited primarily by the accuracy or applicability of the turbine performance data, climatological data, and capital cost data. Estimates of makeup water requirements are based upon rigorous procedures adopted by the Cooling Tower Institute and therefore are limited primarily by the accuracy or applicability of the turbine performance and climatological data. Therefore, as data are refined, the accuracy of estimating energy production costs and makeup water requirements can also be refined.

FIGURE 5-1

ILLUSTRATION OF BUSBAR ENERGY PRODUCTION COST VERSUS MAKE-UP WATER REQUIREMENT FOR DRY/WET PEAKING COOLING TOWER SYSTEM FOR DIFFERENT DESIGN MAXIMUM OPERATING BACK PRESSURES (DMOBP)

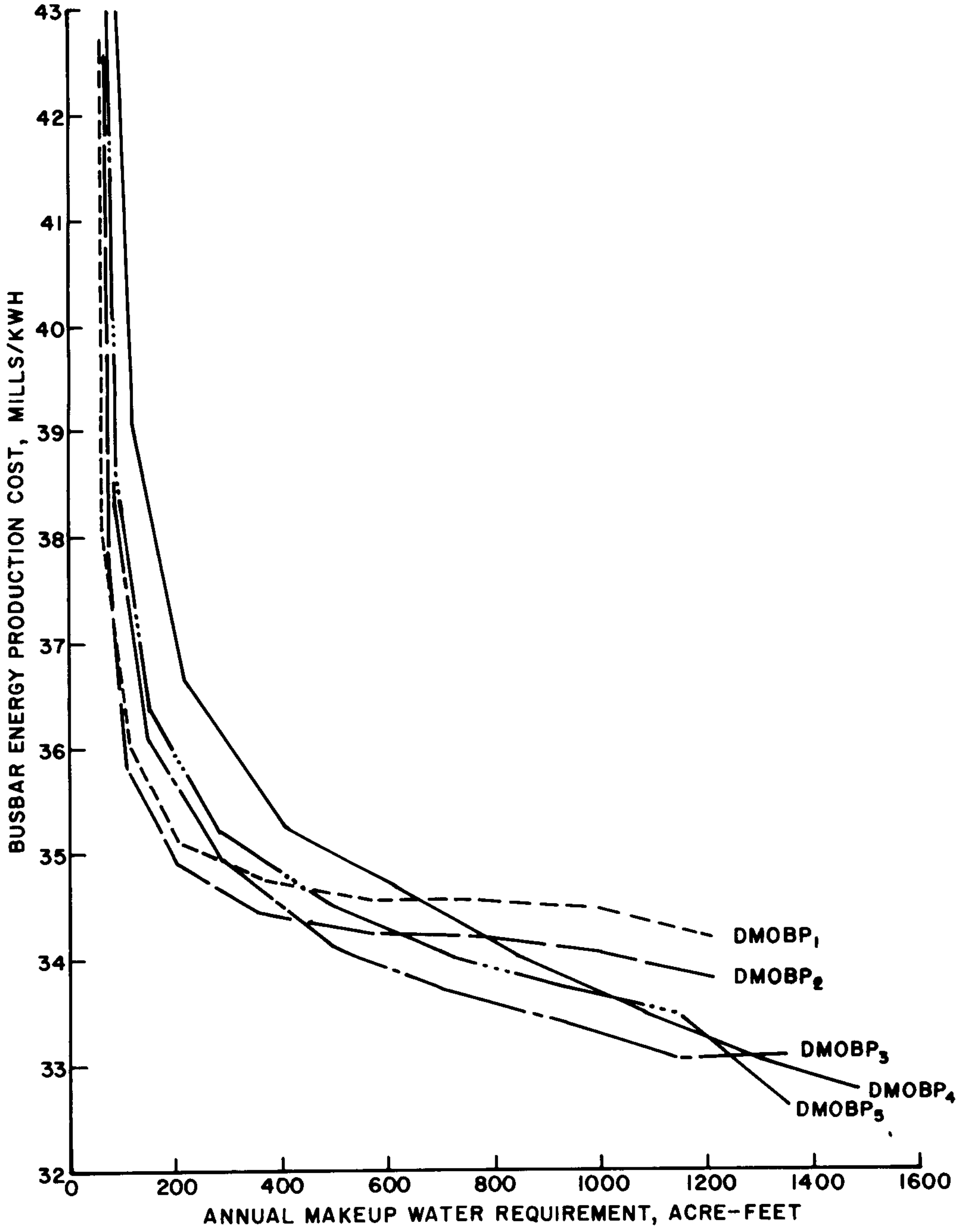


FIGURE 5-2

BUSBAR ENERGY PRODUCTION COST MULTIPLIERS FOR EVAPORATIVE COOLING TOWERS AS A FUNCTION OF RESOURCE TEMPERATURE (ALL SITES) FOR FLASH STEAM SYSTEMS

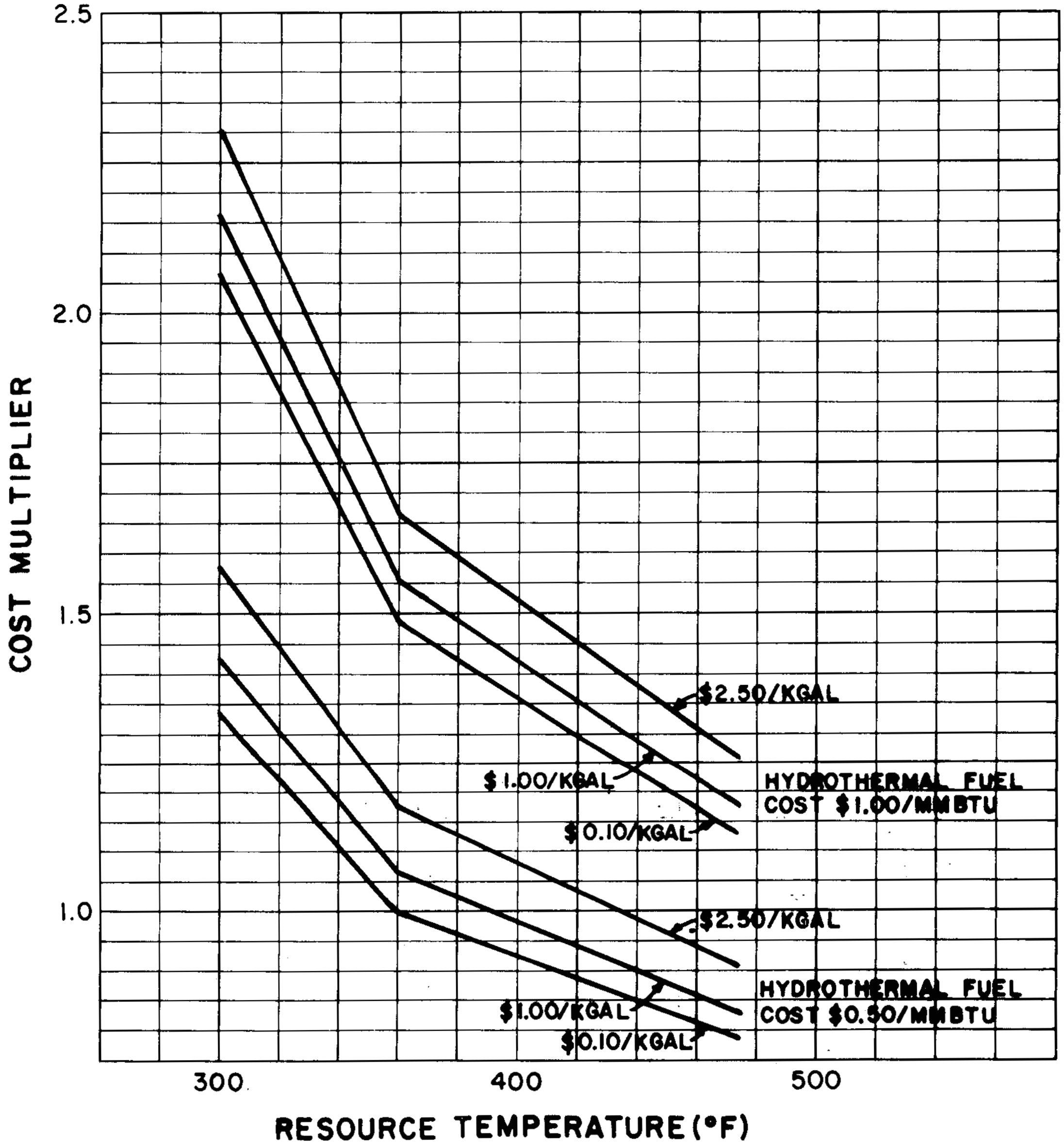
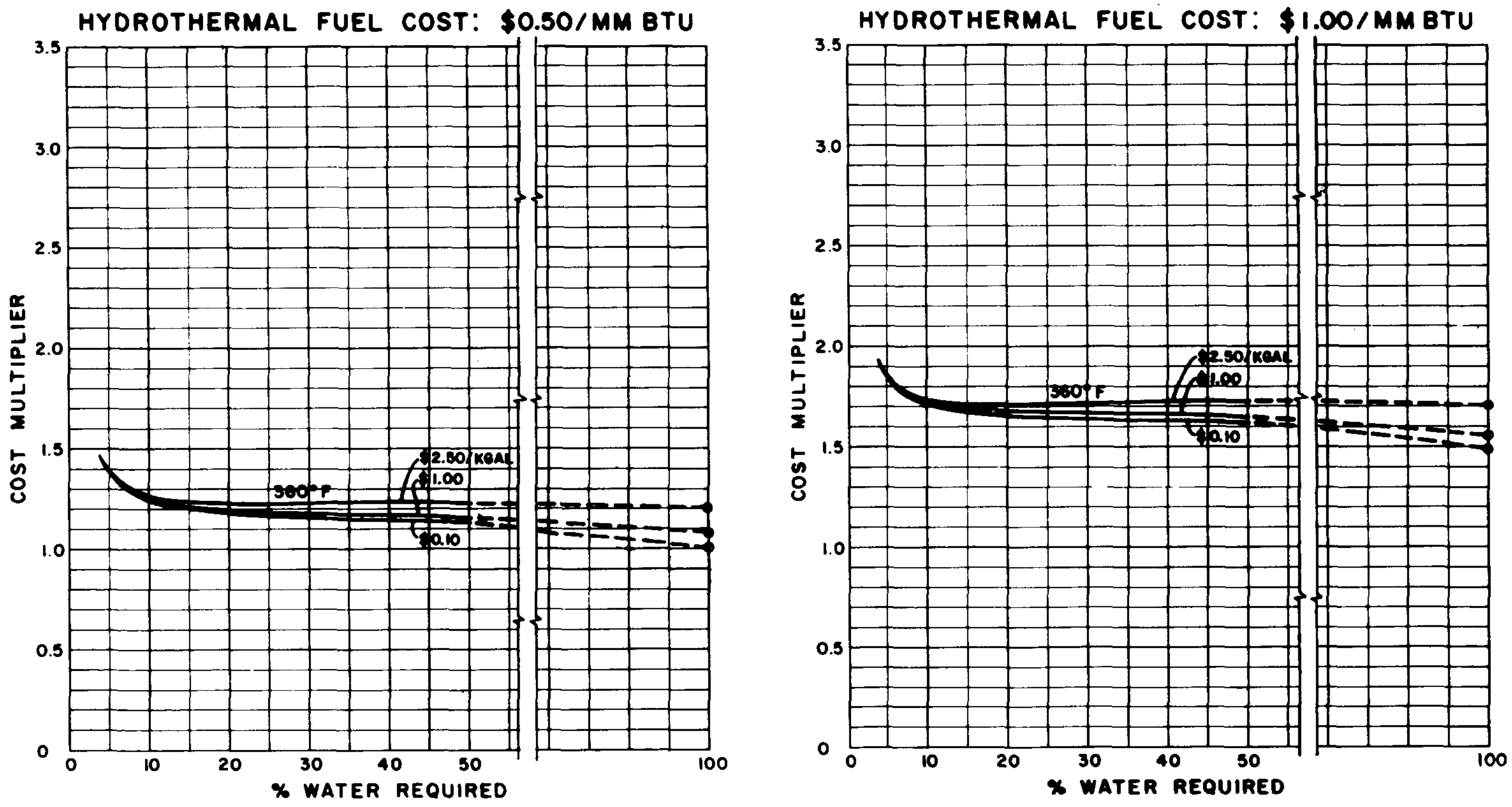


FIGURE 5-3

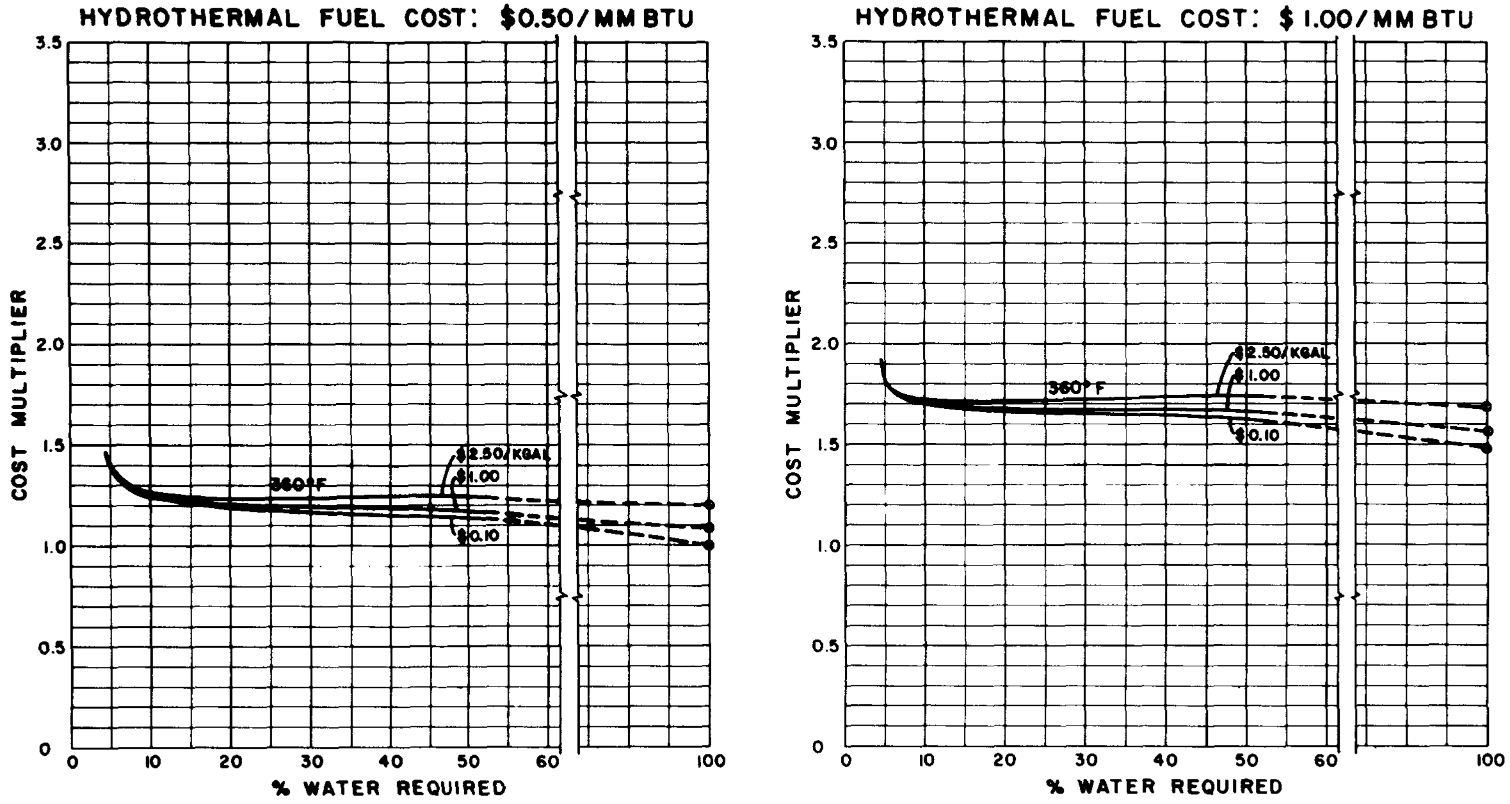
BUSBAR ENERGY PRODUCTION COST MULTIPLIERS
FOR DRY/WET PEAKING COOLING TOWERS
FOR 182°C (360°F) BINARY AT BASIN AND RANGE SITE



NOTE: PERCENT WATER IS BASED UPON MAKEUP WATER REQUIREMENT FOR EVAPORATIVE TOWER

FIGURE 5-4

BUSBAR ENERGY PRODUCTION COST MULTIPLIERS FOR DRY/WET PEAKING COOLING TOWERS FOR 182°C (360°F) BINARY AT PACIFIC NORTHWEST SITE

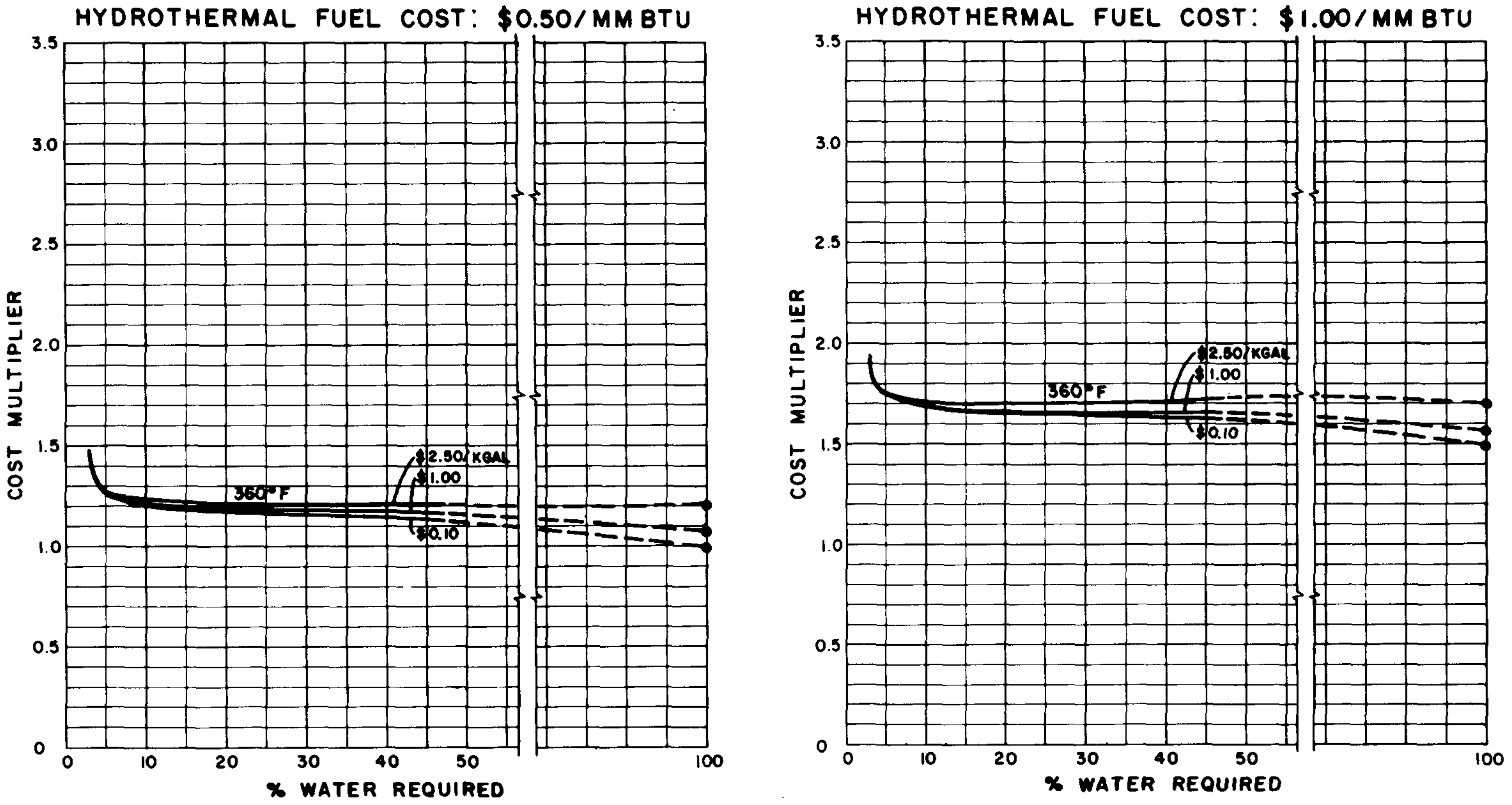

HYDROTHERMAL FUEL COST: $0.50/MM BTU

HYDROTHERMAL FUEL COST: $1.00/MM BTU

NOTE: PERCENT WATER IS BASED UPON MAKEUP WATER REQUIREMENT FOR EVAPORATIVE TOWER

FIGURE 5-5

BUSBAR ENERGY PRODUCTION COST MULTIPLIERS FOR DRY/WET PEAKING COOLING TOWERS FOR 182°C (360°F) BINARY AT HIGH MOUNTAIN SITE



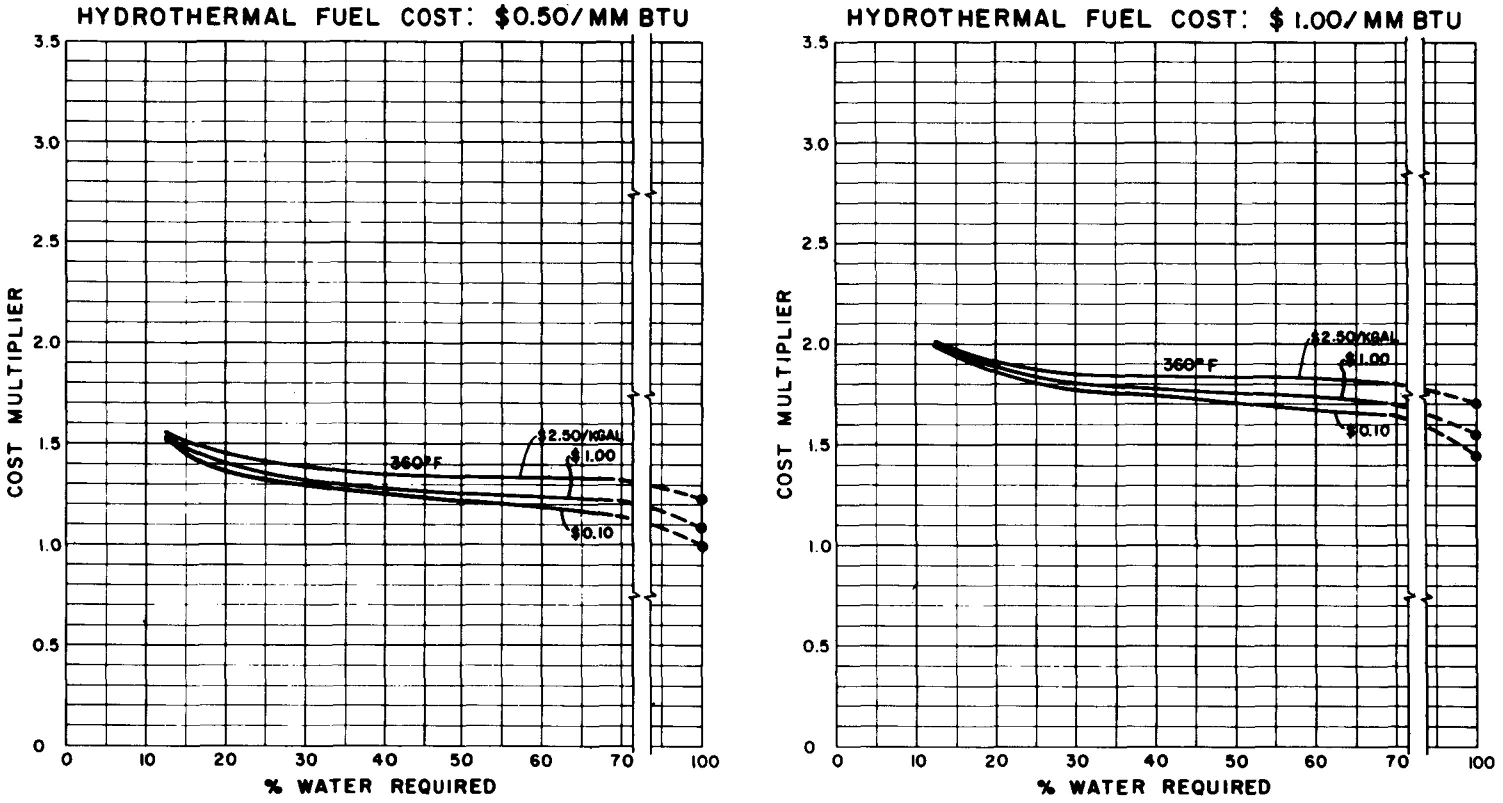
HYDROTHERMAL FUEL COST: $0.50/MM BTU

HYDROTHERMAL FUEL COST: $1.00/MM BTU

NOTE: PERCENT WATER IS BASED UPON MAKEUP WATER REQUIREMENT FOR EVAPORATIVE TOWER

FIGURE 5-6

BUSBAR ENERGY PRODUCTION COST MULTIPLIERS
FOR DRY/WET PEAKING COOLING TOWERS
FOR 182°C (360°F) BINARY AT HOT DESERT SITE

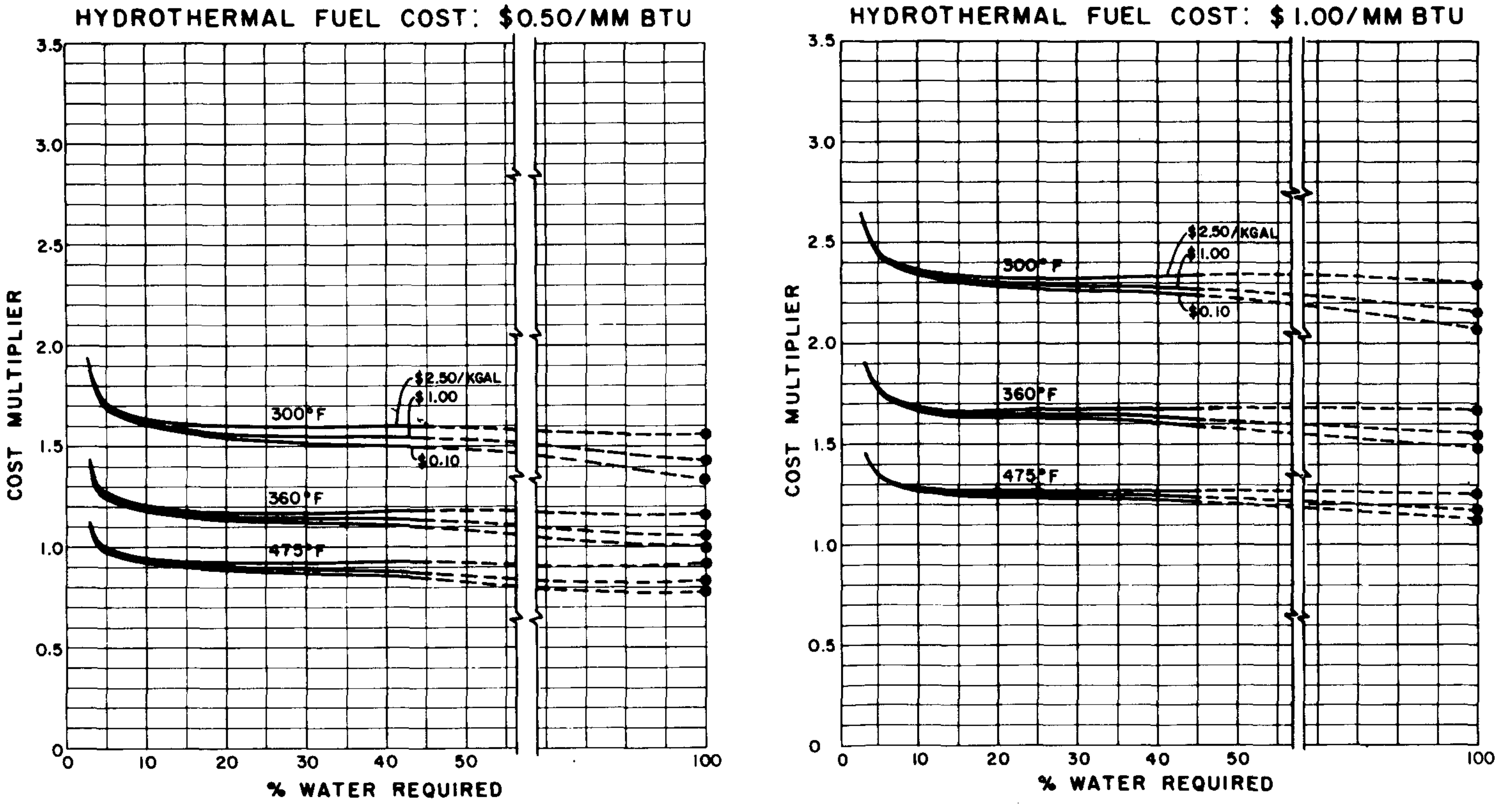

HYDROTHERMAL FUEL COST: $0.50/MM BTU

HYDROTHERMAL FUEL COST: $1.00/MM BTU

NOTE: PERCENT WATER IS BASED UPON MAKEUP WATER REQUIREMENT FOR EVAPORATIVE TOWER

FIGURE 5-7

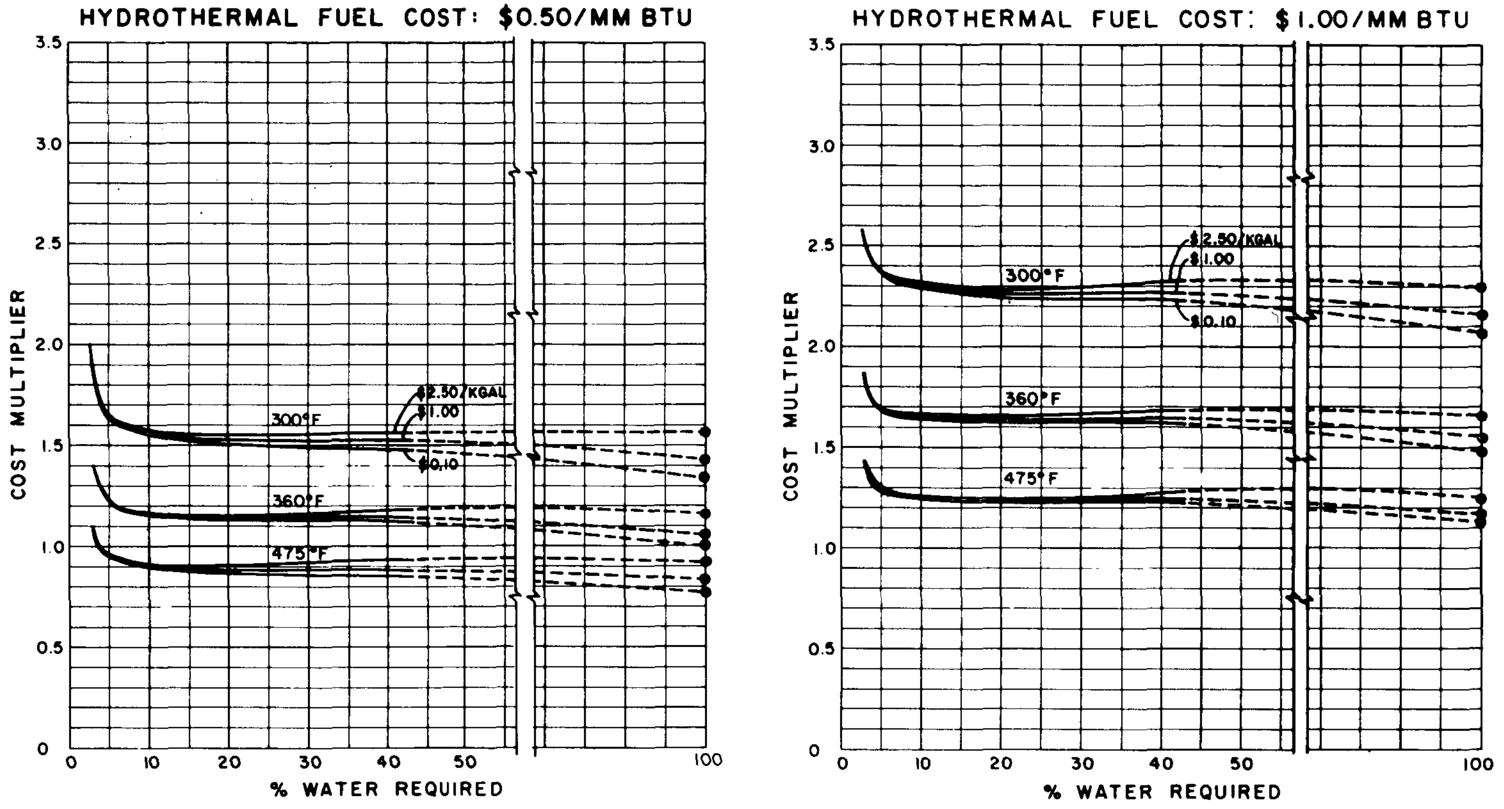
BUSBAR ENERGY PRODUCTION COST MULTIPLIERS FOR DRY/WET PEAKING COOLING TOWERS FOR 150°C (300°F), 182°C (360°F) AND 246°C (475°F) FLASH AT BASIN AND RANGE SITE



NOTE: PERCENT WATER IS BASED UPON MAKEUP WATER REQUIREMENT FOR EVAPORATIVE TOWER

FIGURE 5-8

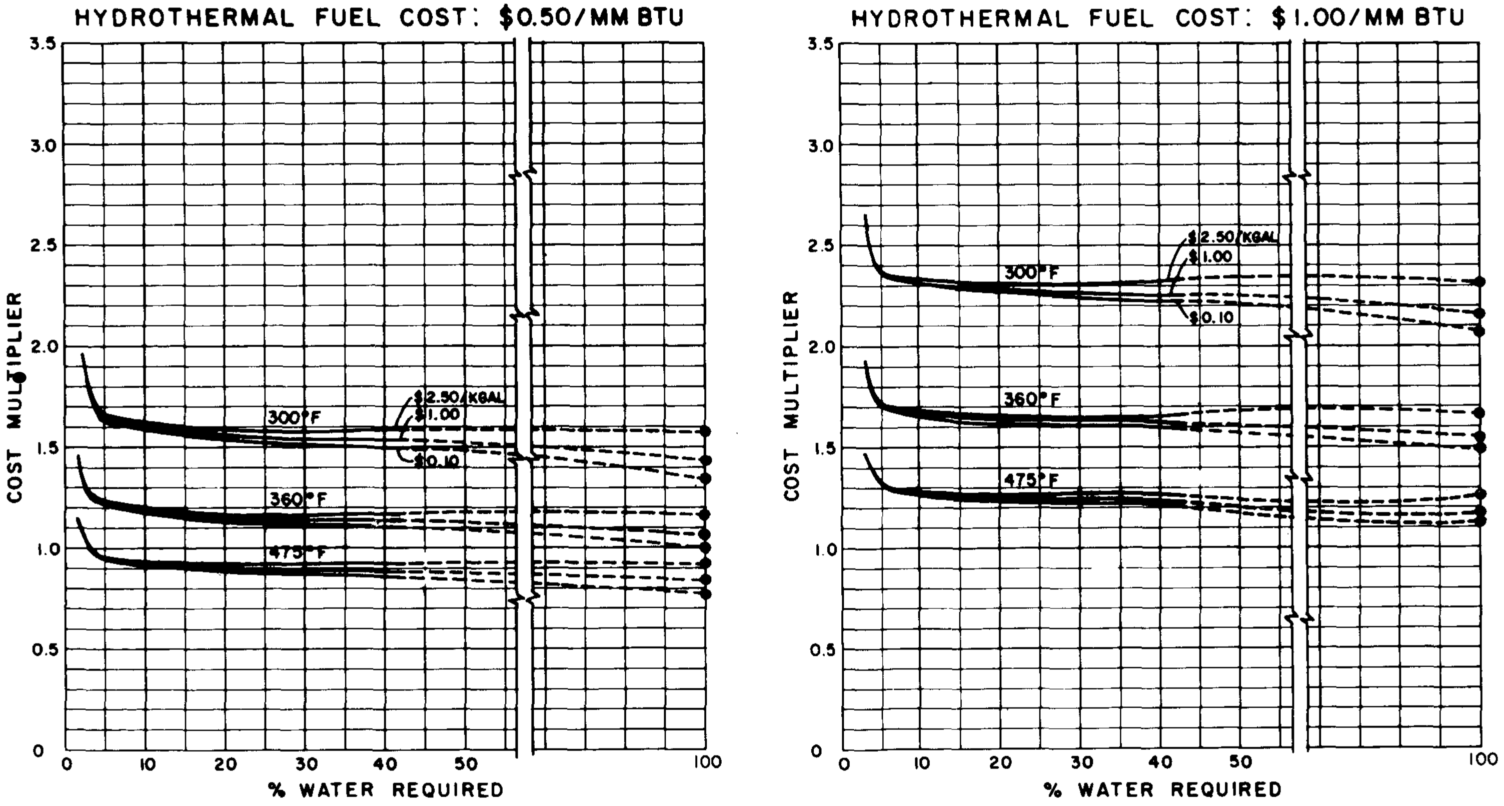
BUSBAR ENERGY PRODUCTION COST MULTIPLIERS FOR DRY/WET PEAKING COOLING TOWERS FOR 150°C (300°F), 182°C (360°F) AND 246°C (475°F) FLASH AT PACIFIC NORTHWEST SITE



NOTE: PERCENT WATER IS BASED UPON MAKEUP WATER REQUIREMENT FOR EVAPORATIVE TOWER

FIGURE 5-9

BUSBAR ENERGY PRODUCTION COST MULTIPLIERS
FOR DRY/WET PEAKING COOLING TOWERS
FOR 150°C (300°F), 182°C (360°F) AND 246°C (475°F) FLASH AT HIGH MOUNTAIN SITE



NOTE: PERCENT WATER IS BASED UPON MAKEUP WATER REQUIREMENT FOR EVAPORATIVE TOWER

Appendix A

DESCRIPTION OF HYDROTHERMAL RESOURCES IN THE WESTERN UNITED STATES

REGIONAL SUMMARY OF KNOWN HYDROTHERMAL RESOURCES

The following is a summary of known hydrothermal resource areas with potential for electrical energy production. The systems described include both the hot water and vapor-dominated convection systems which have been most commonly detected thus far by associated hot springs and/or fumaroles.

Type and Extent of Hydrothermal Resources

Geological and geophysical evidence for hydrothermal energy sources abounds in the eleven western states. Nine geothermal regions are defined in Figure 2-1, based on a combination of features and upper mantle and crustal processes. Major factors used in the identification of different hydrothermal regions include geology, heat flow, tectonic activity, seismicity, volcanism, hydrology, and temperature gradients. Delineation of these nine regions is interpretative, since the quantity and quality of data is extremely limited. Salient elements of each region are summarized below. The regions are listed in order of geographical numbering in Figure 2-1, not in order of estimated potential.

Region I: Central California Coast Ranges. The central California coast range is dominated by the active San Andreas fault system. Heat flow is variable but regionally above normal and is sustained by local frictional heating and volcanism. Young volcanic and hot spring activity are extensive in the Geysers-Clear Lake area (Site 1), which appears to represent the only obvious significant hydrothermal area in the region.

Region II: Cascade Range. Although the Cascade Range is entirely volcanic, the eastern side of the Range is youngest and most volcanically and tectonically active, and of greatest geothermal interest. Hot springs, fumarolic activity, altered groundwater flows, and young lava flows attest to shallow heat concentrations associated with modern volcanoes in the Range, such as Mts. Lassen, Shasta, Belknap, Hood, St. Helens, Rainier, and Baker. Heat flow data are sparse, but the eastern Cascades are believed to exhibit higher-than-normal values associated with extrusion centers. Tensional faulting is concentrated along the eastern margin of the Range. Relatively few thermal data are available for this province, and hydrothermal exploration and drilling have not been extensive to date.

Region III: Snake River Plain. The Snake River Plain is a prominent volcano-tectonic and physiographic hydrothermal province. Numerous thermal springs occur along the fault-bounded north and south margins of the Plain. Cold groundwater migration to the Snake River through highly permeable lavas obscures expression of the high temperature water that is believed to lie within the Snake River Plain graben. A few heat-flow determinations along the margin of the Plain indicate regionally high heat flux. The thick water-saturated sediments and flows that fill the graben should act as excellent thermal insulators, and thereby trap large amounts of heat beneath the shallow zone of cold water sweep.

A few deep oil and gas wildcat wells have been drilled in the western part of the Snake River Plain. All drillings encountered hot water, which indicates significantly higher-than-normal thermal gradient and subsurface temperatures.

Region IV: Northwestern Basin and Range. This province is extremely large and contains abundant evidence that many hydrothermal systems exist. The western part consists of the especially active tectonic and volcanic zone that borders the Sierra Nevada and the Cascades. There are numerous normal faults, many of which are associated with high-temperature springs. Other springs are more clearly related to young volcanic activity. Heat flow in this province is regionally twice normal and joins with the high heat flow regime of the Snake River Plain to make the highest heat flow region known on the North American continent. The northwestern part of the region is underlain by moderately but intricately faulted lava flows and sedimentary interbeds. The southeastern and southern parts of the province are marked by strong Basin and Range topography and comprise a complex of plutonic, volcanic, and sedimentary rocks. Heat may be concentrated beneath thermally insulating layers of the larger basins and lava plateaus.

Several specific high-temperature hydrothermal areas (Sites 2-8) occur in the western Basin and Range. All are believed to hold potential for electrical energy generation.

Region V: Central Basin and Range. This portion of the Basin and Range province contains fewer thermal features than the marginal zones to the west and east. Young volcanism is rare, and the seismic activity which occurs (mainly in the southern part) is markedly less than in adjacent areas. Heat flow is close to normal and even subnormal in this portion of the Basin and Range. Interbasin hydrologic flow is extensive and may drain away much heat from the upper few thousand meters of porous carbonate sequences that occur in the region. High-temperature springs are rare, and moderate- to low-temperature springs are few in number. Clearly, this region has relatively low geothermal potential.

Region VI: Eastern Basin and Range. This region is characterized by many features that indicate relatively high hydrothermal potential similar to the western margin at the Basin and Range province. Heat flow is moderately high and young normal faults are abundant. Volcanism is locally significant and high-temperature springs occur infrequently. Large areas of thick sedimentation fill, such as the Great Salt Lake Basin, Sevien Desert, etc., may act as thermal blankets. One potentially major geothermal field has been discovered in the area of young silicic volcanism and young normal faulting (Site 10), and exploration boreholes have been drilled in another system (Site 9) which has relatively low temperatures.

Region VII: Salton-Imperial Valley. The Imperial Valley is the site of intense lateral faulting, with the Pacific side moving northward with respect to the Continental side. This transform faulting, accompanied by transform faulting at intervals along the main fault trend, has led to incipient rifting and thinning of the crust, bringing the mantle to depths as shallow as ten or fifteen kilometers. The Imperial Valley itself is filled with young alluvium estimated to be as deep as 10,000 meters (33,000 feet). There is evidence of volcanism in the center of the Imperial Valley, although only very minor outcrops of volcanic rock occur at Obsidian Buttes on the southern end of the Salton Sea and the Cerro Prieto in Northern Mexico. Several fields have been drilled in the Imperial Valley, including the Salton Sea field, the Heber field, the North Brawley field, the Dunes field, and the East Mesa field (Site 11).

This outstanding hydrothermal province possesses all the geological and geophysical features that characterize hydrothermal provinces in many areas of the world. Several major anomalies are currently being evaluated.

Region VIII: Southern Basin and Range. In general, this portion of the Basin and Range province has moderate hydrothermal potential. Heat flow is above normal, but young tectonic and volcanic activity is not widespread and thermal springs occur sparingly. Alluvial fill basins, however, are extensive, and there is a good possibility that hydrothermal systems occur in these basins beneath insulating cover. While no hydrothermal reservoirs have been defined in this region to date, the Coso Hot Springs area in Southern California appears to have considerable potential.

Region IX: Rio Grande Rift System. This long and narrow tectonic depression displays all of the features of Basin and Range thermal regimes and is regarded as an extension of the Basin and Range province into the stable and cold Rocky Mountain foreland region. The San Juan volcanic field of southwestern Colorado is included within the Rio Grande province on the basis of high heat flow and thermal springs. Large areas within the Rift have almost twice the normal heat flow. Tectonism and volcanism are moderately active, and hot springs are moderately abundant. Intra-rift basins are large, deep, and filled with water-bearing sediments and volcanics which may have insulating properties.

Apparently, one successful development of a hydrothermal reservoir is taking place at Valles Caldera (Site 12), which is an abnormally large silicic eruptive center.

ESTIMATES OF HYDROTHERMAL RESOURCES BY REGION

The approach used in this report to estimate hydrothermal reserves is based on statistical data available from heat flow determinations which have been made at over 600 locations throughout the continental United States. Assuming that the heat flow determinations are randomly distributed throughout the United States and that the origin of high heat flow and normal heat flow are the same, these data can be used to estimate the hydrothermal resource base.

As a minimum requirement for utilization, a hydrothermal system must have certain minimum temperatures which can be reached by drilling. Temperature will depend both on heat flow and on the thermal conductivity of the section. Conductivity may range from 3 to 5 x 10^{-3} thermal conductivity units* in alluvial sediments up to 7 to 9 x 10^{-3} units in crystalline rocks. If an average conductivity of 6 x 10^{-3} units is selected, then heat flows of varying magnitudes would result in the approximate temperatures shown in Table A-1. These gradients assume that no convection takes place over the indicated range of depths. If rocks with lower conductivities are present in the surficial portion of the section, temperatures will be higher. The values in Table A-1 indicate that a heat flow of 3 hfu (the median heat flow for the United States is 1.52 hfu) is required before temperatures suitable for hydrothermal development are likely to be present at drillable depths.

The distribution of heat flow determinations over the Basin and Range Province is based upon 86 values which have been measured in an area of 680,000 km^2 (262,000 mi^2). This province comprises 14 percent of the data for the United States, although it represents only five percent of the area. Other areas of the west which have high heat flow are correspondingly oversampled in comparison to the eastern United States, where the heat flow is relatively low. The median heat flow in the Basin and Range Province is 2.01 hfu, resulting in the estimated percentages of values in excess of 3, 4, and 5 hfu shown in Table A-3.

*Thermal conductivity is measured as calories per second per square centimeter for a thermal gradient of one degree per centimeter.

Table A-1

ESTIMATED RESOURCE TEMPERATURE AS A FUNCTION OF HEAT FLOW AND DEPTH

Heat Flow,* hfu	Temperature Gradient At Average Conductivity, C/km	(F/mile)	Temperature, C (F) 1 km (0.62 mile)		2 km (1.24 miles)		3 km (1.86 miles)	
3	50	(145)	70	(158)	120	(248)	170	(338)
4	67	(194)	87	(189)	153	(307)	220	(428)
5	83	(240)	103	(217)	186	(367)	269	(516)

Based on the probability distribution for heat flow determinations throughout the United States, the estimated fractions of heat flow determinations and associated areas above 3, 4, and 5 hfu are shown in Table A-2.

Table A-2

ESTIMATED PERCENTAGE OF NATIONAL HEAT FLOW DETERMINATIONS IN EXCESS OF SPECIFIC HEAT FLOW VALUES

Heat Flow, hfu	Percentage of Values in Excess	Area Represented, km^2	($miles^2$)
3	4.5	540,000	(208,500)
4	1.2	144,000	(55,600)
5	0.2	24,000	(9,270)

These areas are based on the assumption that heat flow tests have been made uniformly and randomly throughout the United States. However, it is likely that the far western states have been oversampled, and that these area estimates are therefore too high.

* Heat flow is measured as microcalories per square centimeter per second.

Table A-3

ESTIMATED PERCENTAGE OF BASIN AND RANGE HEAT FLOW DETERMINATIONS IN EXCESS OF SPECIFIC HEAT FLOW VALUES

Heat Flow, hfu	Percentage of Values in Excess	Area Represented, km^2	(miles^2)
3	9.0	61,200	(23,600)
4	2.0	13,600	(5,250)
5	0.3	2,040	(790)

It is not possible to compile exact distributions of heat flow for the nine hydrothermal regions previously described because of the relatively small number of determinations in each area. Approximate distributions based on the average probabilistic heat flow for each province may be used to estimate the areas with heat flows above 3, 4, and 5 hfu in each province as indicated in Table A-4.

Aside from the uncertain knowledge of the distribution, other uncertainties are involved in determining the extent of the area which will have heat flow above a certain value. Some areas will be unavailable because they lie in national parks, wilderness areas, or inaccessible locations. Other areas may have high temperature but will not easily produce fluids (these are called hot dry rocks) or will not be discovered because of ineffective exploration methods. It is therefore assumed that the remaining developable areas will only be one-fourth the size of the original exploration areas.

As a basis for estimating reserves, it is also assumed that a well can drain a vertical section one kilometer thick, so that one cubic kilometer of storage underlies each square kilometer of surface. On the average, 5 to 10 percent of this volume is water which can be extracted to deliver energy to the surface. The amount of water recoverable from each cubic kilometer of rock is therefore 5 to 10 x 10^7 metric tons (5.5 to 11 x 10^7 tons).

Table A-4

ESTIMATED DISTRIBUTION OF HEAT FLOW AREAS IN SPECIFIC HYDROTHERMAL REGIONS

Hydrothermal Region	Total Area, km^2	(miles^2)	Areas of Heat Flow, km^2 (miles^2) 3-4 hfu		4-5 hfu		>5 hfu	
Central Calif. Coast Range	80,000	(31,000)	5,440	(2,100)	1,736	(670)	424	(164)
Cascade Range	80,000	(31,000)	744	(287)	120	(46)	16	(6)
Snake River Plain	60,000	(23,000)	7,680	(2,960)	3,420	(1,320)	1,500	(580)
Northwestern Basin and Range	270,000	(104,000)	21,060	(8,130)	7,560	(2,920)	1,890	(730)
Central Basin and Range	190,000	(73,000)	554	(214)	66	(25)	10	(4)
Eastern Basin and Range	200,000	(77,000)	3,300	(1,270)	620	(240)	80	(30)
Salton-Imperial Valley	14,000	(5,400)	1,792	(690)	798	(310)	350	(135)
Southern Basin and Range	270,000	(104,000)	3,591	(1,390)	413	(160)	46	(18)
Rio Grande Rift System	100,000	(38,600)	6,900	(2,660)	2,050	(790)	550	(210)
TOTAL	1,264,000	(487,000)	51,061	(19,700)	16,783	(6,480)	4,866	(1,880)

Electrical energy production estimates are based on current practice at The Geysers dry steam field. The reservoir temperature at The Geysers is 235 C (455 F), from which the steam expands and cools to a temperature of 150 to 170 C (302 to 338 F). At this temperature, approximately 10 kg (22 lb) of steam are required to generate one kilowatt-hour. Furthermore, only a fraction of the water produced from the reservoir can be flashed to steam for use in a steam turbine. The percentages of useful steam produced at 150 C (302 F) for various resource temperatures are shown in Table A-5.

Table A-5

ESTIMATED PERCENTAGE OF RESOURCE WATER CONVERTIBLE TO STEAM AT VARIOUS RESERVOIR TEMPERATURES

Resource Temperature C	(F)	Percent Water Convertible to Steam at 150 C (302 F)
170	(338)	4.1
220	(428)	14.7
270	(518)	26.2

The total recoverable energy from hydrothermal sources in the western United States can therefore be estimated as a function of heat flow by using the developed information on fluid production, electrical energy production, and the area assumed to be available for hydrothermal development. The estimated recoverable energy over a production life of 30 years is shown in Table A-6.

Table A-6

ESTIMATES OF RECOVERABLE ENERGY FROM HYDROTHERMAL RESOURCES IN THE WESTERN UNITED STATES AS A FUNCTION OF HEAT FLOW

Heat Flow, hfu (C/F)	Recoverable Energy Over 30 Years kWh x 10^{12}
3-4 (170/338)	2.62-5.23
4-5 (220/428)	3.08-6.17
> 5 (270/518)	1.59-3.19
TOTAL	7.29-14.59

Similarly, electrical production capacity for the western United States is estimated in Table A-7 for the nominal 30-year production rates shown. Estimated production capacities for the individual hydrothermal areas are shown in Table A-8.

Table A-7

ESTIMATES OF NOMINAL ELECTRICAL PRODUCTION CAPACITY FROM HYDROTHERMAL RESOURCES IN THE WESTERN UNITED STATES AS A FUNCTION OF HEAT FLOW

Heat Flow, hfu (C/F)	Nominal 30-Year Production Rate, MWe/km^2	Nominal 30-Year Production Capacity, MWe
3-4 (170/338)	0.8	13,610
4-5 (220/428)	3.0	16,800
> 5 (270/518)	6.0	9,730
TOTAL		40,140

Table A-8

ESTIMATES OF NOMINAL 30-YEAR ELECTRICAL PRODUCTION CAPACITY FOR THE MAJOR HYDROTHERMAL REGIONS AS A FUNCTION OF HEAT FLOW

Hydrothermal Region	MWe			
	(3-4 hfu)	(4-5 hfu)	(>5 hfu)	Total
Central California Coast Range	1,450	1,740	850	4,040
Cascade Range	200	120	30	350
Snake River Plain	2,050	3,420	3,000	8,470
Northwestern Basin and Range	5,600	7,560	3,780	16,940
Central Basin and Range	150	70	20	240
Eastern Basin and Range	880	620	160	1,660
Salton-Imperial Valley	480	800	700	1,980
Southern Basin and Range	960	420	90	1,470
Rio Grande Rift System	1,840	2,050	1,100	4,990
TOTAL	13,610	16,800	9,730	40,140

Better utilization of the heat energy can be accomplished with the lower reservoir temperature if successive flashing is used, or if heat is transferred to a working fluid with a low boiling point such as in a binary system. At the lower temperature, approximately twice as much energy can be recovered, or conversely, the amount of mass that must be used per unit of electricity generated is one-half.

The reliability of these estimates is closely related to the reliability of the statistical distributions assumed for the various provinces. As additional wells are drilled, these statistics can be improved. Nevertheless, the total estimated capacity is roughly equivalent to other conservative estimates made in recent years which foresee the ultimate development of several tens of thousands of megawatts of geothermal generating capacity in the western United States.

Some comment should be made on the relatively low potential for production estimated in the Imperial Valley. Extensive exploration has continued for almost three decades in this area and five potentially productive geothermal reservoirs have already been discovered -- Salton Sea, North Brawley, Heber, the Dunes, and East Mesa. Nevertheless, the Imperial Valley represents a mature exploration area where a significant portion of reserves has already been found. The large number of discoveries to date therefore does not reflect an even larger potential for undiscovered systems.

The relatively large potential for discovery of geothermal resources in the northwestern Basin and Range area also requires some discussion. Although numerous prospects have been drilled, no development appears to have taken place. There is also some concern that the distribution of heat flow values reported for this area includes a disproportionate number of recent determinations of heat flow made in areas selected for their geothermal potential.

APPENDIX B

DISTRIBUTION OF AMBIENT DRY-BULB TEMPERATURES AT FOUR SITES - PERCENT OCCURRENCE

DISTRIBUTION OF AMBIENT DRY-BULB TEMPERATURES AT SAMPLE BASIN AND RANGE SITE - PERCENT OCCURRENCE

Temperature Range	Relative Humidity						
	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	Total
104-100	.03	-	-	-	-	-	.03
99-95	.40	-	-	-	-	-	.40
94-90	1.37	-	-	-	-	-	1.37
89-85	2.70	.07	-	-	-	-	2.77
84-80	3.40	.40	-	-	-	-	3.80
79-75	3.38	.79	.03	-	-	-	4.20
74-70	2.96	1.60	.21	.01	-	-	4.78
69-65	2.36	2.41	.48	.13	.05	-	5.43
64-60	1.87	3.11	1.26	.13	.11	.03	6.51
59-55	1.36	3.40	2.40	.49	.15	.09	7.89
54-50	1.13	3.33	3.70	1.06	.33	.09	9.64
49-45	.66	2.99	4.27	1.71	.57	.17	10.37
44-40	.30	2.34	3.85	2.35	1.01	.27	10.12
39-35	.06	1.11	3.46	2.27	1.95	.62	9.47
34-30	.01	.51	2.56	2.03	2.25	1.03	8.39
29-25	-	.15	1.48	1.65	2.16	.59	6.03
24-20	-	.06	.84	1.19	1.85	.49	4.43
19-15	-	-	.27	.74	1.29	.28	2.58
14-10	-	-	.07	.40	.63	.05	1.15
9-5	-	-	.01	.10	.30	-	.41
4-0	-	-	.01	.08	.08	-	.17
(-1)-(-5)	-	-	-	.03	.01	.01	.05
(-6)-(-10)	-	-	-	.01	-	-	.01
TOTAL	21.99	22.27	24.90	14.38	12.74	3.72	100.00

DISTRIBUTION OF AMBIENT DRY-BULB TEMPERATURES AT SAMPLE HIGH MOUNTAIN SITE - PERCENT OCCURRENCE

Temperature	Relative Humidity						
Range	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	Total
99-95	.02	-	-	-	-	-	.02
94-90	.32	-	-	-	-	-	.32
89-85	.57	-	-	-	-	-	.57
84-80	1.14	.03	.02	-	-	-	1.19
79-75	2.00	.87	.14	-	-	-	3.01
74-70	2.64	1.74	.93	-	-	-	5.31
69-65	3.16	2.90	2.10	.03	-	-	8.19
64-60	3.35	3.21	2.45	.22	-	-	9.23
59-55	3.51	2.85	1.68	.83	.61	.02	9.50
54-50	2.99	3.77	1.32	.83	.71	.07	9.69
49-45	2.13	3.50	1.24	.43	.37	.01	7.68
44-40	1.77	4.25	1.48	.63	.63	.06	8.82
39-35	.86	4.26	2.80	.83	.66	.18	9.59
34-30	.45	3.03	3.21	.64	.87	.64	8.84
29-25	.29	2.08	2.48	1.56	.95	.67	8.03
24-20	.06	.94	1.72	1.11	.81	.42	5.06
19-15	.01	.58	.88	.67	.49	.26	2.89
14-10	-	.06	.26	.39	.30	.18	1.19
9-5	-	.01	.15	.11	.10	.31	.68
4-0	-	-	.06	.02	-	.07	.15
(-1)-(-5)	-	-	.02	.01	-	-	.03
(-6)-(-10)	-	-	-	.01	-	-	.01
TOTAL	25.27	34.08	22.94	8.32	6.50	2.89	100.00

DISTRIBUTION OF AMBIENT DRY-BULB TEMPERATURES AT SAMPLE HOT DESERT SITE - PERCENT OCCURRENCE

Temperature Range	Relative Humidity						
	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	Total
124-120 °F	-	-	-	-	-	-	-
119-115	.10	.02	-	-	-	-	.12
114-110	.36	.11	-	-	-	-	.47
109-105	1.20	.39	-	-	-	-	1.59
104-100	2.04	.66	-	-	-	-	2.70
99-95	4.02	1.68	.16	-	-	-	5.86
94-90	4.62	1.97	.70	-	-	-	7.29
89-85	5.23	2.16	1.45	.25	.01	-	9.10
84-80	5.07	2.67	1.28	.73	.24	.01	10.00
79-75	4.25	3.77	.74	.27	.15	.08	9.26
74-70	3.37	4.73	1.08	.14	.06	.06	9.44
69-65	2.51	5.24	2.07	.19	.06	.02	10.09
64-60	1.64	4.69	3.03	.38	.09	.08	9.91
59-55	.99	3.87	2.95	.53	.29	.14	8.77
54-50	.58	2.65	2.74	.46	.35	.19	6.97
49-45	.31	1.59	1.90	.50	.31	.15	4.76
44-40	.16	.77	.88	.38	.24	.15	2.58
39-35	.03	.27	.30	.11	.05	.10	.86
34-30	-	.09	.07	.02	.01	-	.19
29-25	-	.01	.02	-	-	-	.03
24-20	-	-	.01	-	-	-	.01
TOTAL	36.48	37.34	19.38	3.96	1.86	.98	100.00

DISTRIBUTION OF AMBIENT DRY-BULB TEMPERATURES AT SAMPLE PACIFIC NORTHWEST SITE - PERCENT OCCURRENCE

Temperature Range	Relative Humidity						
	0-29%	30-49%	50-69%	70-79%	80-89%	90-100%	Total
124-120 °F	-	-	-	-	-	-	-
119-115	-	-	-	-	-	-	-
114-110	-	-	-	-	-	-	-
109-105	.01	-	-	-	-	-	.01
104-100	.14	-	-	-	-	-	.14
99-95	.58	.05	-	-	-	-	.63
94-90	1.16	.34	-	-	-	-	1.50
89-85	1.54	.85	.01	-	-	-	2.40
84-80	1.35	1.79	.05	-	-	-	3.19
79-75	.93	2.63	.32	-	-	-	3.88
74-70	.53	3.06	1.25	.09	.01	.01	4.95
69-65	.38	2.88	2.73	.33	.09	.03	6.44
64-60	.18	2.09	4.19	1.19	.39	.11	8.15
59-55	.10	1.56	4.35	2.33	1.22	.67	10.23
54-50	.07	1.01	3.91	2.64	2.49	1.42	11.54
49-45	.03	.56	2.64	2.70	3.17	3.24	12.34
44-40	.01	.23	1.49	1.95	3.56	5.53	12.77
39-35	-	.05	.59	1.05	2.60	6.05	10.34
34-30	-	.02	.16	.47	1.62	5.32	7.59
29-25	-	.02	.07	.18	.88	1.93	3.08
24-20	-	.01	.01	.07	.33	.28	.70
19-15	-	-	.01	.02	.05	.02	.10
14-10	-	-	-	.01	.01	-	.02
TOTAL	7.01	17.15	21.78	13.03	16.42	24.61	100.00

APPENDIX C

SUMMARY OF COST ESTIMATES FOR BINARY AND FLASH STEAM CONVERSION PLANTS

SUMMARY OF COST ESTIMATES FOR 65 MWe (GROSS) BINARY CONVERSION PLANTS

	150 C (300 F) Resource	182 C (360 F) Resource	246 C (475 F) Resource
Total Major Equipment			
Pressure Vessels Heat Exchangers Pumps Compressors Freight and Storage Turbine-Generator			
Total	$ 8,847,000	$ 7,763,000	$ 7,107,000
Total Construction Items			
Concrete Pipes, Valves, Fittings Structural Steel Instruments Painting Electrical Insulation Paving, Roads, Fences Buildings			
Total	8,503,000	7,819,000	6,662,000
Indirect Field Costs	4,461,000	3,947,000	3,098,000
Office Cost and Fee	2,624,500	2,402,000	2,074,500
Total Plant Cost	$24,435,500	$21,931,000	$18,941,500

NOTES:

1. "Total Construction Items" includes subcontractors and construction labor.
2. "Total Plant Cost" does not include cooling tower, condenser, or circulating water facilities; special site-specific costs due to site inaccessibility, local labor and materials variability, pollution control measures, or transmission line facilities; or taxes.
3. All costs given are in January, 1980 dollars.
4. Plant cost estimates are based upon information provided by the Ben Holt Company of Pasadena, California.

SUMMARY OF COST ESTIMATES FOR 55 MWe (GROSS) FLASH-STEAM CONVERSION PLANTS

	150 C (300 F) Resource	182 C (360 F) Resource	246 C (475 F) Resource
Total Major Equipment			
Pressure Vessels			
Heat Exchangers			
Pumps			
Compressors			
Freight and Storage			
Turbine-Generator			
Total	$13,102,000	$11,974,000	$11,046,000
Total Construction Items			
Concrete			
Pipes, Valves, Fittings			
Structural Steel			
Instruments			
Painting			
Electrical			
Insulation			
Paving, Roads, Fences			
Buildings			
Total	8,442,000	7,411,000	6,851,000
Indirect Field Costs	4,592,000	4,587,000	3,457,000
Office Cost and Fee	3,214,500	2,948,500	2,627,000
Total Plant Cost	$29,350,500	$26,920,500	$23,981,000

NOTES:

1. "Total Construction Items" includes subcontractors and construction labor.
2. "Total Plant Cost" does not include cooling tower, condenser, or circulating water facilities; special site-specific costs due to site inaccessibility, local labor and materials variability, pollution control measures, or transmission line facilities; or taxes.
3. All costs given are in January, 1980 dollars.
4. Plant cost estimates are based upon information provided by the Ben Holt Company of Pasadena, California.

APPENDIX D

SAMPLE COMPUTER PRINTOUT FOR EVAPORATIVE COOLING TOWER SYSTEMS

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                    MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION


PLANT LOCATION                                                       BASIN AND RANGE

NOMINAL SIZE AND TYPE OF PLANT                                       50.0 MWE (NET) GEOTHERMAL

TYPE OF CONVERSION PROCESS                                           FLASHED STEAM

GEOTHERMAL RESOURCE TEMPERATURE                                      360 F

TURBINE-GENERATOR DESIGN                                             TC4F DOUBLE-ENTRY AXIAL FLOW

PERIOD OF PEAK ELECTRICAL DEMAND                                     SUMMER

NOMINAL TEMPERATURE AT AND ABOVE WHICH
PEAKING CONDITIONS ARE ASSUMED TO EXIST                              82 F

SOURCE OF REPLACEMENT GENERATION - CAPACITY REQUIREMENT
   BASED ON ZERO REPLACEMENT GENERATION

   PEAKING                                                           NONE PROVIDED

   OFF-PEAK                                                          NONE PROVIDED

SITE ELEVATION (REFERENCED TO SEA LEVEL)                             4404 FT

DESIGN WET-BULB TEMPERATURE                                          62 F

SITE CONSTRUCTION COST INDICES

   MATERIALS                                                         1.000

   LABOR                                                             1.000

LENGTH OF CONSTRUCTION PERIOD                                        18 MONTHS

SCHEDULED COMMERCIAL STARTUP DATE                                    1980

ANNUAL HOURS OF BASE-LOAD OPERATION                                  6500
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                     MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST • O+M: $ .50 / MILLION BTU    MAKEUP WATER COST • O+M: $ .10 / K-GAL

PEAKING CAPACITY COST:   $   0 PER KW       NON-PEAKING REPLACEMENT CAPACITY COST:   $   0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:     0.   MILLS PER KWH      BELOW 82 F:     0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


          RATED    GROSS   ANNUAL        REPLACEMENT  ANNUAL   ANNUAL   TOTAL    ANNUAL    ANNUAL                                   TOTAL    BUSBAR
 TOWER   TURBINE  ANNUAL   AUXIL-          CAPACITY  REPLACE- MAKEUP  ANNUAL   REPLACE-    GEO-     ANNUAL   ANNUAL   ANNUAL     ANNUAL   ENERGY
 DESIGN   GENER-   BASE     IARY    ANNUAL REQUIRE-   MENT EN-  WATER   PLANT     MENT    THERMAL   EXCESS  REPLACE-  MAKEUP    CAPITAL  PRODUC-
 CONDI-    ATOR    UNIT    ENERGY   EXCESS   MENT    ERGY REQD   RE-   CAPITAL  CAPACITY  ENERGY   GENER-    MENT    WATER    + OPER-    TION
 TIONS    OUTPUT  GENER-  REQUIRE-  GENER-  ABV BLO   ABV BLO  QUIRE-  AND O+M  AND O+M  AND O+M   ATION    ENERGY   AND O+M   ATING     COSTS
RNG APPR   (*)    ATION     MENT    ATION   82F 82F   82F 82F   MENT    COST      COST     COST    CREDIT    COST     COST     COSTS     MILLS
 F    F    MWE     MWH      MWH      MWH    KW   KW   MWH MWH  AC-FT     $         $         $        $        $        $         $       /KWH
---- --  -----  ------   ------    -----  ---- ----  ---- ---- ------ -------    ------  -------- ------   ------  ------- --------   -----

21.1 25  55.00  385593   39896       0      0    0     0    0  2520  5851933       0    5708194      0        0     82108  11642235  33.68

22.1 24  55.00  385689   39422       0      0    0     0    0  2517  5848778       0    5708426      0        0     82009  11639213  33.61

23.1 23  55.00  385800   39018       0      0    0     0    0  2514  5847899       0    5708658      0        0     81906  11638463  33.56

24.1 22  55.00  385902   38668       0      0    0     0    0  2511  5848502       0    5708891      0        0     81806  11639199  33.52

25.1 21  55.00  386024   38392       0      0    0     0    0  2506  5852656       0    5709188      0        0     81662  11643507  33.49

OPTIMUM

26.1 20  55.00  386141   38153       0      0    0     0    0  2502  5857549       0    5709452      0        0     81544  11648544  33.47

27.1 19  55.00  386254   37992       0      0    0     0    0  2499  5866807       0    5709673      0        0     81430  11657910  33.47

28.1 18  55.00  386385   37856       0      0    0     0    0  2495  5876441       0    5709981      0        0     81296  11667719  33.48

29.1 17  55.00  386507   37804       0      0    0     0    0  2491  5891349       0    5710237      0        0     81164  11682750  33.50

30.1 16  55.00  386643   37769       0      0    0     0    0  2489  5906247       0    5710578      0        0     81090  11697915  33.53

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 * AT  4.0 IN. HGA
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                MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION

                              BUSBAR COMPONENT COST BREAKDOWN - MILLS PER KWH


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST + O+M: $ .50 / MILLION BTU    MAKEUP WATER COST + O+M: $ .10 / K-GAL

PEAKING CAPACITY COST:   $   0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $   0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:    0.   MILLS PER KWH      BELOW 82 F:    0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


                                              ANNUAL                  ANNUAL REPLACEMENT CAPACITY AND ENERGY      ANNUAL
           APPROACH     ANNUAL CAPITAL      GEOTHERMAL     ANNUAL                 AND O+M COSTS                  MAKEUP      BUSBAR
COOLING     TO WET      AND O+M COST          ENERGY       EXCESS      CAPACITY COST           ENERGY COST          WATER      ENERGY
 RANGE       BULB    CONVERSION  COOLING     AND O+M     GENERATION   PEAK-      NON-        ABOVE      BELOW      AND O+M   PRODUCTION
  (F)        (F)       PLANT     SYSTEM       COST         CREDIT      ING      PEAKING       82F        82F        COST       COSTS
 -----       ----     -------    -------    --------      -------    -------    -------    -------    -------    -------    --------

  21.1        25     14.0172     2.9108     16.5121       0.         0.         0.         0.         0.          .2375     33.6776

  22.1        24     13.9941     2.8969     16.4856       0.         0.         0.         0.         0.          .2368     33.6135

  23.1        23     13.9733     2.8900     16.4618       0.         0.         0.         0.         0.          .2362     33.5613

  24.1        22     13.9551     2.8880     16.4410       0.         0.         0.         0.         0.          .2356     33.5197

  25.1        21     13.9391     2.8966     16.4231       0.         0.         0.         0.         0.          .2349     33.4938

OPTIMUM

  26.1        20     13.9249     2.9077     16.4071       0.         0.         0.         0.         0.          .2343     33.4740

  27.1        19     13.9139     2.9320     16.3948       0.         0.         0.         0.         0.          .2338     33.4745

  28.1        18     13.9033     2.9574     16.3831       0.         0.         0.         0.         0.          .2333     33.4771

  29.1        17     13.8963     2.9987     16.3756       0.         0.         0.         0.         0.          .2328     33.5034

  30.1        16     13.8895     3.0399     16.3686       0.         0.         0.         0.         0.          .2324     33.5305
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                    MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST + O+M: $ .50 / MILLION BTU    MAKEUP WATER COST + O+M: $1.00 / K-GAL

PEAKING CAPACITY COST:   $   0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $   0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:    0.   MILLS PER KWH      BELOW 82 F:    0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


          RATED   GROSS   ANNUAL        REPLACEMENT  ANNUAL  ANNUAL  TOTAL   ANNUAL   ANNUAL                                  TOTAL    BUSBAR
 TOWER  TURBINE ANNUAL   AUXIL-           CAPACITY  REPLACE- MAKEUP ANNUAL  REPLACE-   GEO-    ANNUAL  ANNUAL    ANNUAL    ANNUAL   ENERGY
 DESIGN  GENER-   BASE    IARY    ANNUAL  REQUIRE-  MENT EN-  WATER  PLANT    MENT   THERMAL   EXCESS REPLACE-  MAKEUP   CAPITAL   PRODUC-
 CONDI-   ATOR    UNIT   ENERGY   EXCESS   MENT    ERGY REQD   RE-  CAPITAL CAPACITY  ENERGY   GENER-   MENT    WATER    + OPER-    TION
 TIONS   OUTPUT GENER-  REQUIRE-  GENER- ABV BLO    ABV BLO  QUIRE-  AND O+M AND O+M  AND O+M  ATION   ENERGY  AND O+M   ATING     COSTS
RNG APPR  (*)   ATION    MENT     ATION  82F 82F    82F 82F   MENT    COST    COST     COST    CREDIT   COST     COST     COSTS     MILLS
 F   F    MWE    MWH      MWH      MWH   KW  KW     MWH MWH  AC-FT     $       $        $        $       $        $        $        /KWH
---- --  -----  ------   ------   -----  ---- ----  ---- ---- ------ ------- ------  -------- ------  ------  -------  --------   -----

23.1 23  55.00  385800   39018      0     0    0     0    0   2514  5847899      0   5708658     0        0  819056  12375613   35.69

24.1 22  55.00  385902   38608      0     0    0     0    0   2511  5848502      0   5708891     0        0  818059  12375452   35.64

25.1 21  55.00  386024   38392      0     0    0     0    0   2506  5852656      0   5709188     0        0  816623  12378468   35.61

26.1 20  55.00  386141   38153      0     0    0     0    0   2502  5857549      0   5709452     0        0  815439  12382439   35.58

27.1 19  55.00  386254   37992      0     0    0     0    0   2499  5866807      0   5709673     0        0  814298  12390778   35.58

OPTIMUM

28.1 18  55.00  386385   37856      0     0    0     0    0   2495  5876441      0   5709981     0        0  812964  12399386   35.58

29.1 17  55.00  386507   37804      0     0    0     0    0   2491  5891349      0   5710237     0        0  811641  12413227   35.60

30.1 16  55.00  386643   37769      0     0    0     0    0   2489  5906247      0   5710578     0        0  810698  12427724   35.62

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 * AT  4.0 IN. HGA
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        MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION

                    BUSBAR COMPONENT COST BREAKDOWN - MILLS PER KWH


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST + O+M: $ .50 / MILLION BTU    MAKEUP WATER COST + O+M: $1.00 / K-GAL

PEAKING CAPACITY COST:   $    0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $    0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:     0.    MILLS PER KWH      BELOW 82 F:     0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


                                               ANNUAL                         ANNUAL REPLACEMENT CAPACITY AND ENERGY      ANNUAL
               APPROACH     ANNUAL CAPITAL    GEOTHERMAL       ANNUAL                  AND O+M COSTS                      MAKEUP        BUSBAR
  COOLING       TO WET      AND O+M COST       ENERGY          EXCESS         CAPACITY COST          ENERGY COST          WATER         ENERGY
  RANGE          BULB    CONVERSION  COOLING   AND O+M       GENERATION    PEAK-       NON-        ABOVE       BELOW      AND O+M      PRODUCTION
   (F)           (F)       PLANT     SYSTEM     COST          CREDIT        ING       PEAKING       82F         82F        COST          COSTS
  -----         ----     -------    -------   --------       -------      -------     -------     -------     -------    -------      --------

   23.1          23      13.9733    2.8900    16.4618        0.           0.          0.          0.          0.         2.3619       35.6870

   24.1          22      13.9551    2.8880    16.4410        0.           0.          0.          0.          0.         2.3559       35.6401

   25.1          21      13.9391    2.8966    16.4231        0.           0.          0.          0.          0.         2.3491       35.6080

   26.1          20      13.9249    2.9077    16.4071        0.           0.          0.          0.          0.         2.3433       35.5830

   27.1          19      13.9139    2.9320    16.3948        0.           0.          0.          0.          0.         2.3382       35.5789

 OPTIMUM

   28.1          18      13.9033    2.9574    16.3831        0.           0.          0.          0.          0.         2.3326       35.5764

   29.1          17      13.8963    2.9987    16.3756        0.           0.          0.          0.          0.         2.3276       35.5983

   30.1          16      13.8895    3.0399    16.3686        0.           0.          0.          0.          0.         2.3243       35.6224
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                 MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST + O+M: $ .50 / MILLION BTU    MAKEUP WATER COST + O+M: $2.50 / K-GAL

PEAKING CAPACITY COST:   $   0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $   0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:     0.   MILLS PER KWH      BELOW 82 F:     0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


         RATED   GROSS   ANNUAL        REPLACEMENT  ANNUAL   ANNUAL  TOTAL    ANNUAL    ANNUAL                                     TOTAL    BUSBAR
 TOWER  TURBINE ANNUAL   AUXIL-          CAPACITY   REPLACE- MAKEUP ANNUAL   REPLACE-   GEO-     ANNUAL   ANNUAL    ANNUAL     ANNUAL   ENERGY
 DESIGN  GENER-   BASE    IARY    ANNUAL REQUIRE-   MENT EN-  WATER  PLANT     MENT    THERMAL   EXCESS REPLACE-  MAKEUP    CAPITAL   PRODUC-
 CONDI-   ATOR    UNIT   ENERGY   EXCESS   MENT    ERGY REQD   RE-   CAPITAL CAPACITY  ENERGY    GENER-    MENT    WATER     + OPER-    TION
 TIONS   OUTPUT GENER-  REQUIRE-  GENER- ABV  BLO   ABV  BLO  QUIRE- AND O+M AND O+M  AND O+M   ATION    ENERGY   AND O+M    ATING     COSTS
RNG APPR  (*)   ATION    MENT     ATION  82F  82F   82F  82F   MENT    COST     COST     COST    CREDIT     COST     COST      COSTS     MILLS
 F    F   MWE    MWH      MWH      MWH   KW   KW    MWH  MWH  AC-FT     $        $        $         $        $        $          $       /KWH
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23.1 23  55.00  385800   39018      0     0    0     0    0   2514   5847899      0    5708658      0        0 2047639   13604196   39.23

24.1 22  55.00  385902   38668      0     0    0     0    0   2511   5848502      0    5708891      0        0 2045148   13602541   39.17

25.1 21  55.00  386024   38392      0     0    0     0    0   2506   5852656      0    5709188      0        0 2041558   13603402   39.13

26.1 20  55.00  386141   38153      0     0    0     0    0   2502   5857549      0    5709452      0        0 2038597   13605597   39.10

27.1 19  55.00  386254   37992      0     0    0     0    0   2499   5866807      0    5709673      0        0 2035744   13612225   39.09

OPTIMUM

28.1 18  55.00  386385   37856      0     0    0     0    0   2495   5876441      0    5709981      0        0 2032410   13618832   39.08

29.1 17  55.00  386507   37804      0     0    0     0    0   2491   5891349      0    5710237      0        0 2029104   13630689   39.09

30.1 16  55.00  386643   37769      0     0    0     0    0   2489   5906247      0    5710578      0        0 2027246   13644071   39.11

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 * AT  4.0 IN. HGA
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                MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION

                                  BUSBAR COMPONENT COST BREAKDOWN - MILLS PER KWH


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST + O+M: $ .50 / MILLION BTU    MAKEUP WATER COST + O+M: $2.50 / K-GAL

PEAKING CAPACITY COST:   $   0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $   0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:    0.   MILLS PER KWH      BELOW 82 F:    0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


                                                 ANNUAL                ANNUAL REPLACEMENT CAPACITY AND ENERGY        ANNUAL
                    APPROACH   ANNUAL CAPITAL   GEOTHERMAL    ANNUAL              AND O+M COSTS                      MAKEUP     BUSBAR
 COOLING    TO WET     AND O+M COST       ENERGY      EXCESS       CAPACITY COST        ENERGY COST         WATER      ENERGY
  RANGE      BULB   CONVERSION  COOLING   AND O+M   GENERATION   PEAK-      NON-       ABOVE     BELOW      AND O+M   PRODUCTION
   (F)       (F)      PLANT     SYSTEM     COST       CREDIT     ING      PEAKING      82F       82F        COST       COSTS
  -----      ----    -------    -------   --------    -------   -------   -------    -------   -------    -------    --------

  23.1       23      13.9733    2.8900    16.4618     0.         0.        0.         0.        0.         5.9047     39.2298

  24.1       22      13.9551    2.8880    16.4410     0.         0.        0.         0.        0.         5.8898     39.1739

  25.1       21      13.9391    2.8966    16.4231     0.         0.        0.         0.        0.         5.8728     39.1316

  26.1       20      13.9249    2.9077    16.4071     0.         0.        0.         0.        0.         5.8582     39.0979

  27.1       19      13.9139    2.9320    16.3948     0.         0.        0.         0.        0.         5.8454     39.0862

OPTIMUM

  28.1       18      13.9033    2.9574    16.3831     0.         0.        0.         0.        0.         5.8314     39.0752

  29.1       17      13.8963    2.9987    16.3756     0.         0.        0.         0.        0.         5.8190     39.0896

  30.1       16      13.8895    3.0399    16.3686     0.         0.        0.         0.        0.         5.8108     39.1088
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                        MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST + O+M: $1.00 / MILLION BTU    MAKEUP WATER COST + O+M: $ .10 / K-GAL

PEAKING CAPACITY COST:   $   0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $   0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:    0.   MILLS PER KWH      BELOW 82 F:    0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


          RATED   GROSS   ANNUAL        REPLACEMENT  ANNUAL  ANNUAL  TOTAL   ANNUAL    ANNUAL                                   TOTAL    BUSBAR
 TOWER   TURBINE ANNUAL  AUXIL-           CAPACITY  REPLACE- MAKEUP ANNUAL  REPLACE-   GEO-     ANNUAL  ANNUAL    ANNUAL    ANNUAL    ENERGY
 DESIGN  GENER-   BASE    IARY   ANNUAL REQUIRE-  MENT EN-  WATER  PLANT    MENT    THERMAL   EXCESS REPLACE- MAKEUP   CAPITAL   PRODUC-
 CONDI-   ATOR    UNIT   ENERGY  EXCESS   MENT    ERGY REQD  RE-  CAPITAL CAPACITY  ENERGY   GENER-   MENT    WATER   + OPER-    TION
 TIONS   OUTPUT  GENER- REQUIRE- GENER- ABV  BLO   ABV  BLO QUIRE- AND O+M AND O+M  AND O+M   ATION   ENERGY  AND O+M   ATING     COSTS
RNG APPR  (*)    ATION    MENT   ATION  82F  82F   82F  82F  MENT   COST    COST      COST    CREDIT   COST     COST     COSTS     MILLS
 F    F   MWE     MWH     MWH     MWH   KW   KW    MWH  MWH AC-FT    $       $         $        $        $        $        $        /KWH
---- --  -----  ------  ------  ----- ---- ----  ---- ---- ------ ------- ------   -------- ------   ------   ------- --------   -----

23.1 23  55.00  385600  39018      0    0    0     0    0  2514  5847699      0  11417316      0        0     81906  17347121   50.02

24.1 22  55.00  385902  38668      0    0    0     0    0  2511  5848502      0  11417781      0        0     81806  17348089   49.96

25.1 21  55.00  386024  38392      0    0    0     0    0  2506  5852656      0  11418376      0        0     81662  17352695   49.92

26.1 20  55.00  386141  38153      0    0    0     0    0  2502  5857549      0  11418904      0        0     81544  17357996   49.88

27.1 19  55.00  386254  37992      0    0    0     0    0  2499  5866807      0  11419347      0        0     81430  17367584   49.87

OPTIMUM

28.1 18  55.00  386385  37856      0    0    0     0    0  2495  5876441      0  11419963      0        0     81296  17377700   49.86

29.1 17  55.00  386507  37804      0    0    0     0    0  2491  5891349      0  11420474      0        0     81164  17392987   49.88

30.1 16  55.00  386643  37769      0    0    0     0    0  2489  5906247      0  11421157      0        0     81090  17408493   49.90

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 * AT  4.0 IN. HGA
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                     MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION

                                      BUSBAR COMPONENT COST BREAKDOWN - MILLS PER KWH


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST + O+M: $1.00 / MILLION BTU    MAKEUP WATER COST + O+M: $ .10 / K-GAL

PEAKING CAPACITY COST:   $    0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $   0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:    0.   MILLS PER KWH      BELOW 82 F:    0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


                                                ANNUAL                    ANNUAL REPLACEMENT CAPACITY AND ENERGY       ANNUAL
          APPROACH    ANNUAL CAPITAL          GEOTHERMAL     ANNUAL                  AND O+M COSTS                      MAKEUP       BUSBAR
COOLING    TO WET      AND O+M COST             ENERGY       EXCESS        CAPACITY COST          ENERGY COST           WATER        ENERGY
 RANGE      BULB    CONVERSION  COOLING       AND O+M     GENERATION    PEAK-     NON-        ABOVE     BELOW        AND O+M     PRODUCTION
  (F)       (F)       PLANT     SYSTEM         COST         CREDIT       ING     PEAKING       82F       82F          COST         COSTS
 -----      ----    -------    -------      --------      -------     -------   -------     -------   -------      -------      --------

  23.1       23     13.9733     2.8900       32.9236       0.          0.        0.          0.        0.            .2362       50.0231

  24.1       22     13.9551     2.8880       32.8821       0.          0.        0.          0.        0.            .2356       49.9607

  25.1       21     13.9391     2.8966       32.8462       0.          0.        0.          0.        0.            .2349       49.9168

  26.1       20     13.9249     2.9077       32.8141       0.          0.        0.          0.        0.            .2343       49.8811

  27.1       19     13.9139     2.9320       32.7895       0.          0.        0.          0.        0.            .2338       49.8693

OPTIMUM

  28.1       18     13.9033     2.9574       32.7662       0.          0.        0.          0.        0.            .2333       49.8602

  29.1       17     13.8963     2.9987       32.7513       0.          0.        0.          0.        0.            .2328       49.8790

  30.1       16     13.8895     3.0399       32.7372       0.          0.        0.          0.        0.            .2324       49.8990
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                              MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST + O+M: $1.00 / MILLION BTU    MAKEUP WATER COST + O+M: $1.00 / K-GAL

PEAKING CAPACITY COST:   $    0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $   0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:    0.   MILLS PER KWH      BELOW 82 F:    0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


           RATED   GROSS   ANNUAL        REPLACEMENT  ANNUAL   ANNUAL  TOTAL    ANNUAL    ANNUAL                                   TOTAL    BUSBAR
 TOWER   TURBINE ANNUAL  AUXIL-           CAPACITY  REPLACE- MAKEUP ANNUAL  REPLACE-    GEO-    ANNUAL  ANNUAL   ANNUAL    ANNUAL   ENERGY
 DESIGN  GENER-   BASE    IARY    ANNUAL  REQUIRE-  MENT EN-  WATER  PLANT    MENT    THERMAL  EXCESS REPLACE-  MAKEUP   CAPITAL  PRODUC-
 CONDI-   ATOR    UNIT   ENERGY   EXCESS    MENT    ERGY REQD  RE-   CAPITAL CAPACITY  ENERGY  GENER-    MENT    WATER    + OPER-   TION
 TIONS   OUTPUT  GENER- REQUIRE-  GENER-  ABV BLO   ABV BLO  QUIRE-  AND O+M AND O+M  AND O+M  ATION   ENERGY  AND O+M   ATING    COSTS
RNG APPR  (*)    ATION    MENT    ATION   82F 82F   82F 82F   MENT    COST     COST     COST   CREDIT    COST     COST     COSTS    MILLS
 F    F   MWE     MWH     MWH      MWH    KW   KW   MWH MWH  AC-FT     $        $        $       $        $        $        $      /KWH
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23.1 23  55.00  385800  39018      0      0    0     0    0   2514  5847899        0  11417316     0        0   819056 18084271   52.15

24.1 22  55.00  385902  38668      0      0    0     0    0   2511  5848502        0  11417781     0        0   818059 18084343   52.08

25.1 21  55.00  386024  38392      0      0    0     0    0   2506  5852656        0  11418376     0        0   816623 18087656   52.03

26.1 20  55.00  386141  38153      0      0    0     0    0   2502  5857549        0  11418904     0        0   815439 18091891   51.99

27.1 19  55.00  386254  37992      0      0    0     0    0   2499  5866807        0  11419347     0        0   814298 18100452   51.97

OPTIMUM

28.1 18  55.00  386385  37856      0      0    0     0    0   2495  5876441        0  11419963     0        0   812964 18109368   51.96

29.1 17  55.00  386507  37804      0      0    0     0    0   2491  5891349        0  11420474     0        0   811641 18123464   51.97

30.1 16  55.00  386643  37769      0      0    0     0    0   2489  5906247        0  11421157     0        0   810898 18138302   51.99

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 * AT  4.0 IN. HGA
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MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION

BUSBAR COMPONENT COST BREAKDOWN - MILLS PER KWH

ANNUAL FIXED-CHARGE RATE: 15.0 PCT   GEOTHERMAL ENERGY COST * O+M: $1.00 / MILLION BTU   MAKEUP WATER COST * O+M: $1.00 / K-GAL

PEAKING CAPACITY COST: $ 0 PER KW   NON-PEAKING REPLACEMENT CAPACITY COST: $ 0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F: 0. MILLS PER KWH   BELOW 82 F: 0. MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST): CONVERSION PLANT: 3.0   COOLING SYSTEM: 1.0   PEAKING PLANT: 0.

COOLING RANGE (F)	APPROACH TO WET BULB (F)	ANNUAL CAPITAL AND O+M COST		ANNUAL GEOTHERMAL ENERGY AND O+M COST	ANNUAL EXCESS GENERATION CREDIT	ANNUAL REPLACEMENT CAPACITY AND ENERGY AND O+M COSTS				ANNUAL MAKEUP WATER AND O+M COST	BUSBAR ENERGY PRODUCTION COSTS
						CAPACITY COST		ENERGY COST			
		CONVERSION PLANT	COOLING SYSTEM			PEAK-ING	NON-PEAKING	ABOVE 82F	BELOW 82F		
23.1	23	13.9733	2.8900	32.9236	0.	0.	0.	0.	0.	2.3619	52.1488
24.1	22	13.9551	2.8860	32.8821	0.	0.	0.	0.	0.	2.3559	52.0811
25.1	21	13.9391	2.8966	32.8462	0.	0.	0.	0.	0.	2.3491	52.0310
26.1	20	13.9249	2.9077	32.8141	0.	0.	0.	0.	0.	2.3433	51.9901
27.1	19	13.9139	2.9320	32.7895	0.	0.	0.	0.	0.	2.3382	51.9736
OPTIMUM											
28.1	18	13.9033	2.9574	32.7662	0.	0.	0.	0.	0.	2.3326	51.9595
29.1	17	13.8963	2.9987	32.7513	0.	0.	0.	0.	0.	2.3276	51.9739
30.1	16	13.8895	3.0399	32.7372	0.	0.	0.	0.	0.	2.3243	51.9909

MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION

ANNUAL FIXED-CHARGE RATE: 15.0 PCT   GEOTHERMAL ENERGY COST • O+M: $1.00 / MILLION BTU   MAKEUP WATER COST + O+M: $2.50 / K-GAL

PEAKING CAPACITY COST: $ 0 PER KW   NON-PEAKING REPLACEMENT CAPACITY COST: $ 0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F: 0.   MILLS PER KWH   BELOW 82 F: 0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT: 3.0   COOLING SYSTEM: 1.0   PEAKING PLANT: 0.

TOWER DESIGN CONDI-TIONS RNG F	APPR F	RATED TURBINE GENER-ATOR OUTPUT (*) MWE	GROSS ANNUAL BASE UNIT GENER-ATION MWH	ANNUAL AUXIL-IARY ENERGY REQUIRE-MENT MWH	ANNUAL EXCESS GENER-ATION MWH	REPLACEMENT CAPACITY REQUIRE-MENT ABV 82F KW	BLO 82F KW	ANNUAL REPLACE-MENT EN-ERGY REQD ABV 82F MWH	BLO 82F MWH	ANNUAL MAKEUP WATER RE-QUIRE-MENT AC-FT	TOTAL ANNUAL PLANT CAPITAL AND O+M COST $	ANNUAL REPLACE-MENT CAPACITY AND O+M COST $	ANNUAL GEO-THERMAL ENERGY AND O+M COST $	ANNUAL EXCESS GENER-ATION CREDIT $	ANNUAL REPLACE-MENT ENERGY COST $	ANNUAL MAKEUP WATER AND O+M COST $	TOTAL ANNUAL CAPITAL + OPER-ATING COSTS $	BUSBAR ENERGY PRODUC-TION COSTS MILLS /KWH
23.1	23	55.00	385800	39018	0	0	0	0	0	2514	5847899	0	11417316	0	0	2047639	19312855	55.69
24.1	22	55.00	385902	38668	0	0	0	0	0	2511	5848502	0	11417781	0	0	2045148	19311432	55.61
25.1	21	55.00	386024	38392	0	0	0	0	0	2506	5852656	0	11418376	0	0	2041558	19312590	55.55
26.1	20	55.00	386141	38153	0	0	0	0	0	2502	5857549	0	11418904	0	0	2038597	19315049	55.51
27.1	19	55.00	386254	37992	0	0	0	0	0	2499	5866807	0	11419347	0	0	2035744	19321898	55.48
OPTIMUM																		
28.1	18	55.00	386385	37856	0	0	0	0	0	2495	5876441	0	11419963	0	0	2032410	19328813	55.46
29.1	17	55.00	386507	37804	0	0	0	0	0	2491	5891349	0	11420474	0	0	2029104	19340926	55.47
30.1	16	55.00	386643	37769	0	0	0	0	0	2489	5906247	0	11421157	0	0	2027246	19354650	55.48

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* AT 4.0 IN. HGA

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            MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION

                          BUSBAR COMPONENT COST BREAKDOWN - MILLS PER KWH


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST + O*M: $1.00 / MILLION BTU    MAKEUP WATER COST + O*M: $2.50 / K-GAL

PEAKING CAPACITY COST:   $    0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $    0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:    0.   MILLS PER KWH      BELOW 82 F:    0.   MILLS PER KWH

FIXED ANNUAL O*M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


                                                ANNUAL                ANNUAL REPLACEMENT CAPACITY AND ENERGY      ANNUAL
            APPROACH      ANNUAL CAPITAL      GEOTHERMAL    ANNUAL                AND O*M COSTS                   MAKEUP        BUSBAR
COOLING     TO WET        AND O*M COST          ENERGY      EXCESS       CAPACITY COST          ENERGY COST          WATER        ENERGY
 RANGE       BULB     CONVERSION  COOLING      AND O*M    GENERATION   PEAK-      NON-        ABOVE      BELOW      AND O*M     PRODUCTION
  (F)        (F)        PLANT      SYSTEM       COST        CREDIT      ING      PEAKING       82F        82F        COST         COSTS
 -----       ----      -------    -------     -------      -------    -------    -------     -------    -------    -------     --------

  23.1        23       13.9733     2.8900     32.9236      0.          0.         0.          0.         0.         5.9047      55.6916

  24.1        22       13.9551     2.8880     32.8821      0.          0.         0.          0.         0.         5.8898      55.6150

  25.1        21       13.9391     2.8966     32.8462      0.          0.         0.          0.         0.         5.8728      55.5547

  26.1        20       13.9249     2.9077     32.8141      0.          0.         0.          0.         0.         5.8582      55.5050

  27.1        19       13.9139     2.9320     32.7895      0.          0.         0.          0.         0.         5.8454      55.4809

OPTIMUM

  28.1        18       13.9033     2.9574     32.7662      0.          0.         0.          0.         0.         5.8314      55.4583

  29.1        17       13.8963     2.9987     32.7513      0.          0.         0.          0.         0.         5.8190      55.4653

  30.1        16       13.8895     3.0399     32.7372      0.          0.         0.          0.         0.         5.8108      55.4774
```

```
                MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM
                            SUMMARY OF DESIGN DATA


COOLING TOWER

     DESIGN HEAT LOAD                                    1142 MILLION BTU/HR
     DESIGN WET-BULB TEMPERATURE                           62 F
     DESIGN RANGE                                       26.06 F
     DESIGN APPROACH                                    20.00 F
     CIRCULATING WATER FLOW                             87615 GPM
     DESIGN L/G RATIO                                   1.560
     DESIGN KAV/L                                       1.212
     TOTAL FAN BRAKE HORSEPOWER                          1014 BHP
     TOTAL PUMP BRAKE HORSEPOWER
       (BASED ON ASSUMED HEAD OF 75 FT H2O)              2074 BHP

CONDENSER

     CONDENSER DUTY                                      1127 MILLION BTU/HR
     DESIGN BACK PRESSURE                                3.00 IN. HGA
     DESIGN TTD                                          7.00 F
     DESIGN AVERAGE CIRCULATING
        WATER TEMPERATURE                               95.03 F
     VELOCITY THROUGH TUBES                              7.00 FPS
     HEAT TRANSFER SURFACE                             100513 SQ FT
     TUBE TYPE                                                STANDARD
     TUBE MATERIAL                                            ADMIRALTY
     TUBE DIAMETER                                       .875 IN.-OD
     TUBE GAGE                                             18 BWG
```

```
             MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM
                         CAPITAL COST BREAKDOWN


                                                                  $
                                                             -----------
   I. COOLING TOWER

        A. TOWER                                                 1315975
        B. BASIN AND FOUNDATIONS                                  537900
                                                                --------
           TOTAL                                                 1853875

  II. CIRCULATING WATER FACILITIES

        A. PUMPS AND MOTORS                                       684833
        B. PIPING AND STRUCTURE                                  1270240
                                                                --------
           TOTAL                                                 1955073

 III. ELECTRICAL                                                  403408

  IV. CONDENSER                                                   816720
                                                              ==========
      ESTIMATED COOLING SYSTEM CAPITAL COST                      5029076

      ENGINEERING AND CONTINGENCIES ( 15.0 PERCENT)               754361

      INTEREST DURING CONSTRUCTION (  8.00 PERCENT/ANNUM)         540679
                                                                --------
      TOTAL ESTIMATED COOLING SYSTEM CAPITAL COST                6324116

      TOTAL ESTIMATED CONVERSION PLANT CAPITAL COST             26920500

      INSTALLED PEAKING CAPACITY                                       0
                                                              ==========
      TOTAL ESTIMATED CAPITAL INVESTMENT                        33244616
```

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          MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM
                      SUMMARY OF DESIGN DATA


COOLING TOWER

     DESIGN HEAT LOAD                                     1142 MILLION BTU/HR
     DESIGN WET-BULB TEMPERATURE                            62 F
     DESIGN RANGE                                        28.06 F
     DESIGN APPROACH                                     18.00 F
     CIRCULATING WATER FLOW                              81370 GPM
     DESIGN L/G RATIO                                    1.384
     DESIGN KAV/L                                        1.372
     TOTAL FAN BRAKE HORSEPOWER                           1107 BHP
     TOTAL PUMP BRAKE HORSEPOWER
       (BASED ON ASSUMED HEAD OF 75 FT H2O)               1926 BHP

CONDENSER

     CONDENSER DUTY                                       1127 MILLION BTU/HR
     DESIGN BACK PRESSURE                                 3.00 IN. HGA
     DESIGN TTD                                           7.00 F
     DESIGN AVERAGE CIRCULATING
        WATER TEMPERATURE                                94.03 F
     VELOCITY THROUGH TUBES                               7.00 FPS
     HEAT TRANSFER SURFACE                               97136 SQ FT
     TUBE TYPE                                                 STANDARD
     TUBE MATERIAL                                             ADMIRALTY
     TUBE DIAMETER                                        .875 IN.-OD
     TUBE GAGE                                              18 BWG
```

```
                 MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM
                              CAPITAL COST BREAKDOWN

                                                                        $
                                                                   -----------
    I. COOLING TOWER

         A. TOWER                                                     1436283
         B. BASIN AND FOUNDATIONS                                      587076
                                                                     --------
            TOTAL                                                     2023359

   II. CIRCULATING WATER FACILITIES

         A. PUMPS AND MOTORS                                           655114
         B. PIPING AND STRUCTURE                                      1215117
                                                                     --------
            TOTAL                                                     1870230

  III. ELECTRICAL                                                      440288

   IV. CONDENSER                                                       789278
                                                                   ==========
       ESTIMATED COOLING SYSTEM CAPITAL COST                          5123155

       ENGINEERING AND CONTINGENCIES ( 15.0 PERCENT)                   768473

       INTEREST DURING CONSTRUCTION (  8.00 PERCENT/ANNUM)             550564
                                                                     --------
       TOTAL ESTIMATED COOLING SYSTEM CAPITAL COST                    6442192

       TOTAL ESTIMATED CONVERSION PLANT CAPITAL COST                 26920500

       INSTALLED PEAKING CAPACITY                                           0
                                                                   ==========
       TOTAL ESTIMATED CAPITAL INVESTMENT                            33362692
```

MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION

ANNUAL TURBINE OPERATING PROFILE

OPERATING BACK PRESSURE (OBP) - IN. HGA
VS.
HOURS PRESSURE IS EQUALLED OR EXCEEDED

WET TOWER RANGE F	APPR F	OBP	HRS	OBP	HRS	OBP	HRS	OBP	HRS	OBP	HRS	OBP	HRS	OBP	HRS	OBP	HRS
26.06	20.0	3.3	2	3.2	6	3.2	8	3.2	9	3.1	35	3.1	61	3.1	64	3.0	153
		3.0	167	3.0	175	3.0	177	2.9	229	2.9	404	2.9	411	2.9	443	2.8	451
		2.8	555	2.8	782	2.7	792	2.7	874	2.7	1093	2.7	1282	2.7	1288	2.6	1480
		2.6	1501	2.6	1657	2.6	1860	2.6	1929	2.5	2093	2.5	2554	2.5	2592	2.5	2713
		2.5	2824	2.4	2842	2.4	3058	2.4	3336	2.4	3424	2.4	3490	2.4	3643	2.3	3837
		2.3	3951	2.3	4201	2.3	4328	2.3	4475	2.3	4518	2.2	4670	2.2	4895	2.2	4962
		2.2	5108	2.2	5128	2.2	5332	2.2	5498	2.1	5541	2.1	5681	2.1	5714	2.1	5821
		2.1	5918	2.1	5918	2.1	5960	2.0	6080	2.0	6157	2.0	6212	2.0	6216	2.0	6234
		2.0	6318	2.0	6366	2.0	6384	1.9	6387	1.9	6428	1.9	6454	1.9	6458	1.9	6484
		1.8	6485	1.8	6495	1.8	6496	1.7	6499	1.7	6500						
28.06	18.0	3.3	2	3.2	6	3.2	8	3.2	9	3.1	35	3.1	61	3.1	64	3.0	153
		3.0	167	3.0	175	3.0	177	2.9	229	2.9	404	2.9	411	2.9	443	2.8	451
		2.8	555	2.8	782	2.7	792	2.7	874	2.7	1093	2.7	1250	2.7	1282	2.6	1288
		2.6	1480	2.6	1501	2.6	1657	2.6	1860	2.5	1929	2.5	2082	2.5	2093	2.5	2592
		2.4	2824	2.4	2842	2.4	3058	2.4	3336	2.4	3424	2.4	3490	2.3	3643	2.3	3837
		2.3	3910	2.3	3951	2.3	4201	2.3	4328	2.2	4475	2.2	4518	2.2	4670	2.2	4895
		2.2	4962	2.2	5108	2.2	5128	2.2	5260	2.1	5332	2.1	5498	2.1	5537	2.1	5541
		2.1	5681	2.1	5714	2.1	5821	2.1	5918	2.0	5918	2.0	5960	2.0	6080	2.0	6157
		2.0	6212	2.0	6234	1.9	6318	1.9	6366	1.9	6384	1.9	6387	1.9	6428	1.9	6454
		1.9	6458	1.8	6478	1.8	6484	1.8	6485	1.8	6490	1.8	6495	1.7	6496	1.7	6497
		1.7	6499	1.6	6500												

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              MECHANICAL DRAFT EVAPORATIVE COOLING TOWER SYSTEM OPTIMIZATION AND EVALUATION
                                   ANNUAL PLANT GENERATING PROFILE

                                    ELECTRICAL OUTPUT AT GIVEN AMBIENT WET-BULB TEMPERATURE
                                    VS. OPERATING HOURS TEMPERATURE IS EQUALLED OR EXCEEDED

WET TOWER   AMB  GROSS  NET              AMB  GROSS  NET              AMB  GROSS  NET              AMB  GROSS  NET              AMB  GROSS  NET
RNG  APPR   WBT   T-G  PLANT             WBT   T-G  PLANT             WBT   T-G  PLANT             WBT   T-G  PLANT             WBT   T-G  PLANT
 F    F      F    MWE   MWE   HRS         F    MWE   MWE   HRS         F    MWE   MWE   HRS         F    MWE   MWE   HRS         F    MWE   MWE   HRS
---- ----   ---- ----- ----- ----       ---- ----- ----- ----       ---- ----- ----- ----       ---- ----- ----- ----       ---- ----- ----- ----

26.1  20    68.8 57.36 51.49    2       67.9 57.46 51.59    6       66.5 57.62 51.75    8       66.1 57.67 51.80    9       65.6 57.70 51.83   35
            64.1 57.67 52.00   61       63.7 57.89 52.02   64       62.5 58.00 52.13  153       62.1 58.06 52.19  167       61.5 58.12 52.25  175
            61.0 58.15 52.28  177       60.2 58.25 52.38  224       59.3 58.34 52.47  404       58.9 58.37 52.50  411       57.8 58.46 52.59  443
            56.8 58.58 52.71  451       56.4 58.61 52.74  555       56.1 58.64 52.77  776       56.0 58.64 52.77  782       54.2 58.78 52.91  792
            53.5 58.83 52.96  874       53.0 58.85 52.98 1093       52.5 58.89 53.02 1250       52.2 58.89 53.02 1282       51.1 58.96 53.09 1288
            49.8 59.04 53.17 1480       49.4 59.06 53.19 1501       49.2 59.08 53.21 1657       48.6 59.12 53.25 1860       47.6 59.19 53.32 1929
            46.5 59.26 53.39 2082       46.2 59.26 53.39 2093       44.8 59.34 53.47 2554       44.6 59.36 53.49 2592       43.3 59.42 53.55 2713
            43.0 59.44 53.57 2824       41.3 59.51 53.65 2842       40.9 59.53 53.66 3058       40.5 59.55 53.68 3336       40.0 59.56 53.69 3424
            39.8 59.58 53.71 3490       38.4 59.61 53.74 3643       37.0 59.66 53.79 3837       36.6 59.67 53.80 3910       36.3 59.67 53.80 3951
            36.1 59.68 53.81 4201       35.1 59.70 53.83 4328       33.8 59.73 53.86 4475       33.2 59.74 53.87 4518       33.0 59.75 53.88 4670
            31.8 59.77 53.90 4895       31.4 59.78 53.91 4962       30.4 59.79 53.92 5108       29.8 59.81 53.94 5128       29.3 59.82 53.95 5260
            29.2 59.82 53.95 5332       27.6 59.85 53.98 5498       26.5 59.88 54.01 5537       26.4 59.88 54.01 5541       25.6 59.89 54.02 5681
            25.3 59.90 54.03 5714       24.6 59.91 54.04 5821       23.2 59.93 54.06 5918       22.9 59.94 54.07 5918       21.6 59.97 54.10 5950
            21.2 59.97 54.10 5960       20.8 59.98 54.11 6080       20.0 59.99 54.12 6157       18.7 60.01 54.14 6212       17.1 60.04 54.17 6216
            16.6 60.05 54.18 6234       15.9 60.06 54.19 6318       15.3 60.07 54.20 6366       14.2 60.09 54.22 6384       11.7 60.13 54.26 6387
            11.1 60.14 54.27 6428       10.5 60.15 54.28 6454        9.7 60.16 54.30 6458        6.3 60.21 54.34 6478        5.8 60.21 54.34 6484
             5.1 60.22 54.35 6485        1.4 60.25 54.38 6490        1.0 60.25 54.38 6495         .4 60.26 54.39 6496       -3.2 60.27 54.40 6497
            -3.5 60.27 54.40 6497       -3.8 60.27 54.40 6499       -8.6 60.27 54.40 6500

28.1  18    68.8 57.30 51.47    2       67.9 57.43 51.61    6       66.5 57.59 51.77    8       66.1 57.65 51.82    9       65.6 57.70 51.88   35
            64.1 57.84 52.02   61       63.7 57.89 52.07   64       62.5 58.00 52.18  153       62.1 58.06 52.23  167       61.5 58.12 52.30  175
            61.0 58.15 52.33  177       60.2 58.25 52.42  224       59.3 58.34 52.52  404       58.9 58.40 52.58  411       57.8 58.49 52.67  443
            56.8 58.58 52.76  451       56.4 58.64 52.81  555       56.1 58.66 52.84  776       56.0 58.66 52.84  782       54.2 58.81 52.98  792
            53.5 58.85 53.03  874       53.0 58.89 53.07 1093       52.5 58.92 53.09 1250       52.2 58.94 53.11 1282       51.1 59.00 53.18 1288
            49.8 59.08 53.26 1480       49.4 59.10 53.28 1501       49.2 59.12 53.30 1657       48.6 59.17 53.34 1860       47.6 59.23 53.41 1929
            46.5 59.30 53.48 2082       46.2 59.32 53.50 2093       44.8 59.40 53.58 2554       44.6 59.40 53.58 2592       43.3 59.48 53.65 2713
            43.0 59.48 53.65 2824       41.3 59.56 53.74 2842       40.9 59.58 53.75 3058       40.5 59.59 53.77 3336       40.0 59.60 53.78 3424
            39.8 59.61 53.79 3490       38.4 59.66 53.84 3643       37.0 59.69 53.87 3837       36.6 59.70 53.88 3910       36.3 59.71 53.88 3951
            36.1 59.71 53.89 4201       35.1 59.74 53.91 4328       33.8 59.76 53.94 4475       33.2 59.78 53.95 4518       33.0 59.78 53.96 4670
            31.8 59.81 53.98 4895       31.4 59.82 53.99 4962       30.4 59.84 54.01 5108       29.8 59.85 54.03 5128       29.3 59.86 54.03 5260
            29.2 59.86 54.04 5332       27.6 59.89 54.07 5498       26.5 59.91 54.04 5537       26.4 59.92 54.10 5541       25.6 59.93 54.11 5681
            25.3 59.94 54.12 5714       24.6 59.95 54.12 5821       23.2 59.97 54.15 5918       22.9 59.98 54.16 5918       21.6 60.01 54.19 5950
            21.2 60.01 54.19 5960       20.8 60.02 54.19 6080       20.0 60.04 54.21 6157       18.7 60.05 54.23 6212       17.1 60.09 54.27 6216
            16.6 60.09 54.27 6234       15.9 60.11 54.29 6318       15.3 60.12 54.30 6366       14.2 60.14 54.31 6384       11.7 60.18 54.35 6387
            11.1 60.18 54.36 6428       10.5 60.19 54.37 6454        9.7 60.21 54.38 6458        6.3 60.24 54.42 6478        5.8 60.25 54.42 6484
             5.1 60.25 54.43 6485        1.4 60.27 54.44 6490        1.0 60.27 54.44 6495         .4 60.27 54.44 6496       -3.2 60.27 54.45 6497
            -3.5 60.27 54.45 6497       -3.8 60.27 54.45 6499       -8.6 60.27 54.44 6500
```

APPENDIX E

SAMPLE COMPUTER PRINTOUT FOR DIRECT DRY/WET PEAKING COOLING TOWER SYSTEMS

MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION

PLANT LOCATION	BASIN AND RANGE
NOMINAL SIZE AND TYPE OF PLANT	50.0 MWE (NET) GEOTHERMAL
TYPE OF CONVERSION PROCESS	ORGANIC FLUID
GEOTHERMAL RESOURCE TEMPERATURE	360 F
TURBINE-GENERATOR DESIGN	TC2F AXIAL FLOW
WORKING FLUID	COMMERCIAL ISOBUTANE
NOMINAL DESIGN MAXIMUM OPERATING EXHAUST PRESSURE	80.0 PSIA
TYPE OF DRY TOWER	DIRECT
PERIOD OF PEAK ELECTRICAL DEMAND	SUMMER
NOMINAL TEMPERATURE AT AND ABOVE WHICH PEAKING CONDITIONS ARE ASSUMED TO EXIST	82 F
SOURCE OF REPLACEMENT GENERATION - CAPACITY REQUIREMENT BASED ON ZERO REPLACEMENT GENERATION	
PEAKING	NONE PROVIDED
OFF-PEAK	NONE PROVIDED
SITE ELEVATION (REFERENCED TO SEA LEVEL)	4400 FT
SITE CONSTRUCTION COST INDICES	
MATERIALS	1.000
LABOR	1.000
ESTIMATED LENGTH OF CONSTRUCTION PERIOD	18 MONTHS
SCHEDULED COMMERCIAL STARTUP DATE	1980
ANNUAL HOURS OF BASE LOAD OPERATION	6500

MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION

ANNUAL FIXED-CHARGE RATE: 15.0 PCT GEOTHERMAL ENERGY COST • O+M: $ .50 / MILLION BTU MAKEUP WATER COST + O+M: $ .10 / K-GAL

PEAKING CAPACITY COST: $ 0 PER KW NON-PEAKING REPLACEMENT CAPACITY COST: $ 0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F: 0. MILLS PER KWH BELOW 82 F: 0. MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST): CONVERSION PLANT: 3.0 COOLING SYSTEM: 1.0 PEAKING PLANT: 0.

TOWER DESIGN CONDITIONS			GROSS ANNUAL BASE UNIT GENERATION	ANNUAL AUXILIARY ENERGY REQUIREMENT	ANNUAL EXCESS GENERATION	REPLACEMENT CAPACITY REQUIREMENT		ANNUAL REPLACEMENT ENERGY REQD		ANNUAL MAKEUP WATER REQUIREMENT	TOTAL ANNUAL PLANT CAPITAL AND O+M COST	ANNUAL REPLACEMENT CAPACITY AND O+M COST	ANNUAL GEOTHERMAL ENERGY AND O+M COST	ANNUAL EXCESS GENERATION CREDIT	ANNUAL REPLACEMENT ENERGY COST	ANNUAL MAKEUP WATER AND O+M COST	TOTAL ANNUAL CAPITAL + OPERATING COSTS	BUSBAR ENERGY PRODUCTION COSTS
DRY TOWER ITD F	WET PEAKING TOWER RNG F	APPR F	MWH	MWH	MWH	ABV 82F MW	BLO 82F MW	ABV 82F MWH	BLO 82F MWH	AC-FT	$	$	$	$	$	$	$	MILLS /KWH
20	22.0	21	451409	83377	0	0.	0.	0	0	92	11504731	0	5300909	0	0	3010	16808651	45.67
30	22.0	21	450125	86886	0	0.	0.	0	0	162	9461484	0	5300550	0	0	5266	14767300	40.65
40	23.0	20	448533	90469	0	0.	0.	0	0	268	8441041	0	5300102	0	0	8728	13749870	38.40
50	23.0	20	446369	93741	0	0.	0.	0	0	402	7935753	0	5299472	0	0	13100	13248325	37.57
60	23.0	20	443031	96400	0	0.	0.	0	0	582	7487973	0	5298522	0	0	18974	12805469	36.94
70	23.0	20	440040	98102	0	0.	0.	0	0	793	7186093	0	5297665	0	0	25850	12509608	36.58
80	24.0	19	437886	98527	0	0.	0.	0	0	1017	6966856	0	5297059	0	0	33153	12297068	36.24
90	25.0	18	436868	99152	0	0.	0.	0	0	1230	6798956	0	5296783	0	0	40084	12135823	35.93
100	25.0	18	436569	99107	0	0.	0.	0	0	1413	6658079	0	5296734	0	0	46043	12000856	35.56

```
                 MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION
                                      BUSBAR COMPONENT COST BREAKDOWN - MILLS PER KWH


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST + O+M: $ .50 / MILLION BTU    MAKEUP WATER COST + O+M: $ .10 / K-GAL

PEAKING CAPACITY COST:   $   0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $   0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:    0.   MILLS PER KWH      BELOW 82 F:    0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


  TOWER DESIGN                                       ANNUAL                        ANNUAL REPLACEMENT CAPACITY          ANNUAL
   CONDITIONS           ANNUAL CAPITAL             GEOTHERMAL    ANNUAL              AND ENERGY AND O+M COSTS            MAKEUP      BUSBAR
 DRY      WET           AND O+M COSTS                ENERGY      EXCESS          CAPACITY COST          ENERGY COST         WATER       ENERGY
 ITD  RNG   APPR  CONVERSION   COOLING SYSTEM       AND O+M    GENERATION    PEAK-      NON-        ABOVE      BELOW     AND O+M    PRODUCTION
  F    F     F      PLANT        DRY      WET         COSTS       CREDIT      ING      PEAKING       82F        82F       COSTS        COSTS
 ---  ----  ----  -------     ------   -------      -------     --------   -------    -------     -------    -------    --------    ---------

  20  22.0   21    10.7262    17.5060    3.0280     14.4034      0.          0.        0.          0.         0.          .0082      45.6717

  30  22.0   21    10.8677    11.8621    3.3177     14.5925      0.          0.        0.          0.         0.          .0145      40.6546

  40  23.0   20    11.0248     9.0536    3.4957     14.8021      0.          0.        0.          0.         0.          .0244      38.4006

  50  23.0   20    11.1948     7.3777    3.9322     15.0285      0.          0.        0.          0.         0.          .0371      37.5703

  60  23.0   20    11.3884     6.2140    3.9997     15.2858      0.          0.        0.          0.         0.          .0547      36.9427

  70  23.0   20    11.5447     5.4164    4.0546     15.4931      0.          0.        0.          0.         0.          .0756      36.5844

  80  24.0   19    11.6325     4.7904    4.1066     15.6090      0.          0.        0.          0.         0.          .0977      36.2361

  90  25.0   18    11.6890     4.2923    4.1508     15.6841      0.          0.        0.          0.         0.          .1187      35.9350

 100  25.0   18    11.6978     3.8781    4.1539     15.6958      0.          0.        0.          0.         0.          .1364      35.5621
```

MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION

ANNUAL FIXED-CHARGE RATE: 15.0 PCT   GEOTHERMAL ENERGY COST + O+M: $ .50 / MILLION BTU   MAKEUP WATER COST + O+M: $1.00 / K-GAL

PEAKING CAPACITY COST: $ 0 PER KW   NON-PEAKING REPLACEMENT CAPACITY COST: $ 0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F: 0. MILLS PER KWH   BELOW 82 F: 0. MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST): CONVERSION PLANT: 3.0   COOLING SYSTEM: 1.0   PEAKING PLANT: 0.

TOWER DESIGN CONDITIONS			GROSS ANNUAL BASE UNIT GENER-ATION	ANNUAL AUXIL-IARY ENERGY REQUIRE-MENT	ANNUAL EXCESS GENER-ATION	REPLACEMENT CAPACITY REQUIRE-MENT		ANNUAL REPLACE-MENT EN-ERGY REQD		ANNUAL MAKEUP WATER RE-QUIRE-MENT	TOTAL ANNUAL PLANT CAPITAL AND O+M COST	ANNUAL REPLACE-MENT CAPACITY AND O+M COST	ANNUAL GEO-THERMAL ENERGY AND O+M COST	ANNUAL EXCESS GENER-ATION CREDIT	ANNUAL REPLACE-MENT ENERGY COST	ANNUAL MAKEUP WATER AND O+M COST	TOTAL ANNUAL CAPITAL + OPER-ATING COSTS	BUSBAR ENERGY PRODUC-TION COSTS
DRY TOWER ITD F	WET PEAKING TOWER RNG F	APPR F	MWH	MWH	MWH	ABV 82F MW	BLO 82F MW	ABV 82F MWH	BLO 82F MWH	AC-FT	$	$	$	$	$	$	$	MILLS /KWH
20	22.0	21	451409	83377	0	0.	0.	0	0	92	11504731	0	5300909	0	0	30104	16835744	45.75
30	22.0	21	450125	86885	0	0.	0.	0	0	162	9461484	0	5300550	0	0	52664	14814697	40.79
40	23.0	20	448533	90469	0	0.	0.	0	0	268	8441041	0	5300102	0	0	87283	13828425	38.62
50	23.0	20	446369	93741	0	0.	0.	0	0	402	7935753	0	5299472	0	0	130998	13366224	37.90
60	23.0	20	443031	96400	0	0.	0.	0	0	582	7487973	0	5298522	0	0	189740	12976235	37.44
70	23.0	20	440040	98102	0	0.	0.	0	0	793	7186093	0	5297665	0	0	258500	12742258	37.26
80	24.0	19	437886	98527	0	0.	0.	0	0	1017	6966856	0	5297059	0	0	331534	12595448	37.12
90	25.0	18	436868	99152	0	0.	0.	0	0	1230	6798956	0	5296783	0	0	400838	12496577	37.00
100	25.0	18	436569	99107	0	0.	0.	0	0	1413	6658079	0	5296734	0	0	460432	12415244	36.79

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          MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION
                             BUSBAR COMPONENT COST BREAKDOWN - MILLS PER KWH


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST • O+M: $ .50 / MILLION BTU    MAKEUP WATER COST + O+M: $1.00 / K-GAL

PEAKING CAPACITY COST:   $   0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $   0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:    0.   MILLS PER KWH      BELOW 82 F:    0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


  TOWER DESIGN                                        ANNUAL                      ANNUAL REPLACEMENT CAPACITY            ANNUAL
   CONDITIONS              ANNUAL CAPITAL           GEOTHERMAL     ANNUAL          AND ENERGY AND O+M COSTS              MAKEUP       BUSBAR
 DRY     WET               AND O+M COSTS              ENERGY       EXCESS       CAPACITY COST        ENERGY COST          WATER        ENERGY
 ITD  RNG  APPR   CONVERSION   COOLING SYSTEM       AND O+M    GENERATION   PEAK-      NON-      ABOVE     BELOW     AND O+M     PRODUCTION
  F    F     F       PLANT       DRY      WET          COSTS       CREDIT      ING     PEAKING      82F       82F       COSTS        COSTS
 ---  ----  ----   -------     ------   -------      -------     ---------   -------   -------   -------   -------   --------    ---------

  20  22.0   21    10.7262    17.5060    3.0280      14.4034     0.          0.        0.        0.        0.          .0818      45.7453

  30  22.0   21    10.8677    11.8621    3.3177      14.5925     0.          0.        0.        0.        0.          .1450      40.7851

  40  23.0   20    11.0248     9.0536    3.4957      14.8021     0.          0.        0.        0.        0.          .2438      38.6200

  50  23.0   20    11.1948     7.3777    3.9322      15.0285     0.          0.        0.        0.        0.          .3715      37.9046

  60  23.0   20    11.3884     6.2140    3.9997      15.2858     0.          0.        0.        0.        0.          .5474      37.4353

  70  23.0   20    11.5447     5.4164    4.0546      15.4931     0.          0.        0.        0.        0.          .7560      37.2648

  80  24.0   19    11.6325     4.7904    4.1066      15.6090     0.          0.        0.        0.        0.          .9769      37.1154

  90  25.0   18    11.6890     4.2923    4.1508      15.6841     0.          0.        0.        0.        0.         1.1869      37.0032

 100  25.0   18    11.6978     3.8781    4.1539      15.6958     0.          0.        0.        0.        0.         1.3644      36.7900
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MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION

ANNUAL FIXED-CHARGE RATE: 15.0 PCT   GEOTHERMAL ENERGY COST + O+M: $ .50 / MILLION BTU   MAKEUP WATER COST + O+M: $2.50 / K-GAL

PEAKING CAPACITY COST: $ 0 PER KW   NON-PEAKING REPLACEMENT CAPACITY COST: $ 0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F: 0. MILLS PER KWH   BELOW 82 F: 0. MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST): CONVERSION PLANT: 3.0   COOLING SYSTEM: 1.0   PEAKING PLANT: 0.

TOWER DESIGN CONDITIONS DRY TOWER ITD F	TOWER DESIGN CONDITIONS WET PEAKING TOWER RNG F	TOWER DESIGN CONDITIONS WET PEAKING TOWER APPR F	GROSS ANNUAL BASE UNIT GENERATION MWH	ANNUAL AUXILIARY ENERGY REQUIREMENT MWH	ANNUAL EXCESS GENERATION MWH	REPLACEMENT CAPACITY REQUIREMENT ABV 82F MW	REPLACEMENT CAPACITY REQUIREMENT BLO 82F MW	ANNUAL REPLACEMENT ENERGY REQD ABV 82F MWH	ANNUAL REPLACEMENT ENERGY REQD BLO 82F MWH	ANNUAL MAKEUP WATER REQUIREMENT AC-FT	TOTAL ANNUAL PLANT CAPITAL AND O+M COST $	ANNUAL REPLACEMENT CAPACITY AND O+M COST $	ANNUAL GEOTHERMAL ENERGY AND O+M COST $	ANNUAL EXCESS GENERATION CREDIT $	ANNUAL REPLACEMENT ENERGY COST $	ANNUAL MAKEUP WATER AND O+M COST $	TOTAL ANNUAL CAPITAL + OPERATING COSTS $	BUSBAR ENERGY PRODUCTION COSTS MILLS /KWH
20	22.0	21	451409	83377	0	0.	0.	0	0	92	11504731	0	5300909	0	0	75260	16880900	45.87
30	22.0	21	450125	86886	0	0.	0.	0	0	162	9461484	0	5300550	0	0	131659	14893692	41.00
40	23.0	20	448533	90469	0	0.	0.	0	0	268	8441041	0	5300102	0	0	218207	13959349	38.99
50	23.0	20	446369	93741	0	0.	0.	0	0	402	7935753	0	5299472	0	0	327495	13562721	38.46
60	23.0	20	443031	96400	0	0.	0.	0	0	582	7487973	0	5298522	0	0	474349	13260844	38.26
70	23.0	20	440040	98102	0	0.	0.	0	0	793	7186093	0	5297665	0	0	646249	13130008	38.40
80	24.0	19	437886	98527	0	0.	0.	0	0	1017	6966856	0	5297059	0	0	828834	13092749	38.58
90	25.0	18	436868	99152	0	0.	0.	0	0	1230	6798956	0	5296783	0	0	1002094	13097833	38.78
100	25.0	18	436569	99107	0	0.	0.	0	0	1413	6658079	0	5296734	0	0	1151079	13105891	38.84

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           MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION
                                   BUSBAR COMPONENT COST BREAKDOWN - MILLS PER KWH


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST + O+M: $ .50 / MILLION BTU    MAKEUP WATER COST + O+M: $2.50 / K-GAL

PEAKING CAPACITY COST:   $    0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $    0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:     0.   MILLS PER KWH      BELOW 82 F:     0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


  TOWER DESIGN                                          ANNUAL                        ANNUAL REPLACEMENT CAPACITY           ANNUAL
   CONDITIONS             ANNUAL CAPITAL              GEOTHERMAL     ANNUAL             AND ENERGY AND O+M COSTS            MAKEUP       BUSBAR
 DRY      WET             AND O+M COSTS                 ENERGY       EXCESS         CAPACITY COST         ENERGY COST       WATER        ENERGY
 ITD  RNG  APPR   CONVERSION   COOLING SYSTEM          AND O+M    GENERATION     PEAK-      NON-      ABOVE      BELOW    AND O+M    PRODUCTION
  F    F     F       PLANT       DRY       WET          COSTS       CREDIT        ING     PEAKING      82F        82F      COSTS        COSTS
 ---  ----  ----   -------     ------    -------       -------     --------     -------   -------    -------    -------   --------    ---------

  20  22.0  21     10.7262    17.5060     3.0280       14.4034      0.           0.         0.         0.         0.         .2045      45.8680

  30  22.0  21     10.8677    11.8621     3.3177       14.5925      0.           0.         0.         0.         0.         .3625      41.0025

  40  23.0  20     11.0248     9.0536     3.4957       14.8021      0.           0.         0.         0.         0.         .6094      38.9856

  50  23.0  20     11.1948     7.3777     3.9322       15.0285      0.           0.         0.         0.         0.         .9287      38.4619

  60  23.0  20     11.3884     6.2140     3.9997       15.2858      0.           0.         0.         0.         0.        1.3685      38.2564

  70  23.0  20     11.5447     5.4164     4.0546       15.4931      0.           0.         0.         0.         0.        1.8900      38.3988

  80  24.0  19     11.6325     4.7904     4.1066       15.6090      0.           0.         0.         0.         0.        2.4424      38.5808

  90  25.0  18     11.6890     4.2923     4.1508       15.6841      0.           0.         0.         0.         0.        2.9673      38.7835

 100  25.0  18     11.6978     3.8781     4.1539       15.6958      0.           0.         0.         0.         0.        3.4110      38.8366
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MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION

ANNUAL FIXED-CHARGE RATE: 15.0 PCT   GEOTHERMAL ENERGY COST + O+M: $1.00 / MILLION BTU   MAKEUP WATER COST + O+M: $ .10 / K-GAL

PEAKING CAPACITY COST: $ 0 PER KW   NON-PEAKING REPLACEMENT CAPACITY COST: $ 0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F: 0. MILLS PER KWH   BELOW 82 F: 0. MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST): CONVERSION PLANT: 3.0   COOLING SYSTEM: 1.0   PEAKING PLANT: 0.

TOWER DESIGN CONDITIONS			GROSS ANNUAL BASE UNIT GENER-ATION MWH	ANNUAL AUXIL-IARY ENERGY REQUIRE-MENT MWH	ANNUAL EXCESS GENER-ATION MWH	REPLACEMENT CAPACITY REQUIRE-MENT		ANNUAL REPLACE-MENT EN-ERGY REQD		ANNUAL MAKEUP WATER RE-QUIRE-MENT AC-FT	TOTAL ANNUAL PLANT CAPITAL AND O+M COST $	ANNUAL REPLACE-MENT CAPACITY AND O+M COST $	ANNUAL GEO-THERMAL ENERGY AND O+M COST $	ANNUAL EXCESS GENER-ATION CREDIT $	ANNUAL REPLACE-MENT ENERGY COST $	ANNUAL MAKEUP WATER AND O+M COST $	TOTAL ANNUAL CAPITAL + OPER-ATING COSTS $	BUSBAR ENERGY PRODUC-TION COSTS MILLS /KWH
DRY TOWER ITD F	WET PEAKING TOWER RNG F	APPR F				ABV 82F MW	BLO 82F MW	ABV 82F MWH	BLO 82F MWH									
20	22.0	21	451409	83377	0	0.	0.	0	0	92	11504731	0	10601818	0	0	3010	22109559	60.08
30	22.0	21	450125	86886	0	0.	0.	0	0	162	9461484	0	10601099	0	0	5266	20067849	55.25
40	23.0	20	448533	90469	0	0.	0.	0	0	268	8441041	0	10600203	0	0	8728	19049972	53.20
50	23.0	20	446369	93741	0	0.	0.	0	0	402	7935753	0	10598944	0	0	13100	18547797	52.60
60	24.0	19	443032	96186	0	0.	0.	0	0	582	7495146	0	10597044	0	0	18967	18111157	52.22
70	25.0	18	440041	97525	0	0.	0.	0	0	794	7201463	0	10595330	0	0	25883	17822676	52.03
80	25.0	18	437891	98170	0	0.	0.	0	0	1018	6975053	0	10594117	0	0	33163	17602333	51.81
90	25.0	18	436868	99152	0	0.	0.	0	0	1230	6798956	0	10593567	0	0	40084	17432606	51.62
100	27.0	16	436574	98251	0	0.	0.	0	0	1414	6687825	0	10593465	0	0	46073	17327362	51.22

MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION
BUSBAR COMPONENT COST BREAKDOWN - MILLS PER KWH

ANNUAL FIXED-CHARGE RATE: 15.0 PCT GEOTHERMAL ENERGY COST • O+M: $1.00 / MILLION BTU MAKEUP WATER COST • O+M: $ .10 / K-GAL

PEAKING CAPACITY COST: $ 0 PER KW NON-PEAKING REPLACEMENT CAPACITY COST: $ 0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F: 0. MILLS PER KWH BELOW 82 F: 0. MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST): CONVERSION PLANT: 3.0 COOLING SYSTEM: 1.0 PEAKING PLANT: 0.

TOWER DESIGN CONDITIONS			ANNUAL CAPITAL AND O+M COSTS			ANNUAL GEOTHERMAL ENERGY AND O+M COSTS	ANNUAL EXCESS GENERATION CREDIT	ANNUAL REPLACEMENT CAPACITY AND ENERGY AND O+M COSTS				ANNUAL MAKEUP WATER AND O+M COSTS	BUSBAR ENERGY PRODUCTION COSTS
DRY	WET			COOLING SYSTEM				CAPACITY COST		ENERGY COST			
ITD F	RNG F	APPR F	CONVERSION PLANT	DRY	WET			PEAKING	NON-PEAKING	ABOVE 82F	BELOW 82F		
20	22.0	21	10.7262	17.5060	3.0280	28.8068	0.	0.	0.	0.	0.	.0082	60.0751
30	22.0	21	10.8677	11.8621	3.3177	29.1850	0.	0.	0.	0.	0.	.0145	55.2471
40	23.0	20	11.0248	9.0536	3.4957	29.6042	0.	0.	0.	0.	0.	.0244	53.2027
50	23.0	20	11.1948	7.3777	3.9322	30.0570	0.	0.	0.	0.	0.	.0371	52.5988
60	24.0	19	11.3814	6.2101	4.0179	30.5526	0.	0.	0.	0.	0.	.0547	52.2167
70	25.0	18	11.5252	5.4073	4.0927	30.9338	0.	0.	0.	0.	0.	.0756	52.0346
80	25.0	18	11.6201	4.7853	4.1263	31.1848	0.	0.	0.	0.	0.	.0976	51.8141
90	25.0	18	11.6890	4.2923	4.1508	31.3682	0.	0.	0.	0.	0.	.1187	51.6191
100	27.0	16	11.6681	3.8682	4.2313	31.3117	0.	0.	0.	0.	0.	.1362	51.2154

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          MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST + O+M: $1.00 / MILLION BTU    MAKEUP WATER COST + O+M: $1.00 / K-GAL

PEAKING CAPACITY COST:   $   0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $   0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:     0.   MILLS PER KWH      BELOW 82 F:     0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


 TOWER DESIGN  GROSS    ANNUAL          REPLACEMENT  ANNUAL   ANNUAL  TOTAL   ANNUAL    ANNUAL                                   TOTAL    BUSBAR
  CONDITIONS   ANNUAL   AUXIL-            CAPACITY  REPLACE- MAKEUP ANNUAL  REPLACE-    GEO-    ANNUAL   ANNUAL   ANNUAL    ANNUAL   ENERGY
        WET     BASE     IARY    ANNUAL   REQUIRE-  MENT EN-  WATER  PLANT    MENT    THERMAL  EXCESS REPLACE- MAKEUP   CAPITAL  PRODUC-
 DRY  PEAKING   UNIT    ENERGY   EXCESS     MENT    ERGY REQD  RE-  CAPITAL CAPACITY  ENERGY   GENER-    MENT   WATER   • OPER-    TION
TOWER  TOWER   GENER- REQUIRE- GENER- ABV   BLO    ABV BLO  QUIRE- AND O+M AND O+M  AND O+M  ATION   ENERGY  AND O+M  ATING    COSTS
 ITD  RNG APPR ATION    MENT    ATION  82F   82F    82F 82F   MENT    COST    COST     COST    CREDIT   COST     COST    COSTS    MILLS
  F     F   F   MWH     MWH      MWH   MW    MW     MWH MWH  AC-FT     $       $        $        $        $        $        $      /KWH
 --   ----  --  ------  ------  ----- ----  ----   ---- ---- ------ -------  ------  -------- ------   ------  -------  --------   -----

 20   22.0  21  451409   83377      0  0.    0.       0    0    92 11504731      0  10601818      0        0    30104  22136653   60.15

 30   22.0  21  450125   86886      0  0.    0.       0    0   162  9461484      0  10601099      0        0    52664  20115246   55.38

 40   23.0  20  448533   90469      0  0.    0.       0    0   268  8441041      0  10600203      0        0    87283  19128526   53.42

 50   23.0  20  446369   93741      0  0.    0.       0    0   402  7935753      0  10598944      0        0   130998  18665696   52.93

 60   24.0  19  443032   96186      0  0.    0.       0    0   582  7495146      0  10597044      0        0   189669  18281859   52.71

 70   25.0  18  440041   97525      0  0.    0.       0    0   794  7201463      0  10595330      0        0   258828  18055621   52.71

 80   25.0  18  437891   98170      0  0.    0.       0    0  1018  6975053      0  10594117      0        0   331632  17900801   52.69

 90   25.0  18  436868   99152      0  0.    0.       0    0  1230  6798956      0  10593567      0        0   400838  17793360   52.69

100   27.0  16  436574   98251      0  0.    0.       0    0  1414  6687825      0  10593465      0        0   460727  17742017   52.44
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          MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION
                              BUSBAR COMPONENT COST BREAKDOWN - MILLS PER KWH


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST + O+M: $1.00 / MILLION BTU    MAKEUP WATER COST + O+M: $1.00 / K-GAL

PEAKING CAPACITY COST:   $   0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $   0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:    0.   MILLS PER KWH      BELOW 82 F:    0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


  TOWER DESIGN                                       ANNUAL                      ANNUAL REPLACEMENT CAPACITY          ANNUAL
   CONDITIONS             ANNUAL CAPITAL           GEOTHERMAL   ANNUAL             AND ENERGY AND O+M COSTS            MAKEUP       BUSBAR
 DRY     WET              AND O+M COSTS              ENERGY     EXCESS        CAPACITY COST          ENERGY COST        WATER        ENERGY
 ITD  RNG  APPR   CONVERSION   COOLING SYSTEM      AND O+M   GENERATION    PEAK-      NON-       ABOVE      BELOW    AND O+M    PRODUCTION
  F    F     F      PLANT        DRY      WET        COSTS      CREDIT       ING     PEAKING      82F        82F      COSTS        COSTS
 ---  ---- ----   -------     ------   -------     -------    --------    -------   -------    -------    -------   --------    ---------

  20  22.0  21    10.7262    17.5060    3.0280     28.8068     0.          0.        0.          0.         0.        .0818       60.1487

  30  22.0  21    10.8677    11.8621    3.3177     29.1850     0.          0.        0.          0.         0.        .1460       55.3776

  40  23.0  20    11.0248     9.0536    3.4957     29.6042     0.          0.        0.          0.         0.        .2438       53.4221

  50  23.0  20    11.1948     7.3777    3.9322     30.0570     0.          0.        0.          0.         0.        .3715       52.9332

  60  24.0  19    11.3814     6.2101    4.0179     30.5526     0.          0.        0.          0.         0.        .5468       52.7088

  70  25.0  18    11.5252     5.4073    4.0927     30.9338     0.          0.        0.          0.         0.        .7557       52.7147

  80  25.0  18    11.6201     4.7853    4.1263     31.1848     0.          0.        0.          0.         0.        .9762       52.6927

  90  25.0  18    11.6890     4.2923    4.1508     31.3682     0.          0.        0.          0.         0.       1.1869       52.6873

 100  27.0  16    11.6681     3.8682    4.2313     31.3117     0.          0.        0.          0.         0.       1.3618       52.4410
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MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION

ANNUAL FIXED-CHARGE RATE: 15.0 PCT   GEOTHERMAL ENERGY COST + O+M: $1.00 / MILLION BTU   MAKEUP WATER COST • O+M: $2.50 / K-GAL

PEAKING CAPACITY COST: $ 0 PER KW   NON-PEAKING REPLACEMENT CAPACITY COST: $ 0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F: 0. MILLS PER KWH   BELOW 82 F: 0. MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST): CONVERSION PLANT: 3.0   COOLING SYSTEM: 1.0   PEAKING PLANT: 0.

TOWER DESIGN CONDITIONS			GROSS ANNUAL BASE UNIT GENER-ATION	ANNUAL AUXIL-IARY ENERGY REQUIRE-MENT	ANNUAL EXCESS GENER-ATION	REPLACEMENT CAPACITY REQUIRE-MENT		ANNUAL REPLACE-MENT EN-ERGY REQD		ANNUAL MAKEUP WATER RE-QUIRE-MENT	TOTAL ANNUAL PLANT CAPITAL AND O+M COST	ANNUAL REPLACE-MENT CAPACITY AND O+M COST	ANNUAL GEO-THERMAL ENERGY AND O+M COST	ANNUAL EXCESS GENER-ATION CREDIT	ANNUAL REPLACE-MENT ENERGY COST	ANNUAL MAKEUP WATER AND O+M COST	TOTAL ANNUAL CAPITAL + OPER-ATING COSTS	BUSBAR ENERGY PRODUC-TION COSTS MILLS /KWH
DRY TOWER ITD F	WET PEAKING TOWER RNG F	APPR F	MWH	MWH	MWH	ABV 82F MW	BLO 82F MW	ABV 82F MWH	BLO 82F MWH	AC-FT	$	$	$	$	$	$	$	
20	22.0	21	451409	83377	0	0.	0.	0	0	92	11504731	0	10601818	0	0	75260	22181809	60.27
30	22.0	21	450125	86886	0	0.	0.	0	0	162	9461484	0	10601099	0	0	131659	20194242	55.60
40	23.0	20	448533	90469	0	0.	0.	0	0	268	8441041	0	10600203	0	0	218207	19259450	53.79
50	23.0	20	446369	93741	0	0.	0.	0	0	402	7935753	0	10598944	0	0	327495	18862193	53.49
60	24.0	19	443032	96186	0	0.	0.	0	0	582	7495146	0	10597044	0	0	474172	18566362	53.53
70	25.0	18	440041	97525	0	0.	0.	0	0	794	7201463	0	10595330	0	0	647070	18443862	53.85
80	25.0	18	437891	98170	0	0.	0.	0	0	1018	6975053	0	10594117	0	0	829080	18398249	54.16
90	25.0	18	436868	99152	0	0.	0.	0	0	1230	6798956	0	10593567	0	0	1002094	18394616	54.47
100	27.0	16	436574	98251	0	0.	0.	0	0	1414	6687825	0	10593465	0	0	1151818	18433108	54.48

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            MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION
                        BUSBAR COMPONENT COST BREAKDOWN - MILLS PER KWH


ANNUAL FIXED-CHARGE RATE: 15.0 PCT    GEOTHERMAL ENERGY COST + O+M: $1.00 / MILLION BTU    MAKEUP WATER COST + O+M: $2.50 / K-GAL

PEAKING CAPACITY COST:   $    0 PER KW      NON-PEAKING REPLACEMENT CAPACITY COST:   $    0 PER KW

REPLACEMENT ENERGY COST AT AND ABOVE 82 F:    0.   MILLS PER KWH      BELOW 82 F:    0.   MILLS PER KWH

FIXED ANNUAL O+M COSTS (PCT OF CAPITAL COST):   CONVERSION PLANT:  3.0     COOLING SYSTEM:  1.0     PEAKING PLANT:  0.


 TOWER DESIGN                                    ANNUAL                 ANNUAL REPLACEMENT CAPACITY          ANNUAL
  CONDITIONS              ANNUAL CAPITAL       GEOTHERMAL   ANNUAL        AND ENERGY AND O+M COSTS           MAKEUP     BUSBAR
DRY     WET               AND O+M COSTS          ENERGY     EXCESS      CAPACITY COST       ENERGY COST      WATER      ENERGY
ITD  RNG  APPR  CONVERSION    COOLING SYSTEM     AND O+M  GENERATION  PEAK-     NON-      ABOVE     BELOW    AND O+M  PRODUCTION
 F    F     F      PLANT        DRY      WET      COSTS     CREDIT     ING    PEAKING      82F       82F     COSTS      COSTS
---  ----  ----  -------     ------  -------    -------   --------  -------  -------   -------   -------  --------  ---------

 20  22.0   21   10.7262    17.5060   3.0280    28.8068    0.         0.      0.        0.        0.         .2045    60.2714

 30  22.0   21   10.8677    11.8621   3.3177    29.1850    0.         0.      0.        0.        0.         .3625    55.5950

 40  23.0   20   11.0246     9.0536   3.4957    29.6042    0.         0.      0.        0.        0.         .6094    53.7878

 50  23.0   20   11.1948     7.3777   3.9322    30.0570    0.         0.      0.        0.        0.         .9287    53.4904

 60  24.0   19   11.3814     6.2101   4.0179    30.5526    0.         0.      0.        0.        0.        1.3671    53.5291

 70  25.0   18   11.5252     5.4073   4.0927    30.9338    0.         0.      0.        0.        0.        1.8892    53.8482

 80  25.0   18   11.6201     4.7853   4.1263    31.1848    0.         0.      0.        0.        0.        2.4405    54.1570

 90  25.0   18   11.6890     4.2923   4.1508    31.3682    0.         0.      0.        0.        0.        2.9673    54.4677

100  27.0   16   11.6681     3.8682   4.2313    31.3117    0.         0.      0.        0.        0.        3.4045    54.4837
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MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION
SUMMARY OF DESIGN DATA

DRY TOWER SYSTEM									
TOWER ITD - F	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	100.00
DEGREES SUBCOOLING - F	0.	0.	0.	0.	0.	0.	0.	0.	0.
AMBIENT DRY-BULB TEMP - F	82.20	72.20	62.20	52.20	46.49	36.49	26.49	16.49	6.49
TURBINE BACK PRESS - PSIA	75.24	75.24	75.24	75.24	80.00	80.00	80.00	80.00	80.00
TOWER HEAT LOAD - MBTU/HR	1332	1332	1332	1332	1319	1319	1319	1319	1319
AIR FACE VELOCITY - FPM	500	500	500	500	500	500	500	500	500
TOWER SURFACE - SQ FT	1086425	724283	543212	434570	358607	307378	268955	239071	215164
FAN BRAKE HORSEPOWER - HP	10252	6835	5126	4101	3384	2901	2538	2256	2030
TOWER PLAN AREA - ACRES	5.12	3.41	2.56	2.05	1.69	1.45	1.27	1.13	1.01
WET PEAKING TOWER SYSTEM									
COOLING RANGE - F	21.96	21.96	22.96	22.96	22.96	22.96	23.96	24.96	24.96
APPROACH TO WET-BULB - F	21.00	21.00	20.00	20.00	20.00	20.00	19.00	18.00	18.00
CONDENSER TTD - F	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
AMBIENT WET-BULB TEMP - F	62.00	62.00	62.00	62.00	62.00	62.00	62.00	62.00	62.00
TURBINE BACK PRESS - PSIA	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
TOWER HEAT LOAD - MBTU/HR	1020	1120	1170	1319	1319	1319	1319	1319	1319
CIRCULATING WATER FLOW - GPM	92897	101974	101873	114895	114895	114895	110100	105689	105689
CONDENSER SURFACE - SQ FT	795331	873042	896043	1010583	1010583	1010583	993493	977141	977141
TOWER L/G RATIO	1.765	1.765	1.649	1.649	1.649	1.649	1.544	1.447	1.447
TOWER CHARACTERISTIC (KAV/L)	1.080	1.080	1.152	1.152	1.152	1.152	1.229	1.311	1.311
CIRC WATER PUMP BHP - HP	2199	2414	2412	2720	2720	2720	2607	2502	2502
FAN BRAKE HORSEPOWER - HP	914	1004	1090	1229	1229	1229	1285	1340	1340
SUPPLEMENTAL AUXILIARY WET COOLING TOWER SYSTEM									
AUXILIARY HEAT LOAD - MBTU/HR	17.3	17.3	17.3	17.3	17.1	17.1	17.1	17.1	17.1
CIRCULATING WATER FLOW - GPM	2309	2309	2309	2309	2286	2286	2286	2286	2286
CIRC WATER PUMP BHP - HP	55	55	55	55	54	54	54	54	54
FAN BRAKE HORSEPOWER - HP	23	23	23	23	23	23	23	23	23
GENERATING PLANT									
RATED TURBINE-GENERATOR OUTPUT AT 85.0 PSIA - MW	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0
PLANT AUXILIARY POWER - MW	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
INSTALLED PEAKING CAPACITY - MW	0.	0.	0.	0.	0.	0.	0.	0.	0.

NOTES: 1. MBTU/HR = MILLION BTU/HR
2. CONDENSER SURFACE = TOTAL HEAT TRANSFER SURFACE
3. TOWER SURFACE = BARE-TUBE SURFACE OF FINNED-TUBE HEAT EXCHANGER

MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION
CAPITAL COST BREAKDOWN

DRY TOWER ITD - F	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	100.00
WET PEAKING TOWER RANGE - F	21.96	21.96	22.96	22.96	22.96	22.96	23.96	24.96	24.96
WET PEAKING TOWER APPROACH - F	21.00	21.00	20.00	20.00	20.00	20.00	19.00	18.00	18.00
DRY TOWER SYSTEM	$	$	$	$	$	$	$	$	$
DRY TOWER (INCL FOUNDATION)	29480235	19653490	14740117	11792094	9730838	8340719	7298129	6487226	5838503
TURBINE EXHAUST TRUNK	204892	204892	204892	204892	204892	204892	204892	204892	204892
TOTAL	29685127	19858382	14945009	11996986	9935730	8545611	7503021	6692118	6043395
NITROGEN BLANKETING SYSTEM	14019	9346	7010	5608	4628	3966	3471	3085	2777
ELECTRICAL	2156148	1437432	1078074	862459	711701	610030	533776	474468	427021
TOTAL DRY TOWER SYSTEM	31855294	21305160	16030093	12865053	10652059	9159607	8040268	7169670	6473192
WET-PEAKING TOWER SYSTEM (INCLUDING SUPPLEMENTAL AUXILIARY COOLING WET CELL)									
WET TOWER	1217023	1332986	1445020	1625873	1625578	1625578	1697509	1769471	1769471
BASIN AND FOUNDATION	497454	544853	590647	664570	664450	664450	693851	723265	723265
TOTAL TOWER	1714477	1877839	2035667	2290443	2290028	2290028	2391360	2492736	2492736
CONDENSER	1390671	1526551	1564770	1767047	1767047	1767047	1737165	1708572	1708572
CIRCULATING WATER FACILITIES									
PUMPS AND MOTORS	719841	760266	759826	815463	815369	815369	795182	776306	776306
PIPING	1335173	1410154	1409338	1512535	1512361	1512361	1474918	1439906	1439906
TOTAL	2055013	2170420	2169164	2327999	2327730	2327730	2270100	2216213	2216213
ELECTRICAL	373074	408622	442966	498406	498315	498315	520365	542425	542425
TOTAL WET TOWER SYSTEM	5533236	5983433	6214566	6883894	6883120	6883120	6918990	6959946	6959946
INDIRECT COOLING SYSTEM COSTS									
ENGINEERING AND CONTINGENCIES	5608279	4093289	3336699	2962342	2630277	2406409	2243889	2119442	2014971
INTEREST DURING CONSTRUCTION	4235385	3080017	2502770	2214794	1962001	1791571	1667330	1572042	1492508
TOTAL COOLING SYSTEM CAPITAL INVESTMENT AT STARTUP	47232195	34461899	28084128	24926083	22127457	20240707	18870476	17821100	16940617
GENERATING PLANT									
GEOTHERMAL CONVERSION PLANT (INCLUDING TURBINE-GENERATOR)	21931000	21931000	21931000	21931000	21931000	21931000	21931000	21931000	21931000
INSTALLED PEAKING CAPACITY	0	0	0	0	0	0	0	0	0
TOTAL GEOTHERMAL PLANT INVESTMENT AT STARTUP	69163195	56392899	50015128	46857083	44058457	42171707	40801476	39752100	38871617

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          MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION
                                          CAPITAL COST BREAKDOWN

THE FOLLOWING RESULTS ARE THE SAME AS ON PREVIOUS PRINTOUTS EXCEPT FOR THE FOLLOWING ITD(S):  60  70  80 100

DRY TOWER ITD - F                     20.00      30.00      40.00      50.00      60.00      70.00      80.00      90.00     100.00
WET PEAKING TOWER RANGE - F           21.96      21.96      22.96      22.96      23.96      24.96      24.96      24.96      26.96
WET PEAKING TOWER APPROACH - F        21.00      21.00      20.00      20.00      19.00      18.00      18.00      18.00      16.00

DRY TOWER SYSTEM                $          $          $          $          $          $          $          $          $
----------------
DRY TOWER (INCL FOUNDATION)    29480235   19653490   14740117   11792094    9730838    8340719    7298129    6487226    5838503
TURBINE EXHAUST TRUNK            204892     204892     204892     204892     204892     204892     204892     204892     204892
  TOTAL                        29685127   19858382   14945009   11996986    9935730    8545611    7503021    6692118    6043395
NITROGEN BLANKETING SYSTEM        14019       9346       7010       5608       4628       3966       3471       3085       2777
ELECTRICAL                      2156148    1437432    1078074     862459     711701     610030     533776     474468     427021
                               --------   --------   --------   --------   --------   --------   --------   --------   --------
  TOTAL DRY TOWER SYSTEM       31855294   21305160   16030093   12865053   10652059    9159607    8040268    7169670    6473192

WET-PEAKING TOWER SYSTEM
(INCLUDING SUPPLEMENTAL
 AUXILIARY COOLING WET CELL)
----------------------------
WET TOWER                       1217023    1332986    1445020    1625873    1697509    1769471    1769471    1769471    1944359
BASIN AND FOUNDATION             497454     544853     590647     664570     693851     723265     723265     723265     794750
  TOTAL TOWER                   1714477    1877839    2035667    2290443    2391360    2492736    2492736    2492736    2739109
CONDENSER                       1390671    1526551    1566770    1767047    1737165    1708572    1708572    1708572    1654913
CIRCULATING WATER FACILITIES
  PUMPS AND MOTORS               719841     760266     759826     815463     795182     776306     776306     776306     741976
  PIPING                        1335173    1410154    1409338    1512535    1474918    1439906    1439906    1439906    1376229
    TOTAL                       2055013    2170420    2169164    2327999    2270100    2216213    2216213    2216213    2118205
ELECTRICAL                       373074     408622     442966     498406     520365     542425     542425     542425     596037
                               --------   --------   --------   --------   --------   --------   --------   --------   --------
  TOTAL WET TOWER SYSTEM        5533236    5983433    6214566    6883894    6918990    6959946    6959946    6959946    7108264

INDIRECT COOLING SYSTEM COSTS
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ENGINEERING AND CONTINGENCIES   5608279    4093289    3336699    2962342    2635657    2417933    2250032    2119442    2037218
INTEREST DURING CONSTRUCTION    4235385    3080017    2502770    2214794    1965582    1799281    1671459    1572042    1507854
                              ---------  ---------  ---------  ---------  ---------  ---------  ---------  ---------  ---------
TOTAL COOLING SYSTEM CAPITAL
INVESTMENT AT STARTUP          47232195   34461899   28084128   24926083   22172288   20336767   18921704   17821100   17126529

GENERATING PLANT
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GEOTHERMAL CONVERSION PLANT
 (INCLUDING TURBINE-GENERATOR) 21931000   21931000   21931000   21931000   21931000   21931000   21931000   21931000   21931000
INSTALLED PEAKING CAPACITY            0          0          0          0          0          0          0          0          0
                              =========  =========  =========  =========  =========  =========  =========  =========  =========

TOTAL GEOTHERMAL PLANT
INVESTMENT AT STARTUP          69163195   56392899   50015128   46857083   44103288   42267767   40852704   39752100   39057529
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MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION
DISTRIBUTION OF HEAT LOAD BETWEEN DRY AND WET-PEAKING TOWERS

DRY TOWER DESIGN ITD - F

DRY-BULB TEMP F	20			30			40			50			60			70			80			90			100		
	HEAT LOAD	PCT DRY	PCT WET	HEAT LOAD	PCT DRY	PCT WET	HEAT LOAD	PCT DRY	PCT WET	HEAT LOAD	PCT DRY	PCT WET	HEAT LOAD	PCT DRY	PCT WET	HEAT LOAD	PCT DRY	PCT WET	HEAT LOAD	PCT DRY	PCT WET	HEAT LOAD	PCT DRY	PCT WET	HEAT LOAD	PCT DRY	PCT WET
102	1319	23	77	1319	15	85	1319	11	89	1319	0	100	1319	0	100	1319	0	100	1319	0	100	1319	0	100	1319	0	100
97	1319	48	52	1319	32	68	1319	24	76	1319	19	81	1319	16	84	1319	14	86	1319	12	88	1319	11	89	1319	0	100
92	1319	73	27	1319	49	51	1319	37	63	1319	29	71	1319	24	76	1319	21	79	1319	18	82	1319	16	84	1319	14	86
87	1319	98	2	1319	66	34	1319	49	51	1319	39	61	1319	32	68	1319	28	72	1319	24	76	1319	22	78	1319	19	81
82	1332	100	0	1319	82	18	1319	62	38	1319	49	51	1319	41	59	1319	35	65	1319	31	69	1319	27	73	1319	24	76
77	1332	100	0	1318	100	0	1319	74	26	1319	60	40	1319	49	51	1319	42	58	1319	37	63	1319	33	67	1319	29	71
72	1332	100	0	1332	100	0	1319	87	13	1319	70	30	1319	57	43	1319	49	51	1319	43	57	1319	38	62	1319	34	66
67	1332	100	0	1332	100	0	1318	100	0	1319	80	20	1319	66	34	1319	56	44	1319	49	51	1319	44	56	1319	39	61
62	1332	100	0	1332	100	0	1332	100	0	1319	90	10	1319	74	26	1319	64	36	1319	56	44	1319	49	51	1319	44	56
57	1332	100	0	1332	100	0	1332	100	0	1319	100	0	1319	82	18	1319	71	29	1319	62	38	1319	55	45	1319	49	51
52	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1319	91	9	1319	78	22	1319	68	32	1319	61	39	1319	54	46
47	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1318	100	0	1319	85	15	1319	74	26	1319	66	34	1319	59	41
42	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1331	100	0	1319	92	8	1319	81	19	1319	72	28	1319	64	36
37	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1318	100	0	1319	87	13	1319	77	23	1319	69	31
32	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1331	100	0	1319	93	7	1319	83	17	1319	74	26
27	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1318	100	0	1319	88	12	1319	79	21
22	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1331	100	0	1319	94	6	1319	84	16
17	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1318	100	0	1319	89	11
12	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1330	100	0	1319	94	6
7	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1318	100	0
2	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1330	100	0
-3	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0
-8	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0	1332	100	0
ANNUAL HRS OF TOWER OPERATION																											
DRY	6500			6500			6500			6498			6498			6498			6498			6498			6472		
WET	297			544			1128			1904			3043			4376			5537			6217			6459		

NOTES: 1. HEAT LOAD IS TURBINE HEAT REJECTION IN MILLION BTU/HR AT OPERATING BACK PRESSURE OCCURRING AT GIVEN AMBIENT CONDITION
2. AT HIGH AMBIENT TEMPERATURES WHERE OPERATING BACK PRESSURE IS ALLOWED TO EXCEED THE SPECIFIED MAXIMUM, IF NECESSARY WITH A GIVEN COOLING SYSTEM DESIGN, THE HEAT LOAD AND PERCENT DISTRIBUTION MAY DIFFER SLIGHTLY FROM THE RESULTS SHOWN ABOVE

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              MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION
                                                     SUMMARY OF DESIGN DATA

THE FOLLOWING RESULTS ARE THE SAME AS ON PREVIOUS PRINTOUTS EXCEPT FOR THE FOLLOWING ITD(S):  60  70  80 100

DRY TOWER SYSTEM
----------------
TOWER ITD - F                      20.00       30.00       40.00       50.00       60.00       70.00       80.00       90.00      100.00
DEGREES SUBCOOLING - F             0.          0.          0.          0.          0.          0.          0.          0.          0.
AMBIENT DRY-BULB TEMP - F          82.20       72.20       62.20       52.20       46.49       36.49       26.49       16.49        6.49
TURBINE BACK PRESS - PSIA          75.24       75.24       75.24       75.24       80.00       80.00       80.00       80.00       80.00
TOWER HEAT LOAD - MBTU/HR           1332        1332        1332        1332        1319        1319        1319        1319        1319
AIR FACE VELOCITY - FPM              500         500         500         500         500         500         500         500         500
TOWER SURFACE - SQ FT            1086425      724283      543212      434570      358607      307378      268955      239071      215164
FAN BRAKE HORSEPOWER - HP          10252        6835        5126        4101        3384        2901        2538        2256        2030
TOWER PLAN AREA - ACRES             5.12        3.41        2.56        2.05        1.69        1.45        1.27        1.13        1.01

WET PEAKING TOWER SYSTEM
------------------------
COOLING RANGE - F                  21.96       21.96       22.96       22.96       23.96       24.96       24.96       24.96       26.96
APPROACH TO WET-BULB - F           21.00       21.00       20.00       20.00       19.00       18.00       18.00       18.00       16.00
CONDENSER TTD - F                  10.00       10.00       10.00       10.00       10.00       10.00       10.00       10.00       10.00
AMBIENT WET-BULB TEMP - F          62.00       62.00       62.00       62.00       62.00       62.00       62.00       62.00       62.00
TURBINE BACK PRESS - PSIA          90.00       90.00       90.00       90.00       90.00       90.00       90.00       90.00       90.00
TOWER HEAT LOAD - MBTU/HR           1020        1120        1170        1319        1319        1319        1319        1319        1319
CIRCULATING WATER FLOW - GPM       92897      101974      101873      114895      110100      105689      105689      105689       97849
CONDENSER SURFACE - SQ FT         795331      873042      896043     1010583      993493      977141      977141      977141      946453
TOWER L/G RATIO                    1.765       1.765       1.649       1.649       1.544       1.447       1.447       1.447       1.277
TOWER CHARACTERISTIC (KAV/L)       1.080       1.080       1.152       1.152       1.229       1.311       1.311       1.311       1.494
CIRC WATER PUMP BHP - HP            2199        2414        2412        2720        2607        2502        2502        2502        2316
FAN BRAKE HORSEPOWER - HP            914        1004        1090        1229        1285        1340        1340        1340        1475

SUPPLEMENTAL AUXILIARY
WET COOLING TOWER SYSTEM
------------------------
AUXILIARY HEAT LOAD - MBTU/HR       17.3        17.3        17.3        17.3        17.1        17.1        17.1        17.1        17.1
CIRCULATING WATER FLOW - GPM        2309        2309        2309        2309        2286        2286        2286        2286        2286
CIRC WATER PUMP BHP - HP              55          55          55          55          54          54          54          54          54
FAN BRAKE HORSEPOWER - HP             23          23          23          23          23          23          23          23          23

GENERATING PLANT
----------------
RATED TURBINE-GENERATOR
  OUTPUT AT 85.0 PSIA    - MW       65.0        65.0        65.0        65.0        65.0        65.0        65.0        65.0        65.0
PLANT AUXILIARY POWER - MW          11.6        11.6        11.6        11.6        11.6        11.6        11.6        11.6        11.6
INSTALLED PEAKING
  CAPACITY - MW                     0.          0.          0.          0.          0.          0.          0.          0.          0.

---------------------------------------------------------------------------
  NOTES: 1. MBTU/HR = MILLION BTU/HR
         2. CONDENSER SURFACE = TOTAL HEAT TRANSFER SURFACE
         3. TOWER SURFACE = BARE-TUBE SURFACE OF FINNED-TUBE HEAT EXCHANGER
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MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION
ANNUAL TURBINE OPERATING PROFILE

OPERATING BACK PRESSURE (OBP) - PSIA
VS.
HOURS PRESSURE IS EQUALLED OR EXCEEDED

DRY TOWER ITD F	WET-PEAKING TOWER RANGE F	WET-PEAKING TOWER APPR F	OBP	HRS	OBP	HRS	OBP	HRS	OBP	HRS	OBP	HRS	OBP	HRS	OBP	HRS	OBP	HRS
20	21.96	21.0	92.1	2	80.0	297	75.2	6501										
30	21.96	21.0	92.2	2	81.7	28	80.3	301	80.0	817	75.2	6501						
40	22.96	20.0	92.4	2	84.2	28	80.2	381	80.0	1481	75.2	6501						
50	22.96	20.0	92.5	2	82.0	28	80.1	541	80.0	2417	75.2	6501						
60	22.96	20.0	92.5	2	83.6	28	80.5	702	80.0	3717	75.6	4376	75.2	6501				
60	23.96	19.0	92.5	2	83.5	28	80.5	702	80.0	3717	75.6	4376	75.2	6501				
70	22.96	20.0	92.5	2	84.5	28	80.4	643	80.0	4991	75.7	5537	75.2	6501				
70	24.96	18.0	92.7	2	84.5	28	80.4	643	80.0	4991	75.7	5537	75.2	6501				
80	23.96	19.0	92.5	2	85.3	28	80.9	32	80.9	122	80.4	513	80.0	5929	75.8	6217	75.2	6501
80	24.96	18.0	92.7	2	85.2	28	80.9	32	80.8	122	80.4	513	80.0	5929	75.8	6217	75.2	6501
90	24.96	18.0	92.7	2	86.0	28	82.1	32	81.7	122	80.4	289	80.0	6384	76.0	6459	75.2	6501
100	24.96	18.0	92.7	2	90.8	28	83.1	32	82.4	122	80.5	148	80.0	6486	76.0	6497	75.2	6501
100	26.96	16.0	92.8	2	91.0	28	83.0	32	82.3	122	80.5	148	80.0	6486	76.0	6497	75.2	6501

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                    MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION
                                                 ANNUAL PLANT GENERATING PROFILE

DRY TWR ITD-F       20.0         30.0         40.0         50.0         60.0         70.0         80.0         90.0        100.0
WET TWR RNG-F       22.0         22.0         23.0         23.0         23.0         23.0         24.0         25.0         25.0
WET TWR APP-F       21.0         21.0         20.0         20.0         20.0         20.0         19.0         18.0         18.0
----_--------- ----------- ----------- ----------- ----------- ----------- ----------- ----------- ----------- -----------
AMB  HRS TEMP  GROSS  NET  GROSS  NET  GROSS  NET  GROSS  NET  GROSS  NET  GROSS  NET  GROSS  NET  GROSS  NET  GROSS  NET
DRY- EQUALLED   T-G  PLANT  T-G  PLANT  T-G  PLANT  T-G  PLANT  T-G  PLANT  T-G  PLANT  T-G  PLANT  T-G  PLANT  T-G  PLANT
BULB    OR     OUT-  OUT-  OUT-  OUT-  OUT-  OUT-  OUT-  OUT-  OUT-  OUT-  OUT-  OUT-  OUT-  OUT-  OUT-  OUT-  OUT-  OUT-
TEMP EXCEEDED  PUT   PUT   PUT   PUT   PUT   PUT   PUT   PUT   PUT   PUT   PUT   PUT   PUT   PUT   PUT   PUT   PUT   PUT
 F      HRS    MWE   MWE   MWE   MWE   MWE   MWE   MWE   MWE   MWE   MWE   MWF   MWE   MWE   MWE   MWE   MWF   MWE   MWE
---- -------- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- ----- -----
102       2   60.41 37.67 60.37 40.21 60.29 41.47 60.21 45.27 60.21 45.27 60.21 45.27 60.21 45.32 60.12 45.27 60.12 45.27
 97      28   67.20 44.87 66.26 46.10 64.87 46.05 66.10 47.77 65.20 47.46 64.66 47.32 64.24 47.24 63.85 47.13 61.12 46.27
 92     117   67.20 45.20 67.20 47.71 67.20 48.84 67.20 49.41 67.20 49.75 67.20 49.90 66.74 49.75 66.26 49.55 65.86 49.33
 87     297   67.20 46.90 67.20 47.85 67.20 49.18 67.20 49.72 67.20 50.18 67.20 50.45 67.19 50.69 67.17 50.84 67.16 50.89
 82     544   69.55 49.76 67.20 48.86 67.20 49.26 67.20 49.82 67.20 50.35 67.20 50.67 67.20 50.98 67.20 51.21 67.20 51.30
 77     817   69.55 54.64 67.06 49.73 67.20 49.28 67.20 49.86 67.20 50.42 67.20 50.78 67.20 51.12 67.20 51.38 67.20 51.51
 72    1128   69.55 56.26 69.55 52.39 67.20 50.28 67.20 49.88 67.20 50.45 67.20 50.83 67.20 51.19 67.20 51.47 67.20 51.61
 67    1481   69.55 56.95 69.55 55.01 67.10 51.19 67.20 51.00 67.20 50.47 67.20 50.85 67.20 51.23 67.20 51.52 67.20 51.68
 62    1904   69.55 57.30 69.55 56.18 69.55 53.73 67.20 51.30 67.20 50.79 67.20 50.87 67.20 51.25 67.20 51.55 67.20 51.72
 57    2417   69.55 57.49 69.55 56.79 69.55 55.37 67.14 52.08 67.20 51.60 67.20 50.87 67.20 51.26 67.20 51.57 67.20 51.74
 52    3043   69.55 57.61 69.55 57.14 69.55 56.24 69.55 54.55 67.20 52.06 67.20 51.99 67.20 51.27 67.20 51.58 67.20 51.76
 47    3717   69.55 57.68 69.55 57.35 69.55 56.75 69.55 55.66 66.95 52.48 67.20 52.00 67.20 52.34 67.20 51.59 67.20 51.77
 42    4376   69.55 57.73 69.55 57.49 69.55 57.06 69.55 56.33 69.37 54.90 67.20 52.60 67.20 52.35 67.20 51.59 67.20 51.77
 37    4991   69.55 57.77 69.55 57.58 69.55 57.27 69.55 56.75 69.55 55.84 66.96 52.89 67.20 52.55 67.20 52.62 67.20 51.78
 32    5537   69.55 57.79 69.55 57.65 69.55 57.41 69.55 57.03 69.55 56.39 69.33 55.26 67.20 52.98 67.20 52.63 67.20 52.80
 27    5929   69.55 57.81 69.55 57.70 69.55 57.52 69.55 57.23 69.55 56.75 69.55 56.05 66.97 53.21 67.20 52.90 67.20 52.81
 22    6217   69.55 57.82 69.55 57.73 69.55 57.59 69.55 57.36 69.55 57.00 69.55 56.48 69.28 55.51 67.20 53.32 67.20 52.81
 17    6384   69.55 57.83 69.55 57.76 69.55 57.64 69.55 57.47 69.55 57.19 69.55 56.79 69.55 56.22 66.99 53.46 67.20 53.24
 12    6459   69.55 57.84 69.55 57.78 69.55 57.69 69.55 57.54 69.55 57.32 69.55 57.01 69.55 56.57 69.23 55.69 67.20 53.54
  7    6486   69.55 57.85 69.55 57.80 69.55 57.72 69.55 57.60 69.55 57.42 69.55 57.18 69.55 56.84 69.55 56.36 66.94 53.60
  2    6497   69.55 57.85 69.55 57.81 69.55 57.74 69.55 57.65 69.55 57.50 69.55 57.30 69.55 57.03 69.55 56.66 69.19 55.84
 -3    6500   69.55 57.86 69.55 57.82 69.55 57.77 69.55 57.68 69.55 57.56 69.55 57.40 69.55 57.18 69.55 56.88 69.55 56.48
 -8    6501   69.55 57.86 69.55 57.83 69.55 57.78 69.55 57.71 69.55 57.61 69.55 57.48 69.55 57.30 69.55 57.05 69.55 56.73
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            MECHANICAL DRAFT DRY/WET-PEAKING COOLING TOWER SYSTEM ECONOMIC OPTIMIZATION AND EVALUATION
                                             ANNUAL PLANT GENERATING PROFILE

THE FOLLOWING RESULTS ARE THE SAME AS ON PREVIOUS PRINTOUTS EXCEPT FOR THE FOLLOWING ITD(S):  60  70  80 100

DRY TWR ITD-F      20.0         30.0         40.0         50.0         60.0         70.0         80.0         90.0        100.0
WET TWR RNG-F      22.0         22.0         23.0         23.0         24.0         25.0         25.0         25.0         27.0
WET TWR APP-F      21.0         21.0         20.0         20.0         19.0         18.0         18.0         18.0         16.0
-------------  -----------  -----------  -----------  -----------  -----------  -----------  -----------  -----------  -----------
AMB  HRS TEMP  GROSS  NET   GROSS  NET   GROSS  NET   GROSS  NET   GROSS  NET   GROSS  NET   GROSS  NET   GROSS  NET   GROSS  NET
DRY- EQUALLED   T-G  PLANT   T-G  PLANT   T-G  PLANT   T-G  PLANT   T-G  PLANT   T-G  PLANT   T-G  PLANT   T-G  PLANT   T-G  PLANT
BULB    OR      OUT-  OUT-   OUT-  OUT-   OUT-  OUT-   OUT-  OUT-   OUT-  OUT-   OUT-  OUT-   OUT-  OUT-   OUT-  OUT-   OUT-  OUT-
TEMP EXCEEDED   PUT   PUT    PUT   PUT    PUT   PUT    PUT   PUT    PUT   PUT    PUT   PUT    PUT   PUT    PUT   PUT    PUT   PUT
 F      HRS     MWE   MWE    MWE   MWE    MWE   MWE    MWE   MWE    MWE   MWE    MWE   MWE    MWE   MWE    MWE   MWF    MWE   MWE
---- --------  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----
102        2   60.41 37.67  60.37 40.21  60.29 41.47  60.21 45.27  60.21 45.32  60.12 45.27  60.12 45.27  60.12 45.27  60.04 45.23
 97       28   67.20 44.87  66.26 46.10  64.87 46.05  66.10 47.77  65.25 47.55  64.70 47.45  64.28 47.33  63.85 47.13  61.03 46.23
 92      117   67.20 45.20  67.20 47.71  67.20 48.84  67.20 49.41  67.20 49.84  67.20 50.02  66.78 49.82  66.26 49.55  65.94 49.45
 87      297   67.20 46.90  67.20 47.85  67.20 49.18  67.20 49.72  67.20 50.28  67.20 50.63  67.19 50.78  67.17 50.84  67.16 51.00
 82      544   69.55 49.76  67.20 48.86  67.20 49.26  67.20 49.82  67.20 50.44  67.20 50.86  67.20 51.07  67.20 51.21  67.20 51.44
 77      817   69.55 54.64  67.06 49.73  67.20 49.28  67.20 49.86  67.20 50.52  67.20 50.96  67.20 51.21  67.20 51.38  67.20 51.66
 72     1128   69.55 56.26  69.55 52.39  67.20 50.28  67.20 49.88  67.20 50.55  67.20 51.01  67.20 51.28  67.20 51.47  67.20 51.77
 67     1481   69.55 56.95  69.55 55.01  67.10 51.19  67.20 51.00  67.20 50.56  67.20 51.03  67.20 51.31  67.20 51.52  67.20 51.83
 62     1904   69.55 57.30  69.55 56.18  69.55 53.73  67.20 51.30  67.20 50.87  67.20 51.05  67.20 51.33  67.20 51.55  67.20 51.87
 57     2417   69.55 57.49  69.55 56.79  69.55 55.37  67.14 52.08  67.20 51.65  67.20 51.05  67.20 51.35  67.20 51.57  67.20 51.90
 52     3043   69.55 57.61  69.55 57.14  69.55 56.24  69.55 54.55  67.20 52.09  67.20 52.08  67.20 51.35  67.20 51.58  67.20 51.91
 47     3717   69.55 57.68  69.55 57.35  69.55 56.75  69.55 55.66  66.95 52.48  67.20 52.09  67.20 52.38  67.20 51.59  67.20 51.92
 42     4376   69.55 57.73  69.55 57.49  69.55 57.06  69.55 56.33  69.37 54.90  67.20 52.64  67.20 52.39  67.20 51.59  67.20 51.93
 37     4991   69.55 57.77  69.55 57.58  69.55 57.27  69.55 56.75  69.55 55.84  66.96 52.89  67.20 52.59  67.20 52.62  67.20 51.93
 32     5537   69.55 57.79  69.55 57.65  69.55 57.41  69.55 57.03  69.55 56.39  69.33 55.26  67.20 53.02  67.20 52.63  67.20 52.88
 27     5929   69.55 57.81  69.55 57.70  69.55 57.52  69.55 57.23  69.55 56.75  69.55 56.05  66.97 53.21  67.20 52.90  67.20 52.89
 22     6217   69.55 57.82  69.55 57.73  69.55 57.59  69.55 57.36  69.55 57.00  69.55 56.48  69.28 55.51  67.20 53.32  67.20 52.89
 17     6384   69.55 57.83  69.55 57.76  69.55 57.64  69.55 57.47  69.55 57.19  69.55 56.79  69.55 56.22  66.99 53.46  67.20 53.28
 12     6459   69.55 57.84  69.55 57.78  69.55 57.69  69.55 57.54  69.55 57.32  69.55 57.01  69.55 56.57  69.23 55.69  67.20 53.56
  7     6486   69.55 57.85  69.55 57.80  69.55 57.72  69.55 57.60  69.55 57.42  69.55 57.18  69.55 56.84  69.55 56.36  66.94 53.60
  2     6497   69.55 57.85  69.55 57.81  69.55 57.74  69.55 57.65  69.55 57.50  69.55 57.30  69.55 57.03  69.55 56.66  69.19 55.84
 -3     6500   69.55 57.86  69.55 57.82  69.55 57.77  69.55 57.68  69.55 57.56  69.55 57.40  69.55 57.18  69.55 56.88  69.55 56.48
 -8     6501   69.55 57.86  69.55 57.83  69.55 57.78  69.55 57.71  69.55 57.61  69.55 57.48  69.55 57.30  69.55 57.05  69.55 56.73
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APPENDIX F

SUMMARY OF ANALYSIS OF EVAPORATIVE COOLING SYSTEMS

SUMMARY OF ANALYSIS OF EVAPORATIVE COOLING SYSTEMS FOR BASIN & RANGE CLIMATE - 150 C (300 F) RESOURCE
15% FCR

Geothermal Conversion Process	Geothermal "Fuel" Cost ¢/10^6 Btu	Makeup Water Cost ¢/Kgal	Optimum Cooling Tower Range/ Approach, °F	Conversion Plant Capital + OM mills/kWh	Cooling System Capital + OM mills/kWh	Geothermal "Fuel" + OM mills/kWh	Makeup Water + OM mills/kWh	Total Busbar Energy Cost mills/kWh	Annual Makeup acre-feet
Flash	50	10	31.6/20	16.4	3.5	24.6	0.3	44.8	3154
		100	31.6/20	16.4	3.5	24.6	3.2	47.7	3154
		250	31.6/20	16.4	3.5	24.6	8.0	52.5	3154
	100	10	31.6/20	16.4	3.5	49.2	0.3	69.4	3154
		100	31.6/20	16.4	3.5	49.2	3.2	72.3	3154
		250	31.6/20	16.4	3.5	49.2	8.0	77.1	3154
Binary	50	10	21.5/13	13.4	5.4	34.9	0.3	54.0	2976
		100	21.5/13	13.4	5.4	34.9	2.9	56.6	2976
		250	21.5/13	13.4	5.4	34.9	7.4	61.1	2976
	100	10	22.5/12	13.4	5.5	69.6	0.3	88.8	2978
		100	22.5/12	13.4	5.5	69.6	3.0	91.5	2978
		250	22.5/12	13.4	5.5	69.6	7.4	95.9	2978

SUMMARY OF ANALYSIS OF EVAPORATIVE COOLING SYSTEMS
FOR BASIN & RANGE CLIMATE - 182 C (360 F) RESOURCE
15% FCR

Geothermal Conversion Process	Geothermal "Fuel" Cost ¢/10^6 Btu	Makeup Water Cost ¢/Kgal	Optimum Cooling Tower Range/ Approach, °F	Conversion Plant Capital + OM mills/kWh	Cooling System Capital + OM mills/kWh	Geothermal "Fuel" + OM mills/kWh	Makeup Water + OM mills/kWh	Total Busbar Energy Cost mills/kWh	Annual Makeup acre-feet
Flash	50	10	26.1/20	13.9	2.9	16.4	0.3	33.5	2502
		100	28.1/18	13.9	3.0	16.4	2.3	35.6	2495
		250	28.1/18	13.9	3.0	16.4	5.8	39.1	2495
	100	10	28.1/18	13.9	3.0	32.8	0.2	49.9	2495
		100	28.1/18	13.9	3.0	32.8	2.3	52.0	2495
		250	28.1/18	13.9	3.0	32.8	5.8	55.5	2495
Binary	50	10	22.8/16	11.3	4.4	15.2	0.3	31.2	2931
		100	22.8/16	11.3	4.4	15.2	2.8	33.7	2931
		250	23.8/15	11.3	4.4	15.2	6.9	37.8	2930
	100	10	24.8/14	11.3	4.5	30.3	0.3	46.4	2931
		100	24.8/14	11.3	4.5	30.4	2.7	48.9	2931
		250	24.8/14	11.3	4.5	30.4	6.8	53.0	2931

SUMMARY OF ANALYSIS OF EVAPORATIVE COOLING SYSTEMS FOR BASIN & RANGE CLIMATE - 246 C (475 F) RESOURCE

15% FCR

Geothermal Conversion Process	Geothermal "Fuel" Cost ¢/10^6Btu	Makeup Water Cost ¢/Kgal	Optimum Cooling Tower Range/ Approach, °F	Conversion Plant Capital + OM mills/kWh	Cooling System Capital + OM mills/kWh	Geothermal "Fuel" + OM mills/kWh	Makeup Water + OM mills/kWh	Total Busbar Energy Cost mills/kWh	Annual Makeup acre-feet
Flash	50	10	26.1/20	12.2	2.3	11.5	0.2	26.2	1948
		100	28.1/18	12.2	2.3	11.5	1.8	27.8	1941
		250	28.1/18	12.2	2.3	11.5	4.5	30.5	1941
	100	10	28.1/18	12.1	2.3	23.1	0.2	37.7	1941
		100	28.1/18	12.1	2.3	23.1	1.8	39.3	1941
		250	28.1/18	12.1	2.3	23.1	4.5	42.0	1941
Binary	50	10	22.8/16	9.6	4.3	14.8	0.3	29.0	2931
		100	22.8/16	9.6	4.3	14.8	2.7	31.4	2931
		250	22.8/16	9.6	4.3	14.8	6.8	35.5	2931
	100	10	23.8/15	9.6	4.4	29.4	0.3	43.7	2930
		100	23.8/15	9.6	4.4	29.4	2.7	46.1	2930
		250	24.8/14	9.6	4.5	29.4	6.7	50.2	2931

SUMMARY OF ANALYSIS OF EVAPORATIVE COOLING SYSTEMS
FOR HIGH MOUNTAIN CLIMATE - 150 C (300 F) RESOURCE
15% FCR

Geothermal Conversion Process	Geothermal "Fuel" Cost ¢/10⁶ Btu	Makeup Water Cost ¢/Kgal	Optimum Cooling Tower Range/ Approach, °F	Conversion Plant Capital + OM mills/kWh	Cooling System Capital + OM mills/kWh	Geothermal "Fuel" + OM mills/kWh	Makeup Water + OM mills/kWh	Total Busbar Energy Cost mills/kWh	Annual Makeup acre-feet
Flash	50	10	31.6/21	16.5	3.4	24.6	0.3	44.8	3244
		100	31.6/21	16.5	3.4	24.5	3.3	47.7	3244
		250	31.6/21	16.5	3.4	24.6	8.2	52.7	3244
	100	10	31.6/21	16.5	3.4	49.1	.3	69.3	3244
		100	31.6/21	16.5	3.4	49.1	3.3	72.3	3244
		250	31.6/21	16.5	3.4	49.1	8.2	77.2	3244
Binary	50	10	21.5/14	13.4	5.2	34.8	0.3	53.7	3037
		100	22.5/13	13.4	5.3	34.7	3.0	56.4	3037
		250	22.5/13	13.4	5.3	34.7	7.5	60.9	3037
	100	10	23.5/12	13.3	5.4	69.4	0.3	88.4	3038
		100	23.5/12	13.3	5.4	69.4	3.0	91.1	3038
		250	23.5/12	13.3	5.4	69.4	7.5	95.6	3038

SUMMARY OF ANALYSIS OF EVAPORATIVE COOLING SYSTEMS
FOR HIGH MOUNTAIN CLIMATE - 182 C (360 F) RESOURCE
15% FCR

Geothermal Conversion Process	Geothermal "Fuel" Cost ¢/10^6 Btu	Makeup Water Cost ¢/Kgal	Optimum Cooling Tower Range/ Approach, °F	Conversion Plant Capital + OM mills/kWh	Cooling System Capital + OM mills/kWh	Geothermal "Fuel" + OM mills/kWh	Makeup Water + OM mills/kWh.	Total Busbar Energy Cost mills/kWh	Annual Makeup acre-feet
Flash	50	10	27.1/20	13.9	2.9	16.4	0.2	33.4	2569
		100	27.1/20	13.9	2.9	16.4	2.4	35.6	2569
		250	29.1/18	13.9	2.9	16.4	6.0	39.2	2561
	100	10	29.1/18	13.9	3.0	32.7	0.2	49.8	2561
		100	29.1/18	13.9	2.9	32.7	2.4	51.9	2561
		250	29.1/18	13.9	2.9	32.7	6.0	55.5	2561
Binary	50	10	23.8/16	11.3	4.3	15.2	0.3	31.1	3003
		100	23.8/16	11.3	4.3	15.2	2.8	33.6	3003
		250	23.8/16	11.3	4.3	15.2	7.0	37.8	3003
	100	10	24.8/15	11.3	4.3	30.3	0.3	46.2	3003
		100	24.8/15	11.3	4.3	30.3	2.8	48.8	3003
		250	25.8/14	11.2	4.5	30.2	7.0	52.9	3004

SUMMARY OF ANALYSIS OF EVAPORATIVE COOLING SYSTEMS FOR HIGH MOUNTAIN CLIMATE - 246 C (475 F) RESOURCE

15% FCR

Geothermal Conversion Process	Geothermal "Fuel" Cost ¢/10⁶ Btu	Makeup Water Cost ¢/Kgal	Optimum Cooling Tower Range/ Approach, °F	Conversion Plant Capital + OM mills/kWh	Cooling System Capital + OM mills/kWh	Geothermal "Fuel" + OM mills/kWh	Makeup Water + OM mills/kWh	Total Busbar Energy Cost mills/kWh	Annual Makeup acre-feet
Flash	50	10	27.1/20	12.2	2.3	11.5	0.2	26.2	1999
		100	27.1/20	12.2	2.3	11.5	1.8	27.8	1999
		250	29.1/18	12.2	2.3	11.5	4.6	30.6	1993
	100	10	29.1/18	12.2	2.3	23.0	0.2	37.7	1993
		100	29.1/18	12.2	2.3	23.0	1.8	39.3	1993
		250	29.1/18	12.2	2.3	23.0	4.6	42.1	1993
Binary	50	10	23.8/16	9.6	4.3	14.7	0.3	28.9	3003
		100	23.8/16	9.6	4.3	14.7	2.7	31.3	3003
		250	23.8/16	9.6	4.3	14.7	6.9	35.5	3003
	100	10	23.8/16	9.6	4.3	29.4	0.3	43.6	3003
		100	23.8/16	9.6	4.3	29.4	2.7	46.0	3003
		250	24.8/15	9.6	4.3	29.4	6.9	50.2	3003

SUMMARY OF ANALYSIS OF EVAPORATIVE COOLING SYSTEMS
FOR HOT DESERT CLIMATE - 150 C (300 F) RESOURCE
15% FCR

Geothermal Conversion Process	Geothermal "Fuel" Cost ¢/10^6Btu	Makeup Water Cost ¢/Kgal	Optimum Cooling Tower Range/ Approach, °F	Conversion Plant Capital + OM mills/kWh	Cooling System Capital + OM mills/kWh	Geothermal "Fuel" + OM mills/kWh	Makeup Water + OM mills/kWh	Total Busbar Energy Cost mills/kWh	Annual Makeup acre-feet
Flash	50	10	26.4/12	16.7	3.8	24.9	0.4	45.8	3447
		100	26.4/12	16.7	3.8	24.9	3.6	49.0	3447
		250	26.4/12	16.7	3.9	24.9	8.9	54.4	3447
	100	10	26.4/12	16.7	3.8	49.9	0.4	70.8	3447
		100	26.4/12	16.7	3.8	49.9	3.6	74.0	3447
		250	26.4/12	16.7	3.8	49.9	8.9	79.3	3447
Binary	50	10	12.8/8	14.0	6.7	36.5	0.3	57.5	3397
		100	12.8/8	14.0	6.7	36.4	3.5	60.6	3397
		250	12.8/8	14.0	6.7	36.4	8.8	65.9	3397
	100	10	12.8/8	14.0	6.7	72.9	0.3	93.9	3397
		100	12.8/8	14.0	6.7	72.9	3.5	97.1	3397
		250	12.8/8	13.9	6.7	72.9	8.8	102.3	3397

SUMMARY OF ANALYSIS OF EVAPORATIVE COOLING SYSTEMS FOR HOT DESERT CLIMATE - 182 C (360 F) RESOURCE

15% FCR

Geothermal Conversion Process	Geothermal "Fuel" Cost ¢/10^6 Btu	Makeup Water Cost ¢/Kgal	Optimum Cooling Tower Range/ Approach, °F	Conversion Plant Capital + OM mills/kWh	Cooling System Capital + OM mills/kWh	Geothermal "Fuel" + OM mills/kWh	Makeup Water + OM mills/kWh	Total Busbar Energy Cost mills/kWh	Annual Makeup acre-feet
Flash	50	10	21.6/12	14.1	3.3	16.6	0.3	34.3	2773
		100	21.6/12	14.1	3.3	16.7	2.6	36.7	2773
		250	21.6/12	14.1	3.3	16.6	6.6	40.6	2773
	100	10	21.6/12	14.1	3.3	33.3	0.3	51.0	2773
		100	22.6/11	14.1	3.3	33.3	2.6	53.3	2775
		250	22.6/11	14.1	3.3	33.3	6.6	57.3	2775
Binary	50	10	17.0/8	11.6	5.5	15.6	0.3	33.0	3355
		100	17.0/8	11.6	5.5	15.6	3.2	35.9	3355
		250	17.0/8	11.6	5.5	15.6	8.0	40.7	3355
	100	10	17.0/8	11.6	5.5	31.2	0.3	48.6	3355
		100	17.0/8	11.6	5.5	31.2	3.2	51.5	3355
		250	17.0/8	11.6	5.5	31.2	8.1	56.4	3355

SUMMARY OF ANALYSIS OF EVAPORATIVE COOLING SYSTEMS
FOR HOT DESERT CLIMATE - 246 C (475 F) RESOURCE
15% FCR

Geothermal Conversion Process	Geothermal "Fuel" Cost ¢/10^6 Btu 10^6	Makeup Water Cost ¢/Kgal	Optimum Cooling Tower Range/ Approach, °F	Conversion Plant Capital + OM mills/kWh	Cooling System Capital + OM mills/kWh	Geothermal "Fuel" + OM mills/kWh	Makeup Water + OM mills/kWh	Total Busbar Energy Cost mills/kWh	Annual Makeup acre-feet
Flash	50	10	26.4/12	12.4	2.3	11.8	0.2	26.7	2135
		100	26.4/12	12.4	2.3	11.8	2.0	28.5	2135
		250	26.4/12	12.4	2.3	11.8	5.0	31.5	2135
	100	10	26.4/12	12.4	2.3	23.6	0.2	38.5	2135
		100	26.4/12	12.4	2.3	23.6	2.0	40.3	2135
		250	26.4/12	12.4	2.3	23.6	5.0	43.3	2135
Binary	50	10	17.0/8	9.9	5.4	15.1	0.3	30.7	3355
		100	17.0/8	9.9	5.3	15.1	3.2	33.5	3355
		250	17.0/8	9.9	5.4	15.1	7.9	38.3	3355
	100	10	17.0/8	9.9	5.3	30.2	0.3	45.7	3355
		100	17.0/8	9.9	5.3	30.2	3.2	48.6	3355
		250	17.0/8	9.9	5.3	30.2	7.9	53.3	3355

SUMMARY OF ANALYSIS OF EVAPORATIVE COOLING SYSTEMS
FOR PACIFIC NORTHWEST CLIMATE - 150 C (300 F) RESOURCE
15% FCR

Geothermal Conversion Process	Geothermal "Fuel" Cost ¢/10^6 Btu	Makeup Water Cost ¢/Kgal	Optimum Cooling Tower Range/ Approach, °F	Conversion Plant Capital + OM mills/kWh	Cooling System Capital + OM mills/kWh	Geothermal "Fuel" + OM mills/kWh	Makeup Water + OM mills/kWh	Total Busbar Energy Cost mills/kWh	Annual Makeup acre-feet
Flash	50	10	27.6/18	16.6	3.6	24.7	0.3	45.2	3094
		100	27.6/18	16.5	3.6	24.7	3.2	48.0	3094
		250	29.6/16	16.5	3.7	24.6	7.9	52.7	3083
	100	10	28.6/17	16.5	3.7	49.3	0.3	69.8	3088
		100	29.6/16	16.5	3.7	49.3	3.1	72.6	3083
		250	29.6/16	16.5	3.7	49.3	7.9	77.4	3083
Binary	50	10	16.5/12	13.6	5.8	35.2	0.3	54.9	2911
		100	16.5/12	13.6	5.8	35.3	2.9	57.6	2911
		250	16.5/12	13.6	5.8	35.3	7.3	62.0	2911
	100	10	16.5/12	13.6	5.8	70.5	0.3	90.2	2911
		100	16.5/12	13.6	5.8	70.5	2.9	92.8	2911
		250	16.5/12	13.6	5.8	70.5	7.3	97.2	2911

SUMMARY OF ANALYSIS OF EVAPORATIVE COOLING SYSTEMS FOR PACIFIC NORTHWEST CLIMATE - 182 C (360 F) RESOURCE

15% FCR

Geothermal Conversion Process	Geothermal "Fuel" Cost ¢/10^{6}Btu	Makeup Water Cost ¢/Kgal	Optimum Cooling Tower Range/ Approach, °F	Conversion Plant Capital + OM mills/kWh	Cooling System Capital + OM mills/kWh	Geothermal "Fuel" + OM mills/kWh	Makeup Water + OM mills/kWh	Total Busbar Energy Cost mills/kWh	Annual Makeup acre-feet
Flash	50	10	29.6/16	14.1	2.9	16.5	0.2	33.7	2455
		100	29.6/16	14.1	2.9	16.5	2.3	35.8	2455
		250	29.6/16	14.1	2.9	16.5	5.8	39.3	2455
	100	10	29.6/16	14.1	2.8	33.1	0.2	50.2	2455
		100	29.6/16	14.1	2.8	33.1	2.3	52.3	2455
		250	31.6/14	14.1	2.9	33.0	5.8	55.8	2447
Binary	50	10	20.8/12	11.3	4.8	15.2	0.3	31.6	2871
		100	20.8/12	11.3	4.9	15.2	2.7	34.1	2871
		250	20.8/12	11.3	4.9	15.2	6.7	38.1	2871
	100	10	20.8/12	11.3	4.9	30.4	0.3	46.9	2871
		100	20.8/12	11.3	4.9	30.4	2.7	49.3	2871
		250	20.8/12	11.3	4.9	30.4	6.7	53.3	2871

SUMMARY OF ANALYSIS OF EVAPORATIVE COOLING SYSTEMS
FOR PACIFIC NORTHWEST CLIMATE - 246 C (475 F) RESOURCE
15% FCR

Geothermal Conversion Process	Geothermal "Fuel" Cost ¢/10^6 Btu	Makeup Water Cost ¢/Kgal	Optimum Cooling Tower Range/ Approach, °F	Conversion Plant Capital + OM mills/kWh	Cooling System Capital + OM mills/kWh	Geothermal "Fuel" + OM mills/kWh	Makeup Water + OM mills/kWh	Total Busbar Energy Cost mills/kWh	Annual Makeup acre-feet
Flash	50	10	27.6/18	12.3	2.2	11.6	0.2	26.3	1915
		100	29.6/16	12.3	2.2	11.6	1.8	27.9	1909
		250	29.6/16	12.3	2.3	11.6	4.4	30.6	1909
	100	10	29.6/16	12.3	2.2	23.3	0.2	38.0	1909
		100	29.6/16	12.3	2.2	23.3	1.8	39.6	1909
		250	30.6/15	12.2	2.3	23.3	4.4	42.2	1905
Binary	50	10	19.8/13	9.6	4.7	14.8	0.3	29.4	2873
		100	19.8/13	9.6	4.7	14.8	2.7	31.8	2873
		250	20.8/12	9.6	4.8	14.8	6.6	35.8	2871
	100	10	20.8/12	9.6	4.8	29.5	0.3	44.2	2871
		100	20.8/12	9.6	4.8	29.5	2.7	46.6	2871
		250	20.8/12	9.6	4.8	29.5	6.6	50.5	2871

APPENDIX G

BUSBAR ENERGY PRODUCTION COST MULTIPLIERS FOR BINARY AND FLASH STEAM SYSTEMS WITH DRY/WET PEAKING COOLING TOWERS

Busbar Energy Production Cost Multipliers for Binary Systems with Dry/Wet Peaking Cooling Towers for Basin and Range Site

$\$.50/10^6$ Btu

	300° F			360° F			475° F		
% Water	\$.10	\$1.00	\$2.50	\$.10	\$1.00	\$2.50	\$.10	\$1.00	\$2.50
3.75	2.20	2.20	2.21	1.48	1.48	1.49	1.40	1.41	1.41
6.65	2.04	2.05	2.06	1.32	1.32	1.33	1.24	1.25	1.26
10.68	1.97	1.98	1.98	1.24	1.25	1.26	1.17	1.18	1.19
15.69	1.95	1.96	1.98	1.20	1.22	1.24	1.13	1.14	1.16
22.21	1.93	1.95	1.99	1.18	1.20	1.23	1.11	1.12	1.15
29.65	1.93	1.96	1.10	1.17	1.19	1.23	1.09	1.11	1.15
37.36	1.92	1.96	2.01	1.15	1.18	1.23	1.08	1.11	1.15
44.46	1.91	1.95	2.02	1.14	1.18	1.23	1.06	1.10	1.16
50.46	1.90	1.95	2.02	1.13	1.17	1.24	1.05	1.09	1.16

$\$1.00/10^6$ Btu

	300° F			360° F			475° F		
% Water	\$.10	\$1.00	\$2.50	\$.10	\$1.00	\$2.50	\$.10	\$1.00	\$2.50
3.75	3.27	3.27	3.27	1.94	1.94	1.94	1.85	1.85	1.86
6.65	3.13	3.13	3.14	1.78	1.79	1.80	1.70	1.70	1.71
10.68	3.07	3.08	3.07	1.71	1.72	1.73	1.63	1.64	1.65
15.69	3.07	3.08	3.10	1.68	1.70	1.71	1.60	1.61	1.63
22.21	3.07	3.09	3.12	1.66	1.68	1.71	1.58	1.59	1.62
29.65	3.08	3.11	3.15	1.65	1.68	1.72	1.56	1.59	1.63
37.36	3.07	3.12	3.17	1.64	1.67	1.72	1.55	1.58	1.63
44.46	3.08	3.12	3.18	1.63	1.67	1.73	1.54	1.58	1.63
50.46	3.07	3.11	3.19	1.62	1.66	1.73	1.53	1.57	1.63

Busbar Energy Production Cost Multipliers for Flash Steam Systems With Dry/Wet Peaking Cooling Towers for Basin and Range Site

$.50/10^6 Btu

300° F			
% Water	$.10	$1.00	$2.50
2.25	1.93	1.94	1.94
3.74	1.74	1.74	1.75
6.28	1.65	1.66	1.67
9.73	1.60	1.61	1.62
14.24	1.56	1.57	1.60
19.66	1.54	1.57	1.60
25.65	1.53	1.55	1.60
31.45	1.51	1.54	1.60
36.56	1.49	1.53	1.60

360° F			
% Water	$.10	$1.00	$2.50
2.84	1.43	1.44	1.44
4.73	1.29	1.29	1.30
7.93	1.22	1.23	1.23
12.30	1.78	1.19	1.20
17.99	1.15	1.16	1.18
24.84	1.14	1.16	1.18
32.41	1.13	1.15	1.18
39.74	1.12	1.14	1.18
46.19	1.11	1.13	1.18

475° F			
% Water	$.10	$1.00	$2.50
3.66	1.12	1.12	1.13
6.08	1.01	1.01	1.02
10.20	0.96	0.96	0.97
15.81	0.92	0.93	0.93
23.12	0.90	0.91	0.92
31.93	0.90	0.90	0.92
41.66	0.88	0.90	0.92
51.08	0.87	0.89	0.92
59.37	0.86	0.89	0.92

$1.00/10^6 Btu

300° F			
% Water	$.10	$1.00	$2.50
2.25	2.65	2.65	2.65
3.74	2.46	2.46	2.47
6.28	2.37	2.38	2.39
9.73	2.33	2.34	2.35
14.24	2.29	2.31	2.33
19.66	2.28	2.30	2.33
25.65	2.26	2.29	2.34
31.45	2.25	2.28	2.34
36.56	2.23	2.27	2.34

360° F			
% Water	$.10	$1.00	$2.50
2.84	1.91	1.91	1.92
4.73	1.77	1.77	1.78
7.93	1.70	1.71	1.72
12.30	1.66	1.67	1.68
17.99	1.64	1.65	1.67
24.84	1.63	1.65	1.67
32.41	1.62	1.64	1.67
39.74	1.61	1.63	1.67
46.17	1.60	1.63	1.68

475° F			
% Water	$.10	$1.00	$2.50
3.66	1.46	1.46	1.46
6.08	1.35	1.35	1.36
10.20	1.30	1.30	1.31
15.81	1.26	1.27	1.28
23.12	1.24	1.25	1.27
31.93	1.24	1.25	1.27
41.66	1.23	1.24	1.27
51.08	1.22	1.24	1.27
59.37	1.21	1.23	1.27

Busbar Energy Production Cost Multipliers for Binary Systems with Dry/Wet Peaking Cooling Towers for High Mountain Site

$\$.50/10^6$ Btu

	300° F			360° F			475° F		
% Water	$.10	$1.00	$2.50	$.10	$1.00	$2.50	$.10	$1.00	$2.50
2.56	2.20	2.21	2.21	1.48	1.48	1.49	1.39	1.40	1.40
3.46	2.03	2.04	2.04	1.32	1.32	1.32	1.23	1.24	1.24
6.23	1.97	1.98	1.98	1.24	1.25	1.25	1.16	1.17	1.17
11.49	1.94	1.95	1.97	1.20	1.21	1.23	1.13	1.14	1.15
18.41	1.93	1.95	1.97	1.18	1.20	1.22	1.11	1.12	1.14
25.74	1.93	1.95	1.98	1.16	1.18	1.22	1.10	1.12	1.15
33.47	1.92	1.95	2.00	1.15	1.18	1.22	1.09	1.11	1.16
40.79	1.91	1.95	2.00	1.14	1.17	1.23	1.08	1.11	1.16
47.09	1.91	1.95	2.02	1.13	1.17	1.24	1.07	1.11	1.17

$\$1.00/10^6$ Btu

	300° F			360° F			475° F		
% Water	$.10	$1.00	$2.50	$.10	$1.00	$2.50	$.10	$1.00	$2.50
2.56	3.27	3.27	3.27	1.94	1.94	1.95	1.84	1.84	1.85
3.46	3.11	3.12	3.12	1.78	1.78	1.79	1.69	1.69	1.69
6.23	3.07	3.07	3.08	1.71	1.72	1.72	1.62	1.63	1.63
11.49	3.06	3.07	3.08	1.68	1.69	1.70	1.59	1.60	1.61
18.41	3.07	3.08	3.11	1.66	1.69	1.70	1.58	1.60	1.62
25.74	3.07	3.10	3.13	1.65	1.67	1.71	1.58	1.59	1.62
33.47	3.08	3.11	3.16	1.64	1.67	1.71	1.57	1.60	1.64
40.79	3.07	3.11	3.17	1.63	1.66	1.72	1.56	1.60	1.65
47.09	3.07	3.11	3.18	1.63	1.66	1.73	1.55	1.59	1.65

Busbar Energy Production Cost Multipliers for Flash Steam Systems With Dry/Wet Peaking Cooling Towers For High Mountain Site

\$.50/10^6 Btu

300° F				360° F				475° F			
% Water	\$.10	\$1.00	\$2.50	% Water	\$.10	\$1.00	\$2.50	% Water	\$.10	\$1.00	\$2.50
1.88	1.95	1.95	1.95	2.38	1.45	1.45	1.45	3.06	1.13	1.14	1.14
2.22	1.75	1.75	1.76	2.81	1.30	1.30	1.30	3.61	1.02	1.02	1.02
3.45	1.65	1.66	1.66	4.37	1.22	1.22	1.23	5.61	0.96	0.96	0.96
6.57	1.60	1.60	1.61	8.31	1.78	1.18	1.19	10.68	0.92	0.93	0.93
11.44	1.56	1.57	1.59	14.47	1.15	1.16	1.17	18.60	0.90	0.91	0.92
16.89	1.53	1.55	1.58	21.37	1.13	1.14	1.17	27.47	0.89	0.90	0.91
22.75	1.51	1.53	1.58	28.78	1.12	1.14	1.17	36.99	0.87	0.89	0.91
28.64	1.49	1.53	1.58	36.23	1.11	1.13	1.17	46.57	0.87	0.88	0.91
33.91	1.48	1.52	1.58	42.90	1.10	1.12	1.17	55.14	0.86	0.88	0.91

\$1.00/10^6 Btu

300° F				360° F				475° F			
% Water	\$.10	\$1.00	\$2.50	% Water	\$.10	\$1.00	\$2.50	% Water	\$.10	\$1.00	\$2.50
1.88	2.65	2.65	2.65	2.38	1.92	1.92	1.92	3.06	1.47	1.47	1.47
2.22	2.46	2.46	2.47	2.81	1.77	1.77	1.78	3.61	1.35	1.35	1.36
3.45	2.37	2.37	2.38	4.37	1.70	1.70	1.71	5.61	1.30	1.30	1.30
6.57	2.32	2.32	2.34	8.31	1.66	1.66	1.67	10.68	1.26	1.27	1.27
11.44	2.28	2.29	2.32	14.47	1.63	1.64	1.66	18.60	1.24	1.25	1.26
16.89	2.26	2.28	2.31	21.37	1.62	1.63	1.65	27.47	1.23	1.24	1.26
22.75	2.24	2.26	2.30	28.78	1.60	1.62	1.65	36.99	1.22	1.23	1.25
28.64	2.22	2.26	2.31	36.23	1.59	1.61	1.66	46.57	1.21	1.23	1.26
33.91	2.21	2.25	2.31	42.90	1.58	1.61	1.66	55.14	1.20	1.22	1.26

Busbar Energy Production Cost Multipliers for Binary Systems With Dry/Wet Peaking Cooling Towers For Hot Desert Site

\$.50/10^6 Btu

	300° F			360° F			475° F		
% Water	$.10	$1.00	$2.50	$.10	$1.00	$2.50	$.10	$1.00	$2.50
12.70	2.29	2.30	2.23	1.52	1.53	1.55	1.44	1.45	1.46
20.75	2.14	2.17	2.21	1.37	1.39	1.42	1.29	1.31	1.33
29.93	2.08	2.11	2.17	1.30	1.33	1.40	1.22	1.24	1.28
39.17	2.04	2.08	2.15	1.26	1.29	1.35	1.18	1.21	1.27
47.51	2.01	2.06	2.14	1.23	1.27	1.35	1.16	1.20	1.26
54.66	1.98	2.04	2.14	1.21	1.26	1.34	1.13	1.18	1.26
60.45	1.96	2.02	2.13	1.18	1.24	1.33	1.11	1.16	1.25
64.59	1.94	2.01	2.12	1.17	1.23	1.33	1.09	1.15	1.25
68.76	1.93	2.00	2.11	1.16	1.22	1.32	1.08	1.14	1.24

\$1.00/10^6 Btu

	300° F			360° F			475° F		
% Water	$.10	$1.00	$2.50	$.10	$1.00	$2.50	$.10	$1.00	$2.50
12.70	3.38	3.40	3.42	1.99	1.99	2.02	1.89	1.90	1.92
20.75	3.26	3.29	3.33	1.85	1.87	1.90	1.75	1.77	1.79
29.93	3.22	3.25	3.31	1.79	1.81	1.86	1.69	1.71	1.75
39.17	3.19	3.23	3.30	1.75	1.79	1.81	1.66	1.69	1.74
47.51	3.17	3.22	3.30	1.72	1.76	1.84	1.64	1.67	1.74
54.66	3.14	3.20	3.30	1.70	1.75	1.83	1.62	1.65	1.73
60.45	3.12	3.18	3.29	1.67	1.73	1.82	1.59	1.64	1.73
64.59	3.10	3.17	3.28	1.66	1.72	1.82	1.57	1.63	1.72
68.76	3.09	3.15	3.27	1.64	1.71	1.81	1.56	1.62	1.71

Busbar Energy Production Cost Multipliers for Flash Steam Systems With Wet/Dry Peaking Cooling Towers For Hot Desert Site

\$.50/10^6 Btu

300° F				360° F				475° F			
% Water	\$.10	\$1.00	\$2.50	% Water	\$.10	\$1.00	\$2.50	% Water	\$.10	\$1.00	\$2.50
4.29	2.00	2.01	2.02	5.34	1.48	1.48	1.49	6.93	1.14	1.15	1.15
8.47	1.79	1.80	1.82	10.53	1.32	1.33	1.34	13.68	1.05	1.03	1.04
14.47	1.68	1.70	1.73	17.99	1.24	1.26	1.28	23.37	0.96	0.97	0.99
21.09	1.62	1.64	1.68	26.21	1.20	1.22	1.25	34.05	0.93	0.94	0.97
28.02	1.58	1.61	1.67	34.82	1.17	1.20	1.24	45.25	0.91	0.93	0.96
34.67	1.55	1.59	1.66	43.08	1.15	1.18	1.97	55.97	0.90	0.92	0.96
40.35	1.52	1.57	1.65	50.14	1.13	1.17	1.23	65.15	0.88	0.91	0.96
45.05	1.51	1.56	1.65	55.98	1.13	1.17	1.23	72.74	0.87	0.90	0.95
48.68	1.49	1.55	1.64	60.49	1.11	1.16	1.23	75.78	0.87	0.90	0.95

\$1.00/10^6 Btu

300° F				360° F				475° F			
% Water	\$.10	\$1.00	\$2.50	% Water	\$.10	\$1.00	\$2.50	% Water	\$.10	\$1.00	\$2.50
4.29	2.74	2.75	2.76	5.34	1.97	1.97	1.98	6.93	1.49	1.49	1.50
8.47	2.53	2.54	2.56	10.53	1.81	1.82	1.83	13.68	1.37	1.37	1.38
14.47	2.42	2.44	2.47	17.99	1.74	1.75	1.77	23.37	1.31	1.32	1.33
21.09	2.36	2.38	2.42	26.21	1.69	1.71	1.74	34.05	1.28	1.29	1.31
28.02	2.31	2.35	2.40	34.82	1.67	1.69	1.73	45.25	1.26	1.28	1.31
34.67	2.28	2.32	2.39	43.08	1.65	1.68	1.73	55.97	1.24	1.27	1.30
40.35	2.26	2.31	2.39	50.14	1.63	1.67	1.73	65.15	1.23	1.26	1.30
45.05	2.24	2.29	2.38	55.98	1.62	1.66	1.72	72.74	1.22	1.25	1.30
48.68	2.22	2.28	2.37	60.49	1.61	1.57	1.72	75.78	1.21	1.24	1.30

Busbar Energy Production Cost Multipliers for Binary Systems with Dry/Wet Peaking Cooling Towers for Pacific Northwest Site

$\$.50/10^6$ Btu

	300° F			360° F			475° F		
% Water	$.10	$1.00	$2.50	$.10	$1.00	$2.50	$.10	$1.00	$2.50
4.18	2.18	2.23	2.19	1.46	1.46	1.47	1.38	1.39	1.40
6.86	2.02	2.03	2.04	1.30	1.31	1.32	1.23	1.24	1.25
10.69	1.96	1.97	1.98	1.23	1.24	1.25	1.16	1.17	1.18
16.20	1.94	1.96	1.98	1.20	1.21	1.23	1.13	1.14	1.16
23.65	1.94	1.96	1.99	1.18	1.20	1.23	1.11	1.13	1.16
32.32	1.94	1.97	2.01	1.17	1.19	1.24	1.09	1.12	1.16
40.86	1.93	1.96	2.02	1.15	1.19	1.24	1.08	1.11	1.16
47.96	1.92	1.96	2.02	1.14	1.18	1.24	1.07	1.10	1.16
53.71	1.90	1.95	2.02	1.13	1.17	1.17	1.05	1.10	1.16

$\$1.00/10^6$ Btu

	300° F			360° F			475° F		
% Water	$.10	$1.00	$2.50	$.10	$1.00	$2.50	$.10	$1.00	$2.50
4.18	3.23	3.24	3.24	1.91	1.92	1.92	1.83	1.84	1.84
6.86	3.09	3.10	3.11	1.76	1.77	1.78	1.68	1.69	1.70
10.69	3.06	3.06	3.08	1.70	1.71	1.72	1.62	1.63	1.64
16.20	3.06	3.07	3.10	1.68	1.69	1.71	1.59	1.60	1.62
23.65	3.08	3.10	3.13	1.67	1.68	1.71	1.58	1.59	1.63
32.32	3.10	3.12	3.17	1.65	1.68	1.73	1.57	1.59	1.63
40.86	3.09	3.13	3.18	1.65	1.68	1.73	1.55	1.58	1.64
47.96	3.08	3.12	3.19	1.63	1.67	1.73	1.54	1.58	1.64
53.71	3.07	3.11	3.19	1.62	1.66	1.73	1.53	1.57	1.64

Busbar Energy Production Cost Multipliers for Flash Steam Systems With Dry/Wet Peaking Cooling Towers for Pacific Northwest Site

$.50/10^6 Btu

300° F				360° F				475° F			
% Water	$.10	$1.00	$2.50	% Water	$.10	$1.00	$2.50	% Water	$.10	$1.00	$2.50
2.04	1.88	1.88	1.89	2.57	1.40	1.40	1.40	3.30	1.10	1.10	1.10
2.66	1.71	1.71	1.71	3.34	1.27	1.27	1.27	4.30	0.99	0.99	1.00
4.18	1.63	1.63	1.64	5.26	1.20	1.21	1.21	6.76	0.94	0.94	0.95
6.71	1.58	1.58	1.60	8.44	1.17	1.17	1.18	10.84	0.91	0.92	0.92
10.54	1.54	1.55	1.57	13.24	1.15	1.15	1.17	17.02	0.89	0.90	0.91
15.76	1.52	1.53	1.56	19.80	1.13	1.15	1.17	25.46	0.88	0.89	0.91
22.15	1.52	1.53	1.57	27.83	1.13	1.14	1.17	35.78	0.88	0.89	0.91
28.71	1.50	1.53	1.58	36.06	1.12	1.15	1.19	46.36	0.88	0.89	0.92
34.32	1.49	1.52	1.58	43.11	1.12	1.14	1.19	55.42	0.87	0.89	0.92

$1.00/10^6 Btu

300° F				360° F				475° F			
% Water	$.10	$1.00	$2.50	% Water	$.10	$1.00	$2.50	% Water	$.10	$1.00	$2.50
2.04	2.59	2.59	2.60	2.57	1.87	1.88	1.88	3.30	1.43	1.43	1.44
2.66	2.42	2.43	2.43	3.34	1.75	1.75	1.75	4.30	1.33	1.33	1.34
4.18	2.35	2.35	2.36	5.26	1.69	1.69	1.70	6.76	1.28	1.29	1.29
6.71	2.31	2.32	2.33	8.44	1.66	1.66	1.67	10.84	1.26	1.26	1.27
10.54	2.28	2.29	2.31	13.24	1.64	1.65	1.66	17.02	1.24	1.26	1.26
15.76	2.25	2.27	2.30	19.80	1.63	1.64	1.66	25.46	1.23	1.24	1.26
22.15	2.24	2.27	2.30	27.83	1.62	1.64	1.67	35.78	1.23	1.24	1.26
28.71	2.24	2.27	2.32	36.06	1.62	1.65	1.69	46.36	1.23	1.24	1.27
34.32	2.23	2.26	2.33	43.11	1.61	1.64	1.69	55.42	1.22	1.24	1.28