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GEOTHERMAL ENERGY DATABOOK
FOR THE
WESTERN UNITED STATES

by

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Preface

During the past ten years much progress has been made in the United States to develop geothermal energy and to construct power plants. Current electrical power produced is 608 MWe at The Geysers in California which obtains steam to drive turbines from steam wells. However, the major new sources of geothermal energy in the next decade are expected to be hot brine systems located in the Western United States. Data on the power potential and progress toward utilization is needed for these new areas to identify impediments to utilization and to forecast power on-line in the next decades. However, the data is widely scattered and largely unevaluated, thereby impeding the analysis for predictions of power production in the decades 1980, 1990 and beyond the year 2000.

The National Geothermal Information Resource (GRID) project of the Lawrence Berkeley Laboratory was initiated in 1974 with the objective of compiling both basic and site-specific data on major aspects of geothermal energy utilization. The objectives of the database are:

1. To compile information and numerical data for each major geothermal prospect. The data will include that which is measured or estimated (e.g., calculated, inferred, extrapolated); estimated values will be identified as such by an appropriate tag. This is a current on-going activity.
2. To evaluate the data with the idea to recommend values that can be used as reference data for each site.
3. To establish a computer-aided classification file of major U.S. geothermal prospects which lists each site according to the degree of development toward commercial power production.

4. To develop a list of activity indicators for monitoring the progress of power production with the idea that these will serve as a basis for prospect classification.

5. To examine new state-of-the-art electric power technologies developed within and outside the geothermal energy field which may enable a significant reduction in the cost of geothermal power production.

6. To make recommendations for new or additional site-specific data needs where necessary for each prospect.

Abstract

This report consists of available information for electric power production covering selected major geothermal prospects in the western United States; emphasis is on the state of California. Detailed technical, economic and institutional information which is used mainly to evaluate a geothermal area for its potential to produce electrical power is presented for 21 major geothermal prospects. Summary data tables with selected data elements are provided for these 21 geothermal sites as well as over 40 other sites in California to show the current status of each prospect, impediments to its developments and areas of additional data needs. Maps are also included to show the location of each geothermal area. Further additional data, such as location of electric power plants, transmission lines, highways and water transportation routes, quantity and quality of groundwater, land use, land ownership, etc. are presented in the form of maps and tables for California and Nevada.

Acknowledgement

Prologue

Not the fact avails, but the use you make of it.

Ralph Waldo Emerson

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The Lawrence Berkeley Laboratory is funded by the Department of Energy to establish a National Geothermal Information Resource (GRID). The project was established in 1974 to evaluate and disseminate information on geothermal energy in the following major areas: (1) the thermodynamic and transport properties of aqueous solutions to high temperatures and pressures, (2) utilization of the geothermal resource, and (3) environmental aspects, mainly hydrogen sulfide emissions and subsidence. The content of this databook is limited to the available current information for electric power production covering 21 major areas in the western United States, and over 40 sites in California.

A. Introduction

The objective of this work is to provide a single, comprehensive database containing evaluated reference data useful in assessing geothermal sites for their potential to produce electrical power. The compilation and evaluation constitute a databook of current information for plant construction, modeling, research and development for conversion of geothermal energy to electric power production. The results of this work include identification of areas where data are lacking or are inadequate and where technology development is needed. The interest in site-specific data stems from two important concerns: (1) forecasts of power production related to local, state and national goals, for example, the second report on geothermal energy by the Interagency Geothermal Coordinating Council which contains forecasts for power on-line to the year 2000 and beyond (Ref. 1), and (2) the assessment of each site to produce power in an economic manner for a 20 to 30-year time period. An example of (2) is the design of an electric generating

system using the following data: (a) temperature of the fluids produced, (b) chemical composition of the reservoir fluids, (c) availability of cooling water, (d) current land usage, (e) flow rates sustainable by the production wells, (f) cost of drilling within the area, (g) well spacing for production and injection, (h) turbine system to be used, and (i) general operating costs in the area. See for example Reference 2.

The currently available data for geothermal sites is widely scattered, uneven in quantity and quality, and ranges from extensive for The Geysers and East Mesa areas to sparse for Alvord and Lassen. This is especially true for sites outside of California. The best available sources have been used to gather the data and every attempt has been made to assure that figures and facts quoted are the most accurate and up-to-date. Data are compiled from the original sources as much as possible, and new or revised data is added after its receipt.

There is an increasing number of reports covering new regulatory processes and new techniques from research and development to make geothermal power production more economical than at present, and to facilitate obtaining permits. Selected portions of this work are included here to provide relevant information on exploration, drilling, environmental and institutional aspects, and utilization for power production.

No systematic attempt was made to convert numerical data to a consistent set of units; however, a conversion table is included for convenience of the reader. Section G lists these units and conversion factors required for other units.

Material contained here was obtained from publications, reports, correspondence, by visits and other contacts. While it is our intent that this database be as comprehensive as possible, it is recognized that no compilation can be exhaustive. In this context, the reader is urged to communicate important omissions and comments to the National Geothermal Information Resource for inclusion in a subsequent revision.

Additional information on site-specific data is obtained from Geothermal Energy Resources in California: Status Report and Appendix (Ref. 3), Geothermal Handbook (Ref. 4), Site-Specific Analysis of Geothermal Development - Data Files of Prospective Sites, Vol. III (Ref. 5), Cumulative Geothermal Statistical Bid Recap, CY 1974-1978 (Ref. 6), Geothermal Power Plants of the United States: A Technical Survey of Existing and Planned Installations (Ref. 7), Geothermal Exploration and Development in Nevada Through 1973 (Ref. 8,29), GEOTHERM Database (Ref. 9), Proceedings First Geopressured Geothermal Energy Conference (Ref. 10), Regional Hydrothermal Commercialization Plan (Ref. 11), and Analysis of Requirements for Accelerating the Development of Geothermal Energy Resources in California (Ref. 19).

B. Site-Specific Data

Data for geothermal sites in the western United States are presented in three appendixes at the end of this report. Appendix I is a summary of resource characteristics which are recommended for use in assessing each site for its potential to produce electric power, or for direct utilization. This information is the best currently available, or that which is most widely used; such data may subsequently be changed to reflect new measurement selected if necessary from a range of values. References are given to the sources used in arriving at the recommended value. The same procedure is used for non-numerical information.

Appendix II consists of an Energy Conversion (ENCON) database compiled on a text-editing system; the compilation includes numerical values, tables and other information obtained from many referenced sources. All of the information sources are referenced by a short code that has been adopted in our bibliographic file. The short code gives the name of the author (or the first author if more than one author) or the name of the corporation publishing the report and the year of publication. Site-specific data for 21 geothermal prospects is presently stored on the ENCON file. Table 1 lists major geothermal prospects in the western United States expected to be covered; those already on ENCON file are identified by an asterisk.

The data contained in the ENCON file include the following major categories:

General Information consists of a record number, site name, location, developer and description; and the estimated electric power potential.

Reservoir Parameters covers fluid temperature; well cost; field flow rate; well life; non-condensable gas content; steam quality; wellhead temperature; well flow rate; fluid enthalpy.

Operational Parameters contains information on plant size; plant cost; power cost to load center; type of power cycle; operating and maintenance cost; well spacing; parasitic power; well replacement rate; heat transfer coefficient; heat rejection system; make-up water cost; wet bulb temperature.

Hot Water Transmission (Direct Utilization) section covers the non-electric utilization of the resource and includes materials used for pipe, pipe fitting, insulation, casing, pipe support and pump; type of valves; method of installation of pipes, insulation, casing, pipe support and pump.

Field Baseline Data consists of thermal water temperature and flow rate; inferred reservoir temperature; electrical resistivity; heat flow; thermal gradient; gravity survey value; seismic noise correlation; pumping power required; scale control; fouling factor; corrosion control; well logging data, well test data, drilling mud types, acoustic log, temperature log, caliper log, electrical resistivity log, dipmeter, log interpolation, bottomhole pressure; well drilling date, well completion type, depth to production, wellhead pressure; materials used for piping, valves and throttle plates; number of producing wells; number of non-producing wells.

Environmental Aspects are gas data, sample date, and H_2S , CO_2 and other gases contained in sample; fluid data, sample date, total dissolved solids, boron, silica, bicarbonate, carbonate and sulfate content of fluid, fluid pH; waste water disposal method; pre-disposed treatment method; subsidence; status of environmental impact report (EIR) and environmental impact statement (EIS).

Reservoir Engineering includes recharge source; rock porosity; reservoir rocks; thermal conductivity; permeability.

Land Use Factors consists of well spacing; land improvements needed; existing land use; physical conditions of area; land use planning; fresh water supply; water rights; proximity to markets/transmission lines.

Legal Aspects are preleasing procedures; exploration permits; leasing, lease holders, royalty payment, restrictions; depletion allowance; government regulations, loan guarantee, primary term duration, renewal leasehold periods, work requirements, and data monitoring; water laws, pollution control and reinjection control; air laws, emissions control; state income tax; federal income tax; bond interest.

Injection Well Data includes fluid flow rate; well stimulation reinjection power required.

Appendix III contains selected maps and tables to include location of roads and railways, existing land use, availability of water, and proximity to transmission lines. The data in this section is presently limited to California and Nevada.

Table 1. Selected Geothermal Areas in the Western United States (Ref. 61)

Alaska

No. of Acres

1. Akutan Hot Spring	
2. Geyser Spring Basin KGRA	20,960
3. Okmok Caldera KGRA	44,800
4. Pilgrim Springs KGRA	22,400
5. Port Moller	

Arizona

1. Casa Grande	
2. Chandler	
3. Clifton KGRA	780
4. Gillard Hot Springs KGRA	2,920
5. Hookers	

California KGRA

1. Beckwourth Peak	2,558
2. Bodie	640
*3. Brawley	28,886
*4. Coso Hot Springs	106,798
5. Dunes	7,680
*6. East Mesa	38,365
7. Ford Dry Lake	7,687
*8. Geysers-Calistoga	376,030
9. Glamis	25,505
*10. Glass Mountain	33,287
*11. Heber	58,568
12. Knoxville	14,702
*13. Lake City-Surprise Valley	72,940
*14. Lassen Hot Springs	78,642
15. Little Horse Mountain	1,196
16. Love Lady Ridge	6,879
*17. Mono-Long Valley	460,256
18. Randsburg	12,880
19. Saline Valley	3,200
*20. Salton Sea	95,824
21. Sespe Hot Springs	7,034
22. Wendel-Amedee	17,932
23. Witter Springs	18,152
24. Westmorland (not a KGRA)	

Colorado

1. Alamosa County KGRA	6,761
2. Mineral Hot Springs KGRA	5,765
3. Poncha KGRA	3,200
4. Valley View Hot Springs KGRA	5,099
5. San Luis Valley	

No. of Acres

Hawaii

- *1. Puna

Idaho

1. Boise	
*2. Bruneau KGRA	5,120
*3. Castle Creek KGRA	79,722
4. Crane Creek KGRA	4,342
5. Island Park KGRA	28,539
6. Mountain Home KGRA	9,520
7. Preston	
8. Raft River KGRA	30,209
9. Vulcan Hot Springs KGRA	3,836
10. Weiser-Crane Creek	
11. Yellowstone KGRA	14,164
12. Conda KGRA	2,566

Louisiana

- 1. Acadia Parish
- 2. Calcasieu
- 3. Cameron

Montana

1. Boulder Hot Springs KGRA	6,343
2. Corwin Springs KGRA	20,349
3. Ennis Lake	
4. Marysville KGRA	19,200
5. West Yellowstone KGRA	12,763
6. Warm Springs	

Nevada KGRA

1. Baltazor	5,617
*2. Beowawe	33,224
3. Black Rock Desert (not a KGRA)	
4. Brady-Hazen	98,508
5. Colado	640
6. Continental Lake (not a KGRA)	
7. Darrough Hot Springs	8,363
8. Dixie Valley	38,348
9. Double Hot Springs	29,326
10. Elko Hot Springs	8,960

Nevada (continued)

No. of Acres

11. Fly Ranch	20,759
12. Fly Ranch Northeast	7,680
13. Gerlach	26,326
14. Gerlach Northeast	7,971
15. Hot Springs Point	8,549
16. Kyle Hot Springs	2,561
17. Leach Hot Springs	12,846
18. Moana Springs	5,120
19. Monte Neva Hot Springs	10,302
20. Pinto Hot Springs	8,015
*21. Ruby Valley	5,743
22. Rye Patch	801
23. Salt Wells Basin	19,232
24. San Emidio Desert	7,678
25. Silver Peak	5,117
26. Soldier Meadow	5,966
27. Steamboat Springs	8,911
28. Stillwater-Soda Lake	225,260
29. Trego	7,013
30. Wabuska	11,520
31. Warm Springs	3,812
32. Wilson Hot Springs	1,294

New Mexico

1. Mamby's Hot Spring	
2. Animas Valley	
* 3. Baca Location No. 1 KGRA	168,761
4. Gila Hot Springs KGRA	3,202
5. Kilbourne Hole KGRA	25,134
6. Lightning Dock KGRA	23,552
7. Lower Frisco Hot Springs KGRA	5,760
8. Guadalupe	
9. San Ysidro KGRA	1,915
10. Socorro Peak KGRA	89,716
11. Truth or Consequences	
12. Radium Springs KGRA	9,813
13. Columbus	

Oregon KGRA

*1. Alvord	176,835
2. Beulah (not a KGRA)	
3. Belknap-Foley Hot Springs	5,066
4. Breitenbush Hot Springs	13,445
5. Burns Butte	640
6. Carey Hot Springs	7,579
7. Crump Geyser	85,663
8. Glass Butte (not a KGRA)	
9. Harney Lake	
10. Klamath Falls	50,300

Oregon (Continued)

No. of Acres

11. Lakeview	12,165
12. McCredie Hot Springs	3,659
13. Mount Hood	8,671
14. Newberry Crater	31,284
15. Summer Lake Hot Springs	13,631
16. Vale Hot Springs	22,998

Texas

1. Brazoria
2. Corpus Christi
3. Kenedy
4. Matagorda

Utah KGRA

1. Brigham City (not a KGRA)	
*2. Cove Fort-Sulphurdale	24,074
3. Crater Springs	17,321
4. Lund	3,840
5. Meadow-Hatton	1,927
6. Minersville (not a KGRA)	
*7. Monroe-Joseph	16,364
8. Navajo Lake	2,522
9. Neels (not a KGRA)	
10. Newcastle	2,636
*11. Roosevelt Hot Springs	29,791
*12. Thermo Hot Springs	26,019

Washington

*1. Baker	
2. Indian Heaven	2,547
3. Gifford Peak	
4. Kennedy Hot Springs	3,311
5. Mount St. Helens	29,754

Wyoming

1. Afton
2. Strawberry

*Presently on ENCON file

C. Scope of Databook

The data covered in this work is generally from 1970 to 1979. The first date was selected because data on geothermal utilization began to be generally available in 1970, for example, at the U.N. Conference in Pisa, Italy. Information prior to 1970 includes leasing,

drilling, reservoir properties and power plant performance. Besides site-specific geothermal data, this databook also contains selected information on geothermal sites that meet either or both of the following criteria:

(1) research and development in geothermal energy and related fields that may have application to a specific site. New drill bits and testing of additives to control scaling are examples of research and development.

(2) Site-specific but non-geothermal data that is important to the utilization of an area. Examples of (2) are location of the nearest power lines, roads and towns, existing land use, availability of water, and ambient levels of hydrogen sulfide.

D. Technology Developments

Costs associated with electric energy production by geothermal power plants might be reduced by research and development programs to include the following:

- (1) Improvement of geophysical surveys for finding and estimating the potential of geothermal reservoirs.
- (2) Reducing capital costs incurred in field development, to include production wells, reinjection wells and field piping.
- (3) Reducing the capital cost of power plants by improving or developing new processes and equipment design methods; examples are work on heat exchangers and hydrogen sulfide scrubbers.
- (4) Improvement of the plant's specific net energy which will reduce well field costs because less brine and fewer wells will be required for a given power rating. Improvement in turbine efficiency and condenser performance are examples.
- (5) Reducing the scheduled and unscheduled downtime of the plant and hence increasing the plant availability by improvement of equipment reliability and extending service life. A prime example is control of corrosion and scaling caused by geothermal brine in piping, valves and other equipment which are in contact with brine.
- (6) Development of new materials to contain, process, and generally handle high temperature and highly corrosive environments that are encountered in geothermal brines. In this context, research is needed for the following:

1. Geophysical Exploration

In view of the high drilling costs, geophysical well surveys play

an important role in estimating the power potential of geothermal reservoirs. Geophysical exploration includes surface electrical resistivity surveys, seismic ground noise surveys, passive micro-earthquake monitoring surveys, magneto-telluric surveys and all other geophysical surveys including airborne techniques. However, in order to employ these techniques in assessing a geothermal reservoir, correlations between the measurement and the physical properties of the rock types that are commonly found in geothermal reservoirs must be developed. The existing correlations developed for the oil and gas industry apply only for the rocks in which oil and gas are commonly found, such as clastics and carbonates (Ref.30). Some geothermal reservoirs may occur in such rock types, but probably a large fraction will occur in volcanic rocks (Ref.30). Research is needed to establish correlations between measurable properties such as electrical resistivity and acoustic wave speed, and properties which need to be known, such as porosity, water salinity, temperature and well productivity. The Colorado School of Mines has published data on the seismic velocities and resistivities of geothermal reservoir rocks obtained from the Colombia Plateau volcanic basin, New Mexico Jemez Mountains, volcanics from south central Nevada, and Cascade range in Oregon. A strong dependence of seismic velocity and resistivity of Cenozoic Volcanic rocks on porosity was demonstrated (Ref. 30, 31).

2. Drilling and Field Development

A great portion of the expense in geothermal power production is due to costs associated with well drilling, well completion and well logging. It costs about twice as much to drill a geothermal well as it does to drill a comparable oil or gas well. This is partly due to the high temperature corrosive

environment combined with the different geothermal formations and other reservoir parameters associated with geothermal wells which place severe limitations on the use of existing equipment and techniques based on those used in gas and oil industry. Most of these limitations are common to all prospects. On the other hand, some drilling problems can be related to a specific characteristic of a particular prospect. These might include terrain, salinity of the reservoir fluid, high temperature or rock hardness. Research is needed to develop new materials, equipment and techniques appropriate to a geothermal environment. These include the following:

2.1 - Drill Bits

In geothermal drilling, due to high temperature effects on materials, bits have a much shorter lifetime than in gas and oil drilling. Furthermore, the shortened bit life represents only one part of the increased drilling costs. Penetration rates are generally lower since the bits are run at reduced load in order to prevent catastrophic failure. Additionally, bit replacement causes hours of downtime which not only means more drilling costs but also leads to other problems. See the review of patents on bit design in Reference 32. Improvements in seals and bearings, particularly in terms of increase in bit life is needed.

A study of cases of premature drill-bit failure in the geothermal well drilling done by Terra Tek, Inc., (Ref. 33) concluded that research on developing drill bit materials for operation at higher temperatures could achieve significant gains in the bit life. For other research activities on drill bits, the reader is referred to Reference 34, 35.

2.2 - Downhole Motors

Development of downhole motors could provide an ideal drilling method.

Motors reduce the chances of pipe twist-off, provide potentially more power to the rockface, and are convenient for directional drilling (Ref.38). Currently available downhole motors are restricted for their use to specialized applications such as directional drilling even for low temperature oil and gas wells. The main problems causing these limitations are short life due to inadequate or short seal life and high rotational speed. An added problem for geothermal applications is the fact that all elastometric components degrade very rapidly at even very modest temperatures (Ref. 36, 37). Both lifetime and load capacity of downhole motors need improvement. Research is also needed in developing downhole motors with the capability to monitor and correct unwanted deviations or to drill directionally into the producing formation.

2.3 - Drilling Fluid and Lost Circulation

The role of drilling fluids in the geothermal environment is identical to that in the case of oil and gas drilling. The high temperature of the formations in geothermal drilling, however, imposes a major limitation on such fluids.

As the temperature rises, the mud viscosity increases, resulting in an altered flow rate as the mud solidifies. In addition, mud may accumulate within the hole forming a barrier lining that severely limits the potential flow rate in the productive formation or creates a cement-like material if exposed to alkaline solids. Addition of special materials to the mud may solve these problems, but careful selection of these additives is required to avoid other consequences such as mud disposal problems due to additives with toxic heavy metal ions, induced voltage due to the addition of chemicals that could impede effective logging, and cost increases (Ref. 38).

Another common problem in drilling is lost circulation. The drilling fluid after passing through the bit escapes into the fractured geological formation. To control circulation losses, either cement or casing is introduced at the appropriate depth, or organic materials are introduced into the appropriate part of the hole. Packing materials, as used in oil and gas drilling, are not entirely satisfactory for geothermal environments. Control methods must be capable of surviving in the geothermal environment, must be easily removed for production and have no residue to plug the formation (Ref.38).

2.4.- Materials

Although there are many similarities of environment in oil-gas and geothermal wells, potential geothermal holes present a much wider spectrum of variation in the environment, for example, high temperature, presence of hydrogen sulfide, high chloride contents and broad range of pH in these environments. Screening of different available materials and developing new cements, elastomeric materials, metallic and non-metallic materials to be used for well drilling, well control and completion are needed to make the utilization of geothermal resources more economical.

Development of improved high temperature cementing materials for geothermal wells with good bonding and compressive strength, light weight, stability, compatibility with drilling mud and noncorrosive to steel well casing characteristics is needed. This is an ongoing research at many laboratories (Ref. 39, 40). Cement whose hardness approaches that of the local rock is needed to form a base for starting directional drilling. Cement hardness limits have created problems for attempted directional drilling at Roosevelt and Mono (Ref. 38).

Temperature-induced decomposition of elastomers as well as difficulties in bonding it to steel, poor lifetime in an abrasive environment and embrittlement on exposure to H_2S are limitations on the performance of present drilling equipment. Producing suitable elastomers or finding alternative materials and designs need to be investigated. Research on development of elastomers is carried by L'Garde Inc. (Ref. 41).

Durability of steel can be related to the site specific incidence of H_2S . Its effects are embrittlement and corrosion. More appropriate steels will improve the lifetime and performance of a number of important drilling tools. For materials research from co-rosion point of view in geothermal environment refer to (Ref 42).

Development of durable packers and improvement in the quality of drill pipe for long life and higher reliability are other attractive goals. The lifetime of drill pipe is limited, particularly in cases where air drilling is used, for example, The Geysers (Ref. 38).

Blow-outs and well-bore collapse are also major problems in drilling wells. Both blow-out preventers and the cement which might be used for casing the well are poor performers in a high temperature environment. Hence well control methods adequate for geothermal circumstances need to be improved for safety and cost reasons. The likelihood of well collapse is site-specific and can be expected in sedimentary areas like the Imperial Valley (Ref. 38).

2.5 - Well Logging and Instrumentation

The techniques for assessing the reservoir potential or providing a basis for decision making for field development are similar to those already developed to log potential oil producing sites. The high temperature

caustic hostile environment combined with the different geothermal formations and other reservoir parameters associated with geothermal wells has placed severe limitations on the use of existing petrophysical well logging techniques and tools in geothermal systems. Research and development needs for well logging techniques, tools and components include development of new and improved logging tools and associated equipment, development of specialized facilities, simulation techniques and interpretation methods for the measurement of temperature, pressure, wellbore flow rate, permeability, hydrochemical data, porosity, etc. Feasibility studies for the determination of the formation temperature and downhole fluid flow rates by applying nuclear techniques performed by IRT Corporation are examples of research activities in this area (Ref. 43,44). For other research activities in the area of well logging and instrumentation see (Ref. 45-47).

3. Power Plant

Typically, three schemes or combinations are considered for the utilization of liquid dominated resources. The most considered concept is the flash system where the geothermal water is flashed in one or more stages and the vaporized portion of the fluid travels through a steam turbine. The second major scheme is the binary cycle. In this concept, a secondary working fluid exchanges heat with the geothermal liquid and the former vaporizes. The secondary fluid then flows through a typical Rankine cycle. The third scheme called the "Total Flow Concept" (TFC) has been proposed by the workers at Lawrence Livermore Laboratory. In this scheme, a turbine that can expand a two-phase mixture of water and steam is employed. The choice for the appropriate system for a geothermal site is to some extent

site-specific and selection of the optimum system for each prospect must be studied. Flash system should be compared with binary system. Performance of different organic fluids ought to be investigated for the binary cycle and the possibility of total flow concept should be considered. Examples of such studies are the comparison of the performance and cost of power cycles for Niland and East Mesa geothermal sites (Ref. 48) or the research carried by University of Oklahoma to develop a computer simulation program for detailed evaluation of binary cycles (Ref. 49). Other important and major research areas in geothermal power plants are as follows:

3.1 - Heat Exchangers

In the binary cycle systems the geothermal fluid exchanges heat with the binary fluid in a heat exchanger. Most of the binary fluids with the desirable thermodynamic properties have poor thermal transport properties. Thus, the use of conventional heat exchangers would require large surface areas and hence very high costs. Further difficulties are encountered due to the corrosive nature of the brine and scaling problems accompanied with high salinity brines. Approaches to this problem include development of direct contact heat exchangers where the working fluid is directly brought in contact with the geothermal brine (Ref. 50, 51, 56). Another approach to the problem is the liquid-fluidized-bed heat exchangers with the fouling fluid (geothermal brine) passing through the shell side. The geothermal brine passes through a bed of particles such as sand, which surrounds the tube bundle. The fluidized particles scrub the tube surface, keeping them free of scale and increasing heat transfer rates (Ref. 52,53).

3.2 - Turbines

Turbine is one of the expensive pieces of equipment included in a power

plant. Although steam turbines have been developed and used for a long time, development work tailored to the particular steam conditions of a geothermal site could increase the turbine efficiency and reduce costs. The blades of geothermal steam turbines are subject to silica deposition, hydrogen embrittlement, corrosion and moisture erosion. As a result, turbine downtime is excessive. Metalurgical research and development of turbine blade materials capable of withstanding the damaging effects of geothermal steam could lead to reductions in plant maintenance costs. Large hydrocarbon turbines for binary processes are not currently in commercial use and need to be developed to handle their special problems. The concept of two-phase expanders which was developed by Lawrence Livermore Laboratory needs research and development (Ref. 54). The Total Flow Concept seems, at least thermodynamically, to be suitable for obtaining higher efficiency.

3.3 - Other Research Programs

Corrosion and erosion of pump impellers, bearings and seals, and also of valves used to control flows of geothermal brines, causes shutdowns and hence decreasing overall plant availability and adding to maintenance costs. It is recommended that corrosion and erosion tests be conducted with candidate nonferrous and nonmetallic materials and with brines that contain varying levels of H_2S , CO_2 , chlorides and sand.

Scaling is another problem which causes freezing of valves and plugging the pipes etc., resulting in frequent plant shutdowns. There are several scale control techniques such as acidification or addition of different scale control additives. These, however, must be field tested using different

brines to select appropriate scale control method for each particular plant.

Hydrogen sulfide contained in appreciable amounts in most geothermal brines presents a corrosion problem as well as an environmental problem. A number of commercial processes are available for hydrogen sulfide removal. These processes require substantial capital investment and hence research is needed to improve these processes or develop new concepts. An example of such activity is discussed in Ref. 55.

In brine reinjection, scale buildup in the injection pumps and discharge lines and reduction of the permeability of the receiving reservoir or clogging the pores of the formation can be one of the most serious risk areas. Therefore, research is needed to study different procedures such as use of settling ponds, reactor clarifier, test filters, hydrocyclones and observe their effect on composition of suspended matter and the plugging factor (Ref. 57).

E. Data and Information Sources

There are a number of valuable generally available assessments of geothermal power both under way and completed. These are either regional assessments and forecasts, or national assessments. Most are bound volumes and quickly out of date.

The sources containing information of value to geothermal energy include databases, periodicals and research laboratories. Selected sources for site-specific data are the following:

Assessment of Geothermal Resources of the United States - 1975 (Circ. 726)

is valuable, authoritative and provides comprehensive reference data, including geology, chemistry and wells, which is widely used for site evaluations. The data for a large number of prospects is available via the GEOTHERM database. However, data, for example, on scaling, corrosion and institutional factors are not readily obtained from the report. An update was published in 1979 as Circ. 790.

Site-Specific Analysis of Geothermal Development issued in three volumes by Mitre-Mitrek under contract to DOE/DGE is a comprehensive work covering scenarios of geothermal power production in the United States. With minor modifications, the projections for 37 major prospects are included in the second annual report of the Interagency Geothermal Coordinating Council. The forecasts of power on-line utilize data that is inferred or default values as well as measured values.

Geothermal Energy Prospects for the Next 50 Years was prepared by the Electric Power Research Institute. It includes calculated hydrothermal electricity potential in the U.S. and over 20 other nations to the years 1985, 2000 and 2020. Calculations are based in part on site-independent data such as a uniform temperature gradient, and heat capacity.

Geothermal Handbook was prepared by the U.S. Fish and Wildlife Service. It contains detailed information and data on geothermal sites in the western U.S., including location, development status through January 1976, and projected drilling to 1977. Valuable data is included on environmental aspects of geothermal exploration and power production.

Proceedings, First Geopressured Geothermal Energy Conference contains detailed and comprehensive information covering the origin, resource assessment, reservoir research and technology, utilization and legal and environmental aspects of geopressured systems. Newer information is available in proceedings of second and third conferences.

Analysis of Requirements for Accelerating the Development of Geothermal Energy Resources in California published in 1977 summarizes resource potential estimates for major California prospects. A scenario for power production to the year 2020 is given, including the current status of each prospect. This work and two preceding publications provide extensive data on geothermal areas in California.

Geothermal Energy, Research, Development and Demonstration Program, Second Annual Report, April 1978, summarizes the current status of geothermal energy power potential and includes data on well drilling, resource characteristics, and a development scenario.

University of Utah Research Institute provides copies of over 20 publications dealing with geothermal developments in Utah and other areas such as Coso Hot Springs, Calif. Contact:

University of Utah Research Institute
Earth Science Laboratory
391 Shipeta Way, Suite A
Salt Lake City, UT 84108
Tel. (801) 581-5283

Nevada Bureau of Mines and Geology has available comprehensive information on geothermal activities in Nevada. Their publication Report 21 includes a summary of drilling, which has been updated to 1977. A map showing the location of thermal waters and wells of Nevada is available. Information is obtained from:

Nevada Bureau of Mines and Geology
Mackay School of Mines
University of Nevada, Reno
Reno, NV 89507
Tel. (702) 784-6691

The California Division of Oil and Gas (DOG) is lead agency for all geothermal exploratory projects on state and private lands in California. DOG provides maps of geothermal areas to include locations of drillholes, and it publishes weekly summaries of map revision and notices to drill, rework and abandon wells. Besides the main office in Sacramento, field offices are maintained in Santa Rosa and Long Beach in California. Contact:

California Division of Oil and Gas
1416 Ninth St., Room 1316-35
Sacramento, CA 95814
Tel. (916) 445-9686

The National Geothermal Information Resource (GRID) was established in 1974 at the Lawrence Berkeley Laboratory with the objective to compile and disseminate critically evaluated data for geothermal energy utilization.

The data includes both the basic properties of aqueous solutions to high temperatures, and site-specific information for power production and direct utilization. Contact:

National Geothermal Information Resource
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720
Tel. (415) 486-5818, FTS 451-5818

GEO THERM contains site-specific data on geothermal areas in the United States covering thermal water, geology and reservoir properties. Data covered include the following: locality, surface description, heat flow, temperature, chemical analysis, well flow and temperature. The output is available as a computer printout. Contact:

GEO THERM
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025
Tel. (415) 467-2906

The Geopressured Geothermal Information Group is establishing a bibliographic database on geopressured systems along with a well-log database containing digitized well logs for geopressured areas. Information is obtained from:

Geopressured Geothermal Information Group
University of Texas
Austin, TX
Tel.

Technical Information Center provides comprehensive bibliographies on all major aspects of geothermal energy utilization, both United States and foreign. The material is taken from worldwide journals, reports and other publications. Direct inquiries to:

Technical Information Center
P.O. Box 62
Oak Ridge, TN 37830
Tel. (615) 483-8611

Conservation Division provides data on leasing of geothermal areas in the United States as a computer print-out. Both competitive and non-competitive leases are included. Contact:

Office of Area Geothermal Supervisor
Conservation Division
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025
Tel. (415) 467-2884

Periodic Publications

Energy Research Abstracts (ERA) is published by the U.S. Department of Energy, Technical Information Center. The ERA is printed twice monthly, and consists of abstracts and indexes of all scientific and technical reports, journal articles, conference papers and other material originated by DOE or DOE contractors. Subscriptions to ERA are \$184 per year for domestic subscribers and \$230 per year for foreign subscribers. Subscriptions are obtained from:

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402

Geothermal Hot Line includes information on drilling, plant construction and lease sales in the Western United States. Free subscriptions are obtained from:

Geothermal Hot Line
California Division of Oil & Gas
1416 Ninth St., Room 1316-35
Sacramento, CA 95814

Geothermal Energy is published monthly and contains articles covering major aspects of geothermal utilization. Subscriptions are \$50 per year for the U.S.:

Circulation Department
Geothermal Energy
18014 Sherman Way, Suite 169
Reseda, CA 91335

Geothermal World Directory contains selected articles dealing with all aspects of geothermal energy including technical, organizational and planning, and a directory of organizations. It is issued annually:

Geothermal World Corporation
18014 Sherman Way
Reseda, CA 91335

Geothermics is a technical publication consisting of engineering and scientific articles on the exploration, environmental and utilization of geothermal energy, including basic data and site-specific data. Subscriptions are obtained from:

Pergamon Press Inc.
Fairview Park
Elmsford, NY 10523

Geothermal Resources Council Bulletin consists of current information on plant construction, leasing and regulations.

Geothermal Resources Council
P.O. Box 1033
Davis, CA 95616

The Geyser contains information on leasing, plant construction and regulations:

The Geyser
P.O. Box 1525
Beverly Hills, CA 90213

Munger Oilogram contains comprehensive data on all drilling in California, Alaska, Arizona, Nevada and the West Coast, including geothermal drilling.

Munger Oil Information Service, Inc.
9800 South Sepulveda Blvd.
Los Angeles, CA 90045

Petroleum Information, National Geothermal Report is published weekly and provides new locations, completions and drilling progress. An editorial section covers other information such as background on discoveries, proposed exploration, and technological developments. Petroleum information also publishes monthly geothermal Completion Cards which are a permanent record of geothermal well completion data. Annual subscription to the weekly National Geothermal Report is \$420.00 and annual geothermal Completion Cards are \$120.00 a year.

Petroleum Information Corporation
P.O. Box 2612
Denver, CO 80201

Weekly Summary of notices to drill, rework and abandon wells, and map revisions for well locations is available for all wells in California, including geothermal.

California Division of Oil and Gas
1416 Ninth St., Room 1316-35
Sacramento, CA 95814

Organizations

U.S. Fish and Wildlife Service (FWS) was established in 1974 within the Department of Interior. The FWS predecessor organizations include the Bureau of Fisheries, established 1871, and the Bureau of Biological Survey,

established in 1885. The Fish and Wildlife Service has 7 regional offices throughout the United States. The geothermal interest of FWS is environmental aspects of land and water; it is one of the agencies with responsibility for environmental assessment. For information:

U.S. Fish and Wildlife Service
Department of Interior
Washington, D.C. 20240

U.S. Geological Survey (USGS) was established by the act of March 3, 1879 for the classification of public lands and the examination of the geological structure, mineral resources, and products of the national domain; and, in 1962 to include those outside the national domain.

Area Geothermal Supervisor
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025

Department of Energy (DOE) was established August 4, 1977; DOE provides the framework for a comprehensive national energy plan to include research and development of energy technology, energy conservation and regulation of energy production and use. For geothermal energy, the predecessor agencies were the Atomic Energy Commission and Energy Research and Development Administration. Contact:

U.S. Department of Energy
Division of Geothermal Resources
Washington, D.C. 20545

Bureau of Land Management (BLM) was established in 1946 with responsibility for total management of 450 million acres of public lands, to include mineral resources. It is within the Department of Interior.

The BLM supervises lease sales for geothermal lands. Contact:

Bureau of Land Management
U.S. Department of Interior
Washington, D.C. 20240

Bureau of Reclamation (BuRec) was established in 1923 to locate, construct, operate and maintain works for the development and storage of waters in the western United States, as related to reclamation of arid and semiarid lands. The BuRec has been active in desalination efforts at the East Mesa site in California. Contact:

Bureau of Reclamation
Department of Interior
Washington, D.C. 20240

Forest Service (FS) was created February 1, 1905 to manage the forest reserves of the U.S. The FS is involved in environmental aspects of geothermal energy. Contact:

Forest Service
Department of Agriculture
P.O. Box 2417
Washington, D.C. 20013

Electric Power Research Institute (EPRI) was founded in 1972 to expand electric energy research and development under the voluntary sponsorship of the nation's utility industry; to develop coordinated advanced technology programs for improving electric power production, transmission, distribution and utilization in an environmentally acceptable manner. Primary areas of research are: nuclear power, fossil fuel and advanced systems, electrical systems and energy analysis and environment. Maintains library. Publishes monthly journal; also publishes reports from

research projects. Contact:

Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303

National Electric Reliability Council (NERC) was founded in 1968 to periodically review regional and inter-regional activities on reliability and adequacy, and to act as an information exchange media relating to power supply in North America. Address inquiries to:

National Electric Reliability Council
Research Park, Terhune Rd.
Princeton, NJ 08540

F. Summary and Conclusion

Accurate assessment of individual sites for power production or direct utilization and forecasts for utilization of the resources in the western United States require reliable data.

Geothermal power plants are currently only in The Geysers region in California where the 1979 power output is 608 MWe from 12 units. Construction and plans include over 10 additional plants in California, New Mexico, Idaho, Utah, Nevada and Hawaii (Ref. 7,12,13). See Table 2.

Tables 3 and 4 show drilling activities in California during 1978 and 1979. For drilling activities in California in 1977 refer to (Ref. 59), and for years prior to 1977, see (Ref. 19, 60). Table 5 gives drilling data for the state of Nevada. Leasing data for the state of California is presented in Table 6 and 7. The increase in geothermal activities in California and other western states is obvious, and hence the need for accurate data.

This geothermal databook provides up-to-date reference data useful in assessing geothermal areas for their potential to produce electric power. A summary of current site-specific data for the western United States is given in Appendix I. The site-specific data for 21 geothermal prospects presently stored on the Energy Conversion (ENCON) file is presented in Appendix II. And finally, the exploration and development of geothermal energy requires data to include diverse areas as location of roads and railways, existing land use, availability of water, proximity to transmission lines and annual rainfall. Appendix III consists of maps of California and Nevada containing this information.

TABLE 2. - POWER PLANT CONSTRUCTION IN THE WESTERN UNITED STATES (Ref. 11,62-77)

Geothermal Area	Developer and Constructor	MWe	Year On-Line
<u>California</u>			
The Geysers Unit 12	Pacific Gas & Electric Co., Union-Magma-Thermal	106	March 1979
Unit 13	Pacific Gas & Electric Co., Aminoil USA, General Electric Turbine	135	1980
Unit 14	Pacific Gas & Electric Co., Union-Magma-Thermal, Toshiba Turbine	110	March 1980
Unit 15	Pacific Gas & Electric Co., General Electric Co., Thermogenics	55	June 1979
Units 16, 17	Pacific Gas & Electric Co., Aminoil USA, Union-Magma- Thermal, Toshiba	110, 110	1981 (16) 1982 (17)
Units 18, 19	Pacific Gas & Electric Co., Aminoil USA, Union-Magma- Thermal, Toshiba	110, 110	1982 (18) 1983 (19)
Units 20, 21	Pacific Gas & Electric Co.	110, 110	1984
Units 22, 23	Pacific Gas & Electric Co.	110, 110	1985, 1986
Units 24, 25	Pacific Gas & Electric Co.	110, 110	1987, 1988
—	Northern California Power Agency, Shell Oil Co., Plumas-Sierra Rural, Electric Cooperative	55, 55	Oct. 1981 (55 MWe) Mar. 1982 (55 MWe)
—	Northern California Power Agency, Resource Funding Limited	33, 33	Oct. 1983 (33 MWe) Jan. 1984 (33 MWe)
Bottle Rock	California Division of Water Resources	55	1983
South Geysers	DWR South Geysers	55	1984
	SMUD No. 1	110	1985
	SMUD No. 2	110	1986
	DWR Newfield	55	1985
	Hot Water No. 1	50	1986

TABLE 2. (continued)

Geothermal Area	Developer and Constructor	MWe	Year On-Line
South Geysers (Contd.)	Hot Water No. 2, 3	100	1987
	Hot Water No. 4, 5, 6	150	1988
	Hot Water No. 7, 8, 9, 10	200	1989
	Hot Water No. 11, 12, 13, 14	200	1990
Brawley	Union Oil Co., Southern California Edison Co.	10	mid-1980
	CUI Venture	50	—
Salton Sea	Union Oil Co., Southern California Edison, Southern Pacific Land Co.	10	early-1980
	Magma Power Co., San Diego Gas & Electric Co., Morrison Knudsen Co.	50	1982
East Mesa	Republic Geothermal, Inc., San Diego Gas & Electric Co., Ralph M. Parsons Co., General Electric Co.	48 net 10 (initial)	1981 June 1980
	Magma Power Co., Imperial Irrigation District	10	June 1979
Heber	Chevron Resources Co., Southern California Edison Co.	50	1982
Wendel-Amedee	California Department of Water Resources, Geo-Products Corp.	55	—
Westmorland	Republic Geothermal, Inc., MAPCO	50	1983
<u>New Mexico</u>			
Baca Location No. 1	Union Oil Co., Public Service Company of New Mexico, U.S. Department of Energy	50	Jan. 1982
<u>Idaho</u>			
Raft River	Idaho National Engineering Laboratory, EG&G, Idaho	5	early-1980
<u>Hawaii</u>			
Puna	Hawaii Electric Co., State of Hawaii	3	—

TABLE 2. (continued)

Geothermal Area	Developer and Constructor	MWe	Year On-Line
<u>Utah</u>			
Roosevelt	Phillips Petroleum Co., Thermal Power Co., Utah Power & Light,	20	early-1984
Roosevelt	AMAX, O'Brien Resources, VTN Consolidated, Utah Power & Light, Natomas	(may be unitized)	—
<u>Nevada</u>			
Desert Peak (Brady-Hazen)	Phillips Petroleum Co., Southern Union Production Co., Sierra Pacific Power Co., Stone & Webster Engineering	20	1983
To be selected	Sacramento Municipal Utility District, Eugene Water & Electric Board, Sierra Pacific Power	20 to 50	—

TABLE 3. - GEOTHERMAL DRILLING IN CALIFORNIA IN 1979 (Ref. 16,17)

Geothermal Area	Operator	Drilling Rig	Comments
The Geysers	Aminoil USA Inc. (CA956) 37A-34	Montgomery Drilling	spud 1/4/79, completed 2/12/79
	(CA1862) 57-27	Montgomery Drilling	spud 4/19/79
	D & V3	Montgomery Drilling	spud 2/16/79, completed 3/31/79
	Geothermal Kinetics, Inc. "Rorabaugh" 2	Atlantic Oil	spud 4/16/79
	McCulloch Geothermal Corp.		
	Coleman 1-5	Monterey Drilling	spud 2/8/79, rel. rig 4/23/79
	Coleman 1-6	Monterey Drilling	spud 2/8/79
	Natomas Co. Davies-State 5206-1	Atlantic Oil Co.	spud 1/4/79
	Union Oil Co. DX State 4596-43	Loffland Bros.	spud 1/1/79
	"Cobb Mountain Hunting Club" 7	Loffland Bros.	spud 1/27/79, completed 3/28/79
Brawley/Imperial County	DX State 4596-40	Loffland Bros.	spud 3/20/79
	DX State 4596-44	Loffland Bros.	spud 3/6/79
	McCulloch Geothermal Corp.		
	Mercer 2-28 (I)	Republic Drilling Co.	spud 1/27/79, completed
	Union Oil Co. Veysey 9	Loffland Bros.	spud 2/19/79, completed Mar. 1979
Salton Sea/Imperial County	Union Oil Co. I.I.D. 5 (E)	Loffland Bros.	spud 1/2/79, completed 1/30/79
	I.I.D. 6	Loffland Bros.	spud 1/29/79, completed 2/18/79
	"Sinclair" 13 (E)	Loffland Bros.	spud 4/9/79
	McCulloch Geothermal Corp.		
	Hot Mineral 1-15 (E) Hot Mineral 2-15 (E)	Republic Drilling Co.	spud 1/30/79
	Imperial Magma IW 5 (I)	Coastal Drilling Co.	spud 2/12/79, rel. rig 2/18/79

TABLE 4. - GEOTHERMAL DRILLING IN CALIFORNIA IN 1978 (Ref. 16,18)

Geothermal Area	Operator	Drilling Rig	Comments
Brawley/Imperial County	Chevron USA Inc. Brandt 1 (E)	Peter Bawden Drilling Co.	spud 8/7/78
	Orita C-131 (O)	Peter Bawden Drilling Co.	spud Mar. 78
	McCulloch Geothermal Corp. Mercer 1-28 (E)	Republic Drilling	spud 7/11/78, completed
	Francisco 2-5 (E)	Hunnicut & Camp Drilling	
	Phillips Petroleum East Brawley Strat Test 1 (E)		spud Feb. 78, did not reach proposed depth, moved to drill 1-A
	East Brawley Strat Test 1A (E) (O)	Dixie Drilling	Completed 4/22/78
	East Brawley Strat Test 2 (O)		
	East Brawley Strat Test 3 (O)		
	Union Oil Co. Slater 1 (E)	Peter Bawden Drilling	spud 11/5/78 ^{3/22/79} completed
	Veysey 7 (E) (I)	Peter Bawden Drilling	completed 8/25/78
	Veysey 8 (P)	Peter Bawden Drilling	spud 8/25/78
Borax Lake/Lake County	Phillips Petroleum Co. Borax Lake 7-1(E)(O)	originally Cammay Drilling, change to Montgomery Drilling	spud 2/16/78, 11/22/78 idle
Clear Lake/Lake County	Occidental Geothermal Inc. Bouscal 1 (E) (S)	Atlantic Oil Co.	spud 9/3/78, suspended 12/29/78
East Mesa/Imperial County	Magma Power Co. 7, 44A-7	Coastal Drilling Co.	spud 6/3/78
	7, 44B-7	Coastal Drilling Co.	spud 7/30/78
	7, 46A-7 (I)	Coastal Drilling Co.	completed Sept. 78
	7, 46B-7 (I)	Coastal Drilling Co.	completed 11/8/78
	7, 48A-7 (P)	Coastal Drilling Co.	spud 10/30/78

TABLE 4. (continued)

Geothermal Area	Operator	Drilling Rig	Comments
The Geysers	Republic Geothermal Inc. East Mesa 58-30	Kenai-Camrich Drilling	spud 7/9/78
	Aminoil USA Inc. (CA956) 37-34	Montgomery Drilling	spud 11/15/78, Rel. rig 1/2/78
	(CA956) 73-34	Montgomery Drilling	spud 2/11/78
	(CA958) 56A-34	Montgomery Drilling	spud 6/3/78, Rel. rig 9/16/78 completed
	Thorne 7	Montgomery Drilling	spud 4/1/78, suspended 7/24/78
	Aidlin 3 (S)	Montgomery Drilling	
	McCulloch Geothermal Corp. Newfield 1-33 (E)	Hunnicut & Camp Drilling	spud 11/27/78
	Thermogenics Inc. GRI-Rorabaugh 1	Hoover Drilling	
	GRI-Rorabaugh 2	Hoover Drilling	
	Rorabaugh A-9	Hoover Drilling	
	Rorabaugh A-11	Big "O" Drilling	spud 5/8/78, completed
	Klau Mines-K-1A(S)	Big "O" Drilling	spud 1/20/78, suspended 5/12/78
	Union Oil Co. Angeli 1 (E)(S)	Loffland Bros.	spud 9/2/78, suspended 12/30/78
	Occidental Federal 1	Loffland Bros.	spud 10/4/78, completed 1/30/79
	"Cobb Mountain Hunting Club" 6	Loffland Bros.	spud 7/18/78
	LF State 4597, 21 (S)	Loffland Bros.	spud 1/21/78, suspended 2/9/78
	LF State 4597, 23	Loffland Bros.	spud 2/5/78
	LF State 4597, 24	Loffland Bros.	completed 8/31/78
	DX State 4596-19	Loffland Bros.	completed Apr. 78
	DX State 4596-38	Loffland Bros.	completed June 78
	Ottoboni State 4596-25 (P)	Loffland Bros.	spud 5/30/78
	Sulphur Bank 25	Hoover Drilling Co.	completed 2/23/78
	Sulphur Bank 26 (P)	Hoover Drilling Co.	spud 2/21/78, completed Apr. 78
	Sulphur Bank 27	Hoover Drilling Co.	
	Shell Oil Co. U.S. Geothermal 33A-4		
	U.S. Geothermal 43-4 (E) (A)	Atlantic Oil Co.	spud 3/28/78, abandoned 6/24/78

TABLE 4. (continued)

<u>Geothermal Area</u>	<u>Operator</u>	<u>Drilling Rig</u>	<u>Comments</u>
	U.S. Geothermal 69-2 (E) (A)	Atlantic Oil Co.	spud 6/30/78, abandoned 8/23/78
Middletown/Napa County	Amax Exploration Inc. Amax 1	Montgomery Drilling	spud 8/4/78, Rel. rig 11/5/78
Salton Sea/Imperial County	Union Oil Co. Sinclair 15 (P)	Loffland Bros.	spud 10/22/78, completed 1/10/79

E = exploratory, P = production, I = injection, S = suspended, A = abandoned, O = observation

TABLE 5. - GEOTHERMAL DRILLING IN NEVADA TO 1977 (Ref. 8,29)

Operator	Well Name	Depth, m	Completion Date	Maximum Temperature (°C)
CHURCHILL COUNTY				
Brady's Hot Springs				
Magma Power Co.	Brady No. 1	213?	1959?	
Magma Power Co.	Brady No. 2	73	1959?	166
Magma Power Co.	Brady No. 3	186	1961?	168
Magma Power Co.	Brady No. 4	220	1961?	
Magma Power Co.	Brady No. 5	181	1961?	
Magma Power Co.	Brady No. 6	235	?	
Magma Power Co.	Brady No. 7	76	?	
Earth Energy Inc.	R Brady EF.No.1	1543?	1964	212
Earth Energy Inc.	Brady Pros.No.1	536?	1965?	179
Union Oil Co. of Calif.	SP-Brady No.1	2217	1974	188
Magma Energy Inc.	SP-Brady No.2	1355	1975	
Magma Energy Inc.	SP-Brady No.8	1057	1975	
Desert Peak Area				
Phillips Petroleum Co.	Desert Peak No.29-1	2335	1974	
Phillips Petroleum Co.	Desert Peak B No.21-1	1265	1976	208
Phillips Petroleum Co.	Desert Peak B No.21-2	973	1976	199
Soda Lake				
Chevron-Phillips	Soda Lake No.1-29	1312	1974	
Chevron Resources Co.	Soda Lake No.44-5	1545	1978	
Stillwater				
O'Neill Geothermal Inc.	J.I. O'Neill, Jr.- Reynolds No.1	1291	1964	129
Union Oil Co.	Weishaupt No.1	1219	1976	
Union Oil Co.	Weishaupt No.2	1219	1977	
Union Oil Co.	De Braga No.1	1219	1977	
Lee Hot Springs				
Oxy Geothermal Inc.	Federal No.72-33(K)	919	1978?	
DOUGLAS COUNTY				
Wally's Hot Springs				
U.S. Steel Corp.	Wally's No.1	386	1962	83
U.S. Steel Corp.	Wally's No.2	152	1962	

TABLE 5. - GEOTHERMAL DRILLING IN NEVADA TO 1977 (continued)

Operator	Well Name	Depth, m	Completion Date	Maximum Temperature (°C)
EUREKA COUNTY				
Beowawe Geysers				
Magma Power Co.	Beowawe No.1	585	1959?	
Magma Power Co.	Beowawe No.2	218	1959?	
Vulcan Thermal Power Co.	Vulcan No.1	194	1961	212
Vulcan Thermal Power Co.	Vulcan No.2	200	1961	208
Vulcan Thermal Power Co.	Vulcan No.3	243	1961	208
Vulcan Thermal Power Co.	Vulcan No.4	234	1961	210
Vulcan Thermal Power Co.	Vulcan No.5	72	1963?	
Vulcan Thermal Power Co.	Vulcan No.6	146	1963	139
Sierra Pacific Power Co.	Sierra No.1	283	1964?	
Sierra Pacific Power Co.	Sierra No.2	127	1964	
Sierra Pacific Power Co.	Sierra No.3	625	1965	
Sierra Pacific Power Co.	Sierra No.4	306	1964?	116
Magma Energy Inc.	Batz No.1	1660	1975	
Hot Springs Point (Crescent Valley)				
Magma Power Co.	Hot Springs Point No.1(?)	125	1965	74
Chevron Oil Co.	Hot Springs Point No.1	712	1975	
HUMBOLDT COUNTY				
Hot Springs Ranch				
Magma Power Co.	Tipton No.1	936	1974	
LANDER COUNTY				
Beowawe Geysers				
Chevron-American Thermal Resources	Ginn No.1-13	2915	1974	
Chevron U.S.A. Inc.	Rossi No.21-19 (Beowawe No.1)	1731	1976	
LYON COUNTY				
Hazen (Fernley)				
Magma Power Co.	Hazen No.1 (?)	229	1962	135+
Magma Power Co.	Hazen No.2 (?)	91?	1962	

TABLE 5. - GEOTHERMAL DRILLING IN NEVADA TO 1977 (continued)

Operator	Well Name	Depth, m	Completion Date	Maximum Temperature (°C)
Hazen (Fernley) - continued				
Magma Power Co.	Hazen No.3 (?)	91?	1962	
Magma Energy Inc.	Fernley No.1	1118	1974	
Wabushka Hot Springs				
Magma Power Co.	Wabushka No.1	149	1959	
Magma Power Co.	Wabushka No.2	162?	1959	
Magma Power Co.	Wabushka No.3	678	1959	108
Hind's Hot Springs				
U.S. Steel Corp.	Hind's No.1 (?)	?	1962?	66
U.S. Steel Corp.	Hind's No.2 (?)	?	1962?	
U.S. Steel Corp.	Hind's No.3 (?)	?	1962?	
NYE COUNTY				
Darrough Hot Springs				
Magma Power Co.	Darrough No.1 (?)	247	1962	129
PERSHING COUNTY				
Humboldt (Rye Patch)				
Phillips Petroleum Co.	Campbell E No.1	565	1977	163
Union Oil Co.	Campbell No.1	~2012	1978	
WASHOE COUNTY				
Ward's Hot Springs (Fly Ranch)				
Western Geothermal Inc.	Fly Ranch No.1 (?)	305+	1964	
Granite Ranch				
Western Geothermal Inc.	(?)Granite Creek Ranch 1	244	1965?	
San Emidio Desert				
Chevron Oil Co.	Cosmos No.1-8	1223	1975	
Chevron Oil Co.	Cosmos No.1-9	1636	1978	
The Needles (Pyramid Lake)				
Western Geothermal Inc.	Needles No.1	1795	1964	~ 116

TABLE 5. - GEOTHERMAL DRILLING IN NEVADA TO 1977 (continued)

Operator	Well Name	Depth, m	Completion Date	Maximum Temperature (°C)
The Needles (Pyramid Lake) - continued				
Western Geothermal Inc.	Needles No.2 (?)	1219±	1962	
Western Geothermal Inc.	Needles No.3 (?)		1964	
Steamboat Hot Springs				
Nevada Thermal Power Co.	Steamboat No.1	558	1954	
Nevada Thermal Power Co.	Steamboat No.2	294	1959	
Nevada Thermal Power Co.	Steamboat No.3	385	1960?	
Nevada Thermal Power Co.	Steamboat No.4	158?	1960	186
Nevada Thermal Power Co.	Steamboat No.5	252	1961	175
Nevada Thermal Power Co.	Steamboat No.6	218	1961	179
WHITE PINE COUNTY				
Monte Neva Hot Springs				
Magma Power Co.	Monte Neva No.1 (?)	123	1965	88

TABLE 6. - GEOTHERMAL LEASES IN CALIFORNIA
AS OF DEC.1978* (Ref. 27,78,79)

Geothermal Area and/or County	Current Lessee	Lease No.	Acerage Leased	Date
COMPETITIVE LEASES				
East Mesa/Imperial County	Magma Power Co.	CA964	1867.60	9/1/74
	" "	CA965	1437.12	"
	" "	CA968	1760.00	"
	Republic Geothermal	CA966	2549.09	8/1/74
	" "	CA967	1596.19	"
	" "	CA1903	2560.00	11/1/76
Lake City-Surprise Valley/Modoc	Suporn Energy Corp.	CA3064	2586.46	4/1/76
Mono Long Valley/ Mono	Geothermal Resources Int.	CA961	1815.08	3/1/75
	" "	CA962	1895.21	"
	City of Burbank	CA963	1772.70	5/1/77
The Geysers	Shell Oil Co.	CA949	2477.12	8/1/74
	" "	CA950	1599.63	"
	Thermogenics Inc.	CA951	174.72	"
	Union Oil, Magma Power , Thermal Power	CA952	251.85	10/1/74
	" "	CA953	168.90	"
	" "	CA954	2395.23	"
	Aminoil USA Inc.	CA956	79.95	8/1/74
	Aminoil USA and Occidental Geoth.	CA956A	169.60	"
	" "	CA958	223.79	"
	Union Oil, Magma Power , Thermal Power	CA959	45.00	10/1/74
	" "	CA960	736.94	11/1/74
	Aminoil USA Inc.	CA1862	625.03	8/1/74
	Union Oil, Magma Power , Thermal Power	CA1863	160.00	"
	Shell Oil Co.	CA4602	1653.15	12/1/77
	" "	CA4603	1203.81	"
Wendel Amedee/Lassen	R.O.Elliott	CA5411	1205.20	12/1/78
NONCOMPETITIVE LEASES				
Imperial County	Natomas Co.	CA1063	2243.33	7/1/78
	Black, Quirk, Zebal and VTN Consolidated Inc.	CA1156	2122.42	"
	" "	CA1158	1710.80	7/1/78
	Magma Energy Inc.	CA2364	761.00	6/1/78
Inyo County	Kerr McGee Chemical	CA1065	2561.50	12/1/76
	" "	CA1066	2556.00	"
	" "	CA1067	1760.00	"
	" "	CA1068	1880.05	"
	" "	CA1069	2025.73	"

TABLE 6. - GEOTHERMAL LEASES IN CALIFORNIA
AS OF DEC.1978 (Continued)

Geothermal Area and/or County	Current Lessee	Lease No.	Acerage Leased	Date Leased
NONCOMPETITIVE LEASES(Continued)				
Modoc County	Eason Oil Co.	CA1305	1280.00	9/1/75
	Mobil Oil Co.	CA1140	1037.76	11/1/75
	" "	CA1141	873.65	"
	Supron Energy Corp.	CA3075	1279.00	4/1/76
	" "	CA3076	1824.03	"
San Bernardino County	Getty Oil and Mono Power	CA998	1640.00	9/1/78
	" "	CA1026	1118.36	"
	" "	CA2251	1599.88	"
	" "	CA2444	1120.00	"
INDIAN LEASES				
Modoc County	Geothermal Power Corp.	SBL115	480.00	1/29/74
Mono County	Getty Oil Co.	SBL74	120.00	10/5/71

* Additional information on leasing and sale dates beyond Dec.1978 may be obtained from References (20-26,28).

TABLE 7. - ISSUED FEDERAL LEASES* - CALIFORNIA

AS OF DEC. 5, 1978 (Ref. 27)

County	Noncompetitive Leases		Competitive Leases		Indian Leases		Total Leases Issued		
	No. of Leases	Acreage	No. of Leases	Acreage	No. of Leases	Acreage	No. of Leases	Acreage	Indian Acreage
Imperial	4	6,837.55	6	11,770.00	—	—	10	18,607.55	—
Inyo	5	10,783.28	—	—	—	—	5	10,783.28	—
Lassen	—	—	1	1,205.20	—	—	1	1,205.20	—
Modoc	5	6,294.44	1	2,586.46	1	480.00	7	9,360.90	480.00
Mono	—	—	3	5,482.99	1	120.00	4	5,602.99	120.00
San Bernardino	4	5,478.24	—	—	—	—	4	5,478.24	—
Sonoma, Lake Mendocino	—	—	15	12,134.32	—	—	15	12,134.32	—
TOTAL	18	29,393.51	26	33,178.97	2	600.00	46	63,172.48	600.00

*All leases are currently active.

G. Unit Conversion Factors

<u>To Convert From</u>	<u>To</u>	<u>Multiply By</u>
Acres	m ²	4047
Acres	ft ²	43560
Acre-feet	ft ³	43560
Acre-feet	m ³	1233.48
Atmospheres	bars	1.01325
Atmospheres	kg/cm ²	1.03323
Atmospheres	psi	14.696
Atmospheres	MPa	
Bars	atmospheres	0.986923
Bars	kg/cm ²	1.01972
Bars	psi	14.5038
Bars	pascal	
Btu	cal	251.996
Btu	joules	1054.8
Calories	joules	4.184
Feet	meters	0.3048
Gallons	liters	3.7854
Hectares	acres	2.47105
Hectares	m ²	10000
Hectares	ft ²	107639.10
Joules	Btu	0.9480x10 ⁻³
Kilograms(kg)	pounds(lb)	2.2046
Kilometers(km)	miles	0.62137
Km ²	mile ²	0.3861006
Kg/cm ²	bar	0.980665
Psi	bar	0.068947
Liters (L)	gallons(U.S.liq.)	0.264178
Meters (m)	feet (ft)	3.280833
Miles	kilometers	1.60935
Mile ²	km ²	2.59001
Pascals	bars	10 ⁻⁵

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