A-53

REPORT TO CITY COUNCIL OF BOUNTIFUL

July 9, 1977

A. L. McDonald Geothermal Resources Lease

Serial No. U 14990

Roosevelt Hot Springs KGRA

CONTENTS

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7/9/77

A. L. McDonald

Geothermal Resource Lease

Serial No. U-14990

Roosevelt Hot Springs KGRA

The information herein is to supplement facts and data that has been submitted earlier regarding the Federal geothermal lease presently held by A. L. McDonald, Milford, Utah.

We have received counsel and other valuable assistance from many professionals in the geothermal field. Acknowledgement for special services must go to the following:

Dr. Burton Barnes
Frank L. Battuello
Dr. C. W. Berge
Buddy Bowden
Kenneth W. Bull
Eugene V. Ciancanelli
James B. Cotter
Dr. Gary W. Crosby
William L. D'Olier
Dr. Val Finlayson
Dr. Robert M. Galbraith
Stanley Green
Dr. John Wallace Gwynn
Dee Hansen
Kent E. Hatfield
Claire C. Heinzelman
Bruce Hellier
Norman P. Ingraham
Lowell Johnson
Jerry Klein
Dr. James B. Koenig
James Kohler
Dr. Jay F. Kunze, P.E.
Robert Lindquist
Nancy McArtie
Frank Metcalf
Gordon A. Needham
Dr. Carl Ott
Milan Papulak
Dr. Joseph Ricco
H. Rogers, Jr.
Dr. Vern Rogers
Dr. Jack Salisbury
Carol Shobe
Randall Stephens
Dr. Stanley H. Ward
Dr. James Whelen
Dr. Mark M. Wright
Robert Wright

Through their cooperation, a series of facts have been identified that should be given serious consideration in Bountiful's assessment of purchasing the McDonald lease, such as:

A. Availability of Resource and Magnitude of Reservoir:

There is complete agreement that a viable resource has been discovered and proven to be of commercial value; however, to date there has not been enough testing to characterize the reservoir. Additional testing and ultimately putting the reservoir into production will be required to determine the production capabilities of individual wells and whether the reservoir will sustain continuous high volume output. The entity who leads out by installing surface equipment for long term testing will be exposed to high risk.

The paper prepared by R. C. Linzer, G. W. Crosby, and C. W. Berge, Phillips Petroleum Company, entitled "Recent Developments at the Roosevelt Hot Springs KGRA" is an excellent summary of the status of geothermal development surrounding the McDonald property. A copy of the paper is under Index "E".

B. Development of Wells:

The McDonald property is located straddle the Dome fault. Approximately one-half of the forty (40) acres lies west of the Dome. The wells that have been drilled on the West side have been non-productive; however, all major wells drilled on the East side have been productive.

It is believed there is a greater risk to drill geothermal wells toward the top of the Dome. A study is near completion in the feasibility of Bountiful drilling at least one (1) well and perhaps two (2) on the east half of the McDonald property. It appears this can be accomplished, but the cost will be greater per well than Phillips Petroleum Company experienced in their drilling program. Carol A. Petersen quotes Dr. Gary Crosby, Phillips Petrolem Company on Page 1 of her memorandum dated May 5, 1976 to J. W. Gwynn. A copy of the memorandum is found under Index "F".

A copy of the drilling study will be made available to you as soon as it is complete and should be inserted under Index "F".

C. Underground Water Rights:

The courts are still considering whether geothermal resources are mineral, water or what. The general feeling is that geothermal resources will be identified as mineral. However, the Utah Legislature has delegated the Engineer of the State of Utah full authority in the regulation of geothermal resources. The premise being that geothermal steam is water.

The position of the State Engineer's office is that all waters (geothermal steam) in the State are public property whether under State or Federal lands, and appropriations by the State Engineer are necessary before geothermal resources can be utilized. Applications have to be filed and hearings held just as if an irrigation or a culinary well is to be drilled. Approval is subject to the same requirements.

McDonald has previously filed applications for three (3) wells. The filings are No. 38796, 38797 and 38798. These applications will be transferred to Bountiful under the Lease Purchase Agreement. The State has agreed to this assignment but warns Bountiful will be subject to the same regulations as others.

The paper under Index E, page 4, under the section entitled "Water Application Proceeding" explains the question of water appropriations. Also question of water appropriations. Also refer to Carol A. Petersen's memorandum under Index F for additional on water.

The State favors unitization of lease holders in the Roosevelt KGRA and will apparantly use the authority of the office to accomplish the goal. The objective is to appropriate a defined amount of water for the entire KGRA and the use will be apportioned based on the amount of individual acreage.

It is the State's opinion that Phillips has done an extremely impressive job in all phases of their exploration activities. It appears that Phillips can do no wrong. That Phillips would likely be selected as the operating agent for the Roosevelt KGRA.

The question has been raised whether the chemical make-up of the water will, during sustained flow through a casing, reduce the diameter through scaling.

It has been determined, based on the analysis of water generally found in the KGRA, that over a long period of time scaling will occur. However, it has also been determined that through economical chemical treatement of the geothermal resource that casing life can be extended to more than thirty (30) years.

The chemical characteristic of the water is discussed beginning on page 6 and continuing on page 7 of Index "E", Table 3, on page 7 shows the water analysis.

D. Rights-of-Way, State and Federal Lands:

To utilize the geothermal resource pipe lines, transmission and distribution lines, power plants and other related equipment will have to be installed within the Roosevelt KGRA. The question whether the use of the land for these facilities would be prohibited where geothermal leases had been previously granted needed to be answered.

The letter from William Lowell Johnson, Land Specialist, State of Utah, Division of State Lands, and from Carol Shobe, Chief, Lands Section, United States Department of the Interior, Bureau of Land Management, (BLM) under Index "G", in general confirms that rights-of-way across State and Federal lands can be acquired under certain conditions and regulations.

The attachments and enclosures referred to in the above letters are available.

The United States Geological Survey (USGS) can also issue the use of Federal lands for research and development of geothermal power plants and associated equipment up to twenty-five megawatts. This special use is limited to five (5) years.

A letter from USGS confirming this was expected but failed to arrive. It will be furnished later and should be inserted under Index "G".

E. Disposition of Surplus Water:

It has been indicated that the potential geothermal resources on the McDonald property could produce as much as 2850 barrels per hour (barrel = 42 gallons) of surplus water.

The State will require that surplus water be reinjected into the underground. At the present time the exact point that reinjection will occur to regenerate the reservoir is unknown. Until this is determined, production well owners will have to, individually or jointly, furnish a reinjection well or wells.

Phillips plans to conduct a long term flow test this summer on Well No. 54-3. The flow will be piped to Well No. 82-33, for reinjection underground. An explanation of this plan can be found in the final paragraphs on page 7 of the paper under Index "E".

The reinjection of surplus water can best be done under a unitized area; however, during an extended interim period individual or joint reinjection wells will be used.

F. Generation and Transmission:

The estimated cost of the geothermal steam turbine generation can be determined quite accurately. A letter from F. L. Battuello, Senior Application Engineer, General Electric Company quotes $190 per kilowatt for the turbine-generator and accessories. A copy of the letter, a drawing No. RW 80-2557-B, and the turbine generator equipment list under Index "H" covers the equipment proposed to be furnished.

The letter continues and estimates the total installed value of $600 per kilowatt. The equipment that serves the turbine generator is shown on drawing #3051J91 and listed on the sheets that follow and are under Index "I".

It is my opinion that the total cost would be about $490 per kilowatt instead of $600.

Additional information is under Index "J". Carol Petersen attended a geothermal short course entitled "Geothermal Energy and Electric Utilities--a Background for Decision". Her memorandum to J. W. Gwynn is a summary of the seminar.

The Utah Power and Light Company (UP&L) has a 46,000 volt transmission line serving the Milford area that crosses the McDonald property. A copy of a map showing the location of the transmission lines is under Index "J".

We have determined that this transmission line can transmit at least ten (10) megawatts under normal loading conditions and can be tapped at a reasonable cost.

A letter has been sent to J. C. Taylor, Vice President, UP&L, requesting the transmission service and an opportunity to meet with him to discuss the details. A copy of the letter is under Index "J".

The estimated cost per kilowatt hour to deliver geothermal generated power to Bountiful from the Roosevelt KGRA based on the best information available is determined as follows:

ONE (1) TEN (10) MEGAWATT GEOTHERMAL TURBINE-GENERATOR

Capital Costs

Drilling of Two (2) Producing Wells	$1,500,000
Drilling of One (1) Reinjection Well	400,000
Power Plant and Auxiliaries	4,900,000
SUB TOTAL	$6,800,000
Engineering and Overhead	850,000
TOTAL PROJECT COST	$7,650,000

Energy Cost (Mills 1 Kw Hr)

Wells and Power Plant	7.570
Engineering and Overhead	0.947
Operation and Maintenance	1.611
Royalty	0.900
Transmission	2.000
TOTAL ENERGY COST (1)	11.228

(1) Based on 10 MW @85% plant capacity factor and a fixed charge rate of 8.30%.

General information on geothermal electric power generation is also under Index "J".

A paper by Ronald C. Barr, Earth Power Corporation, entitled "Geothermal Energy and Electric Power Generation" and one by Robert Lengquist, "Magma-Thermal Power" and Fritz Hirschfeld, Historian, entitled "Geothermal Power -- The 'Sleeper' in the Energy Race", furnishes excellent information.

G. Taxation:

Under the State Constitution, Bountiful would not be subject to state and local taxes.

Private corporations will be subject to tax payments.

A copy of a memorandum in the form of an opinion handed down by Robert H. Cooper, Assistant Director, Property Tax Division, State of Utah State Tax Commission on January 20, 1976 is under Index "K".

H. Financing:

To finance a project of this magnitude Bountiful would have to issue revenue or general obligation bonds.

The United States Energy Research and Development Administration (ERDA) has announced a vigorous program to have 3000 MW of geothermal electric power generation in operation by 1985.

To help accomplish this goal Congress has passed Public Law 93-410 in 1974. The Act established the Geothermal Loan Guaranty Program. The first loan was made on May 6, 1977.

A notice of the loan being made and an explanation of the guaranty loan program is under Index "L".

During our investigation we consulted many times with ERDA officials regarding their geothermal electric power generating programs.

We have been advised that within a few months ERDA will be requesting proposals from organizations desiring to participate in a demonstration project for the utilization of geothermal energy for electric power generation. The RFP will cover a five (5) megawatt and a ten (10) megawatt power plant. The principal funding will be through ERDA.

In our discussions with Dr. Val Finlayson, Utah Power and Light Company (UP&L) he brought to our attention a request for expression of interest for a fifty (50) megawatt geothermal demonstration power plant UP&L had received from ERDA.

A copy of a part of the request is under Index "L"

I. General:

It has been extremely gratifying to have so many people come forth and give assistance during our investigation of this project, including a number of Bountiful citizens.

In our discussions with most of the people we have consulted with, we have encouraged them to express their personal opinions pertaining to Bountiful purchasing the McDonald geothermal lease, drilling geothermal wells and constructing and operating a geothermal electric generating plant. It was understood that we were asking for their comments and under no circumstances would they or their firms or companys' be bound by their expressions.

The negative comments were about equal to the positive. The significant ones are as follows:

1. Phillips Petroleum has spent about 6.5 million dollars to prove the McDonald property is favorably situated.
2. Phillips Petroleum has so much money invested in the Roosevelt KGRA that they will not be able to market steam at a price compleptive with coal costs for more than five (5) years from now.
3. Forty (40) acres is too small. Not more than one well can be

drilled on it.

4. Bountiful can not realize any value back from the McDonald lease even under unitization.

5. If Bountiful purchases the lease it should promptly drill four (4) wells before regulations are adopted that limit the number of wells per acre.

6. Bountiful should not use public funds in high risk projects. Let others develop and prove the geothermal resource and Bountiful purchase steam.

7. The cost to drill wells on the McDonald property will be risky and expensive. If Bountiful purchases the lease it should immediately approve the unitization agreement and participate in the benefits of the entire KGRA.

8. Even though the cost of the lease is expensive, Bountiful could develop the geothermal resource and build and operate a geothermal electric power generating plant at a lower cost than any other operator.

This represents the type of comments received.

Excellent comments were received from Dr. Gary W. Crosby, Exploration Director, Phillips Petroleum Company. They covered a broader range and are extremely more pertinent than any others received. A copy of his letter is under Index "M" and should be studied carefully.

Dr. James B. Koenig, Geotherm Ex, Berkeley, California, has been retained to prepare a paper giving his opinion on benefits and adversities that would result from Bountiful purchasing the McDonald lease.

Unfortunately we have not received his paper at the time this information was being assembled nor have we received the geothermal well drilling plan being prepared. As soon as these documents are received they will be furnished and should be inserted in Index "N" and "F" respectively.

E

RECENT DE LOPMENTS AT THE ROOSEVELT HOT S INGS KGRA

R. C. LENZER, G. W. CROSBY AND C. W. BERGE

PHILLIPS PETROLEUM COMPANY, GEOTHERMAL OPERATIONS

DEL MAR, CALIFORNIA 92014

ABSTRACT

The Roosevelt geothermal field, located in southwestern Utah, has been the focus of a high level of activity by both private industry and the academic community. Phillips Petroleum Company has drilled seven and Thermal Power Company two, of nine exploration wells to depths ranging between 370 and 2300 meters into a late Tertiary granitic igneous complex which intruded Precambrian (?) metamorphic rocks. The reservoir is confined to fractures within the granitic and metamorphic rocks. The nature of the reservoir is such that all wells drilled are wildcats.

The geothermal field lies along the west side of the central Mineral Range. Young rhyolite domes, with associated flows, pierce the late Tertiary granitic complex a few kilometers to the east and south of the producing wells. The heat at Roosevelt is probably supplied by the parent magma for the rhyolite domes.

Phillips' integrated exploration program combining geology, geochemistry and geophysics culminated in the drilling of the discovery well in April of 1975. The resource is a water dominated geothermal system with a maximum temperature in excess of 265°C. The water is a sodium chloride water with salinity less than 8000 mg/l. Recent activities include the formation of the Roosevelt Hot Springs Unit, applications to appropriate water from the state, the establishment of a groundwater monitoring system in the valley, and preparation for additional reservoir testing.

INTRODUCTION

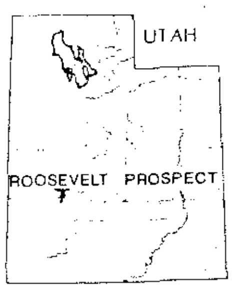

Fig. 1
Utah Index Map

The Roosevelt geothermal field is situated in the western foothills of the Mineral Range in eastern Beaver County, Utah, near the eastern edge of the Basin and Range physiographic province (Fig. 1). The field named for a now dry-hot springs is about 12 miles northeast of the city of Milford and about 18 miles northwest of Beaver, the county seat. Among previous investigations are water studies by Lee (1908), Mundorff (1970) and Mower and Cordova (1974). Earll (1957) geologically mapped portions of the Mineral Range. Condie (1960) investigated the petrogenesis of the Mineral Range Pluton. Recently, Petersen (1974) focused attention on the geology and geothermal potential of the Roosevelt Hot Springs area. In 1975 the University of Utah researchers launched an in-depth program and have published many reports, too numerous to be mentioned here.

Phillips Petroleum Company's exploration activities in Utah began in late 1972 and a chronological listing of the activities at Roosevelt are given in Table 1. As shown, many exploration surveys were completed in the 1-1/2 years preceding the Roosevelt KGRA lease sale. An evaluation of these surveys led to the conclusion that the Roosevelt area showed exceptional promise. The lease sale in July 1974, was the first KGRA put up for bid in the state. The original eight sections in the KGRA had grown to 36.5 sections as a result of the competitive interest shown in the January 1974 noncompetitive acreage filing period. Of twelve tracts offered in the July sale, Phillips acquired nine tracts totaling 18,871 acres at a cost of $798,860. The location of the tracts, the successful bidder, cost of each tract, and cost per acre are shown in Fig. 2. After the leases issued in October 1974, exploration activity shifted to drilling the acquired acreage. During 1975 six exploratory wells and two stratigraphic tests were drilled. The discovery well (3-1), the second well drilled, came in at the end of April. During 1976, efforts focused toward furthering the knowledge of the geothermal system through resevoir tests and a variety of geophysical and geochemical surveys.

TABLE

CHRONOLOGY OF PHILLIPS ACTIVITIES AT THE ROOSEVELT PROSPECT

LATE	1972	LITERATURE SURVEY & FIELD RECONNAISSANCE
FEB	1973	RECONNAISSANCE GEOCHEMICAL SURVEY
MAR	1973	GRAVITY SURVEY
MAY	1973	GEOCHEMICAL SURVEY (CONTINUING)
MAY	1973	EARLY LEASING ACTIVITIES (CONTINUING)
JUNE	1973	BIPOLE - DIPOLE SURVEY
JUNE	1973	GROUNDNOISE SURVEY
JULY	1973	TEMPERATURE GRADIENT SURVEY (CONTINUING)
OCT	1973	MAGNETOTELLURIC SURVEY
JULY	1974	COMPETITIVE LEASE SALE (~18,000 ACRES)
OCT	1974	LEASES ISSUE
DEC	1974	REFLECTION SEISMIC SURVEY
FEB	1975	SPUDDED OBSERVATION HOLE #2
MAR	1975	SPUDDED OBSERVATION HOLE #1
MAR	1975	SPUDDED ROOSEVELT KGRA #9-1
APR	1975	SPUDDED ROOSEVELT KGRA #3-1 - DISCOVERY WELL
APR	1975	GROUND LEVEL MAGNETIC SURVEY
MAY	1975	MAGNETOTELLURIC SURVEY
JUNE	1975	PETROLOGIC STUDIES
JULY	1975	SPUDDED ROOSEVELT KGRA #54-3
AUG	1975	SPUDDED ROOSEVELT KGRA #12-35
OCT	1975	SPUDDED ROOSEVELT KGRA #13-10
NOV	1975	SPUDDED ROOSEVELT KGRA #82-33
JAN	1976	WATER OBSERVATION SYSTEM
FEB	1976	MAGNETOTELLURIC SURVEY
FEB	1976	MOST SIGNIFICANT FLOW TEST (#54-3)
MAR	1976	ISOTOPIC STUDIES
APR	1976	WATER APPROPRIATION HEARING
APR	1976	UNIT APPROVED
MAY	1976	HELIUM SURVEY
AUG	1976	SPUDDED ROOSEVELT HOT SPRINGS UNIT #25-15
OCT	1976	MICROEARTHQUAKE AND GROUNDNOISE SURVEYS
OCT	1976	SPONTANEOUS POTENTIAL SURVEY
NOV	1976	HIGH RESOLUTION SEISMIC SURVEY
DEC	1976	LANDSAT IMAGERY STUDY

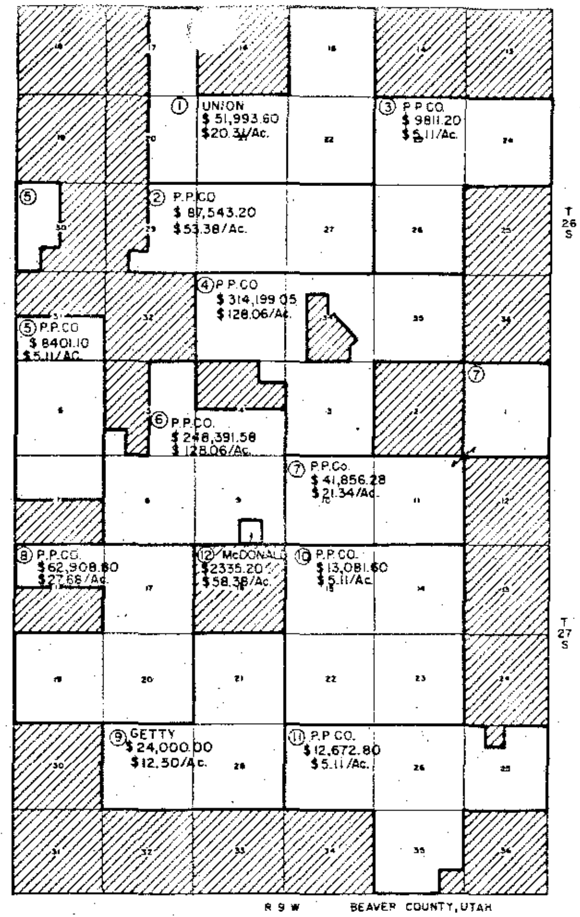

Fig. 2. The Roosevelt Hot Springs KGRA showing the location of 12 tracts offered at the July 1974 lease sale.

GEOLOGY

The Roosevelt geothermal field is located at the junction between Escalante Valley, a north-south trending graben, and the Mineral Range, a horst block paralleling the east side of the valley (Fig. 3). The valley is flanked on the west by a horst forming a number of smaller mountain ranges. The graben is filled with upwards of 5,000 feet of poorly consolidated sediments, volcanics and alluvium resting on more dense consolidated rocks. The valley fill is thickest immediately northeast of Milford.

The Mineral Range is about thirty miles long and six to ten miles wide. Topography is rugged, with steep slopes and high relief. The southern third of the range is composed of folded and faulted Paleozoic and Mesozoic sediments and Tertiary volcanic rocks which have been intruded by small acidic igneous stocks. The central Mineral Range has a granitic central core which is recognized as Utah's largest pluton. The granite has intruded and metamorphosed Paleozoic sedimentary rocks now cropping out along the southeast edge of the Range. To the west, granite intruded Precambrian schists and gneisses (Fig. 4). The granite-metamorphic rock contact is gradational with a zone about one-mile wide consisting of metamorphic inclusions within the granite forming the granite-metamorphic rock contact (Earll, 1957). North of Roosevelt Springs, granite is in gradational contact with a granodiorite intrusive which in turn intruded a sequence of upper Precambrian and lower Paleozoic sedimentary rocks at the north end of the range (Liese, 1957). Late Cenozoic acidic ash flow tuffs and lava flows partly fill older erosional valleys cut in the granite and partly cap portions of the granite in the central Mineral Range. These volcanics appear to be younger than the basin-range faulting which exhumed and permitted dissection of the granite pluton. Age dates of 400,000 years to 0.8 m.y. are reported by W. P. Nash (1976) for the volcanics. Bearskin Mountain has been identified as one of perhaps several volcanoes supplying the tuffs and lavas (Earll, 1957). Other possible sources are North and South Twin Flat Mountain and a small siliceous stock in Section 31, T26S, R8W.

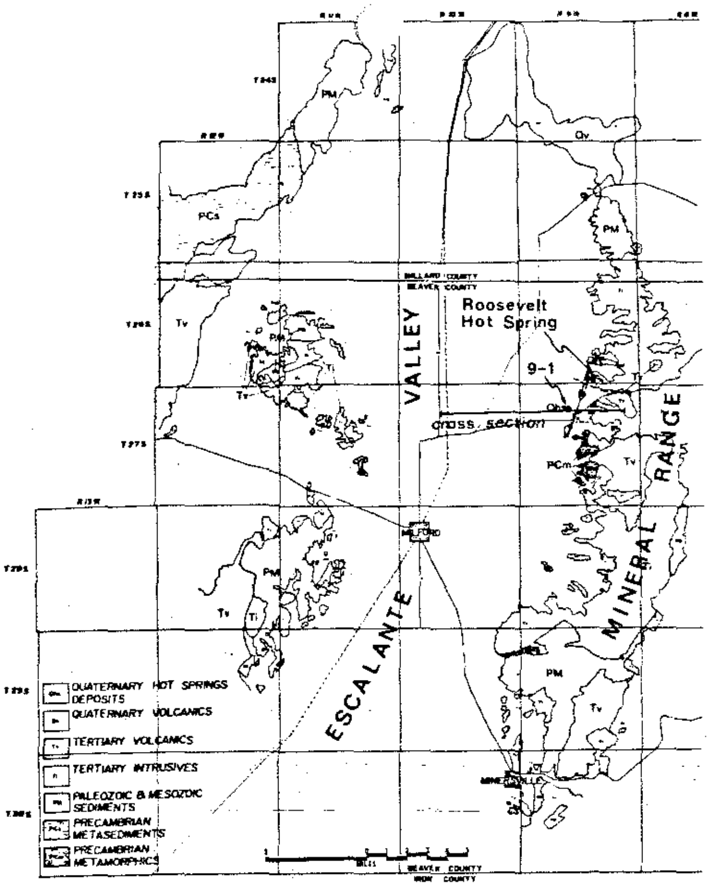

Fig. 3. Geologic Map of Northern Escalante Valley. Modified after Petersen, 1974; Liese, 1957; Earll, 1957; Hintze, 1963.

Fault ; is ubiquitous throughout the area. Several faults within the Roosevelt KGRA apparently have a significant influence on the hydrology. These are the Dome Fault, striking NNE through the center of the KGRA, and the east-west striking Negro Mag Wash fault.

The Phillips exploration program has been discussed elsewhere by Berge et. al. (1976) and Lenzer et. al. (1976) and only the results of temperature gradient surveys will be repeated here. In addition, the University of Utah investigating team led by Dr. Ward have published many reports on the Roosevelt area, which will not be discussed. The temperature gradient map (Fig. 5) is based on a total of thirty-nine holes and combines Phillips' results with data from Petersen (1975) and Whelan (University of Utah, personal communication). Depths of gradient holes vary from 60 to 610 m (200 to 2,000 ft). Gradients in five holes in the center of the thermal anomaly exceed 40°C/100m. The anomaly is elongate north-south with a change in trend to the northwest in the northern third of the anomaly. The north-south trace of the Dome Fault centers on the anomaly, and the east-west Negro Mag Wash fault is coincident with the zone of the change in trend. All exploration wells presently drilled fall in areas having gradients exceeding 30°C/100 m. Drilling activity to date totals nine geothermal wells and four stratigraphic test holes (Table 2 and Fig. 7). Seven of the nine wells encountered geothermal resources. Two wells (54-3 & 72-16) are reported to be capable of producing 1 x 10^6 pounds per hour or more total mass flow. One of the seven, (3-1), cannot be produced due to safety considerations.

The rocks encountered in drilling beneath the thin veneer of alluvium, are either igneous intrusive rocks of the Tertiary Mineral Range granitic complex or metamorphic rocks of the Precambrian Wildhorse Canyon series (Fig. 6). These rocks have almost no intergranular porosity or permeability. The geothermal reservoir is associated with interconnected fracture zones and faults lending local high effective permeability to the crystalline rocks. The reservoir is confined beneath a cap varying from 300 to several thousand feet in thickness—the cap apparently formed by precipitated silica sealing the fractures. All the wells drilled to date are considered wildcats since the targets sought are fracture systems whose attitudes are poorly known and are not related to any particular lithology or formation. Using the classification of White and Williams (1975), the geothermal resource is identified as a high temperature, low salinity, liquid dominated type. Geothermal reservoir water is classified as sodium chloride water containing 6000 to 8000 mg/l T.D.S. (Table 3). These waters contain anomalously high amounts of Si, Na, K, Cl, F, B, Li, NH_3 and salinity relative to other basin waters. The Na-K-Ca emperical geothermometer of Fournier and Truesdell (1973) has been applied to the reservoir water from geothermal wells 54-3 and 3-1, Roosevelt Hot Springs water, and present surface water discharging near the old hot springs (Table 3). There is close agreement (within 10%) between the calculated reservoir temperatures and the reservoir temperatures measured in the wells.

ROOSEVELT HOT SPRINGS UNIT AGREEMENT

Efforts to unitize the Roosevelt Hot Springs reservoir have been successful. The

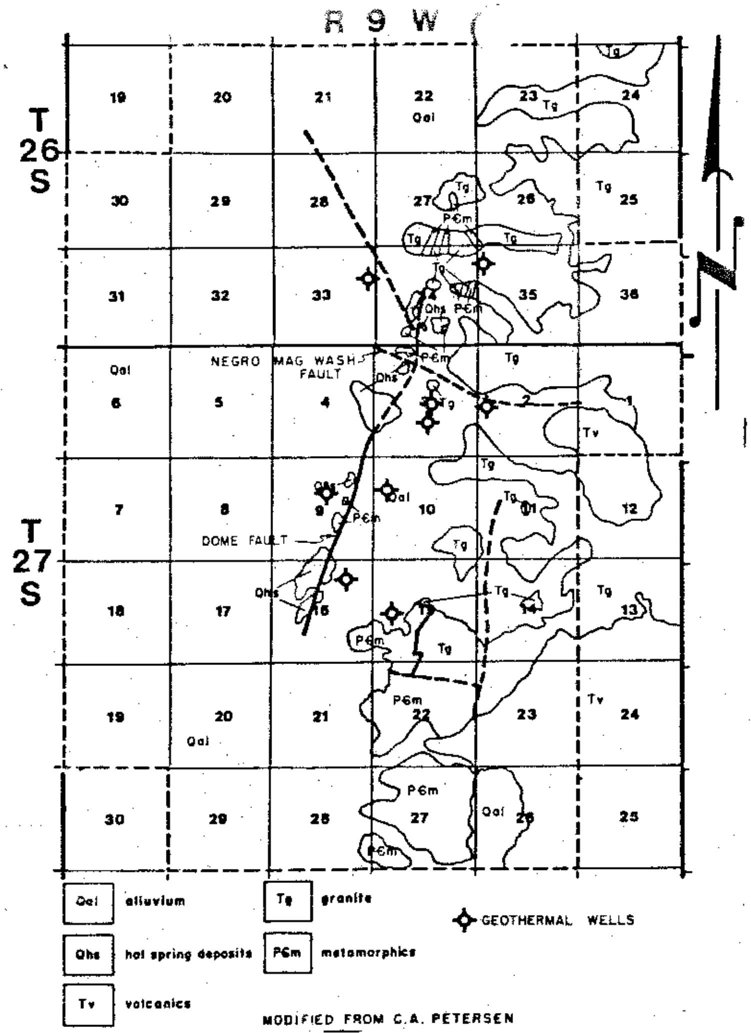

Fig. 4. Geologic Map of the Roosevelt Hot Springs area. Modified after Petersen, 1974.

purpose of forming a geothermal unit is for the same purposes as unitization in oil and gas exploration, and that is the efficient and economic development of the resource. A unit accomplishes this by eliminating lease lines, allowing the field to be developed in the most prudent manner; offset situations are thereby avoided.

The Roosevelt Hot Springs Unit is the first approved Federal geothermal unit in the United States. The unit area is shown in Fig. 7. The formation of any unit can be an extremely involved process, and the Roosevelt Unit, being the first of its kind, took well over a year to write and to receive final approval. The Federal geothermal unit agreement, which states the regulations regarding unit operation, was derived from the basic Federal oil and gas unit agreement. If more than one party holds land in the area to be unitized, as is the case at Roosevelt, a Unit Operating Agreement setting forth the operating conditions must be agreed upon by the different parties.

The fact that the geothermal reservoir at Roosevelt is contained in fractures and the distribution of fractures can be highly erratic led to the adoption of a divided type unit on a tract basis. Under this system, costs and production are apportioned to each party based on the amount of their acreage included within a participating area, and entrance into a participating area is gained by drilling a production well. Each well drilled is credited with a certain amount of acreage which, if the well is a producer, is then included within the participating area. Dry holes do not count and acreage credited to them is not included in a participating area.

WATER APPROPRIATION PROCEEDING

Everyone desiring to develop geothermal resources in Utah is faced with the same problem and that is the appropriation of water necessary to run the power plant. This holds true even if the resource to be developed is on Federal lands, for in the state of Utah, all waters within the state are public property. The basis for granting a water right in Utah is that the water shall be put to beneficial use. Phillips has taken steps to appropriate the necessary water by submitting applications to the State Engineer. The notices of application were published, protests were filed, and a public hearing before the State Engineer was held in Beaver, Utah, in April 1976 to consider the applications. For the State Engineer to approve any application, the following requirements must be met: (1) There is unappropriated water in the proposed source. (2) The proposed use will not impare existing rights, or interfere with more beneficial use of the water. (3) The proposed plan is physically and economically feasible and would not prove detrimental to the public welfare. (4) The applicant has the financial ability to complete the proposed works and the application has been filed in good faith and not for purposes of speculation or monopoly. At the hearing specific testimony was presented to meet each of these specific requirements.

As a result of the geothermal discovery and the concern of existing water users in the Valley, Phillips has initiated a monitoring system in Escalante Valley in consul-

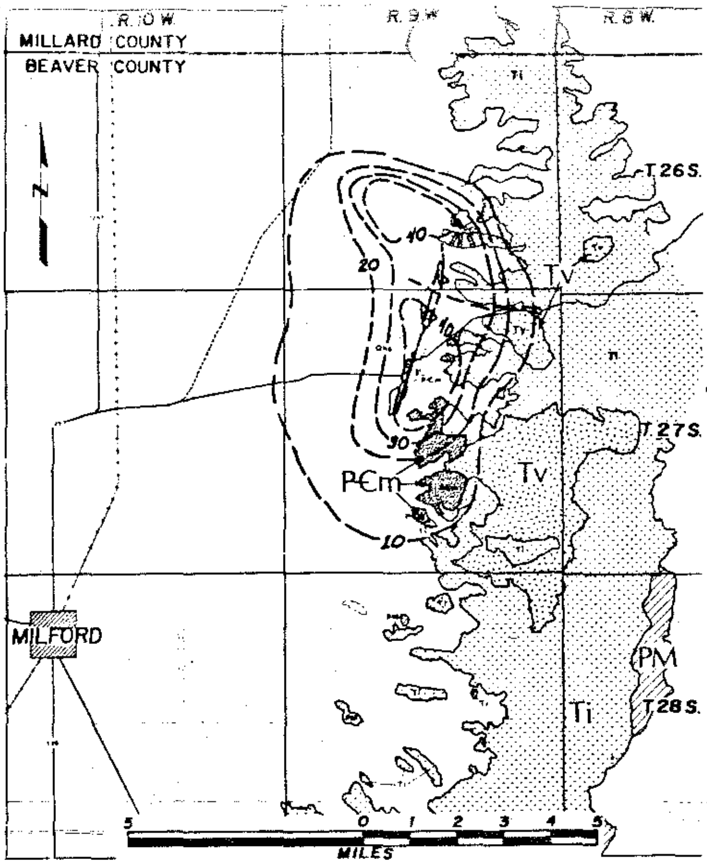

Fig. 5. Temperature gradients in the Roosevelt Hot Springs area. Contour Interval is 10°C/100m (Includes data from Petersen, 1975 and Whelan, 1976, personal communication).

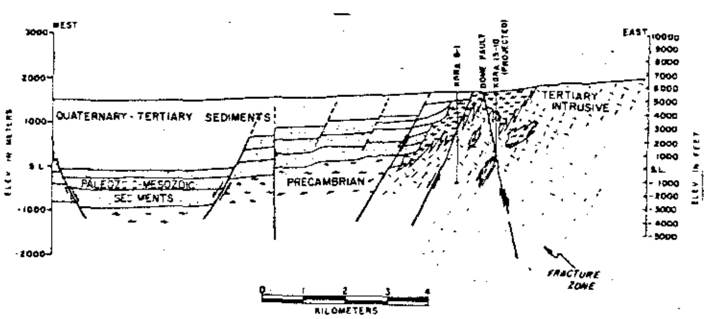

Fig. 6. Generalized Structure section through Well No. 9-1.

tation with the USGS Water Resources Division. At present, the system includes six stock wells, the Roosevelt seep, four water observation wells specifically drilled by Phillips for monitoring purposes, and one stratigraphic test hole modified to act as a water observation well (Fig. 8). The Phillips' wells are located between the geothermal wells and the existing water users points of diversion and penetrate the same reservoir utilized by the ranchers and farmers in the valley. The well sites were located far from existing irrigation wells to minimize or eliminate the effect that present pumping in the irrigation district might have on the water table at the monitoring sites.

The system is an early warning system designed to detect any effect that testing or production would have on existing water users source of supply. Additional monitoring points will be added to the system as necessary.

EXPLORATION ACTIVITY

Most recently, exploration activity at Roosevelt has consisted of drilling several 2000 foot observation holes or deep temperature gradient holes. These have been drilled to test certain ideas concerning the Roosevelt geothermal system. This intermediate depth drilling step has proven extremely valuable in evaluating other prospects.

The chief benefit of drilling a 2000 foot observation hole is the large quantity of information obtained for a relatively low cost. Our average drilling cost is less than $50,000, which is 1/10 that of drilling an exploration well to 6000 feet. Information generated by drilling these holes includes the following: temperature gradients, stratigraphy, hydrology, alteration, drilling problems and structure. These holes are particularly useful in minimizing the risk in picking the proper spot to drill an exploration well. Such a hole might be drilled if it were suspected that the thermal anomaly might be caused by lateral movement of warm waters below depths reached by shallow temperature gradient holes.

ENGINEERING

The engineering program at Roosevelt is a multipurpose program designed (1) to gain experience, (2) to determine the production capabilities of each well drilled, and (3) to characterize the reservoir. Testing has been limited to short term flow tests of about two days duration on the production wells. The longest test was a 3.5 day flow of Well 54-3. With tests of such short duration, we have not reached all our objectives. We have gained invaluable experience and confidence in operating equipment and in interpreting the results and we have been successful in determining each well's capabilities. Two systems have been used for testing. The initial testing at Well 54-3 used ıble 2. Exploratory Geothermal Wells & St graphic

Test Holes, Roosevelt KGRA Utah.

Location	Operator	Well	Status	Depth
SW NW Sec. 10, T.27S., R.9W.	Phillips Petroleum Co.	O.H. 2	Abandoned 1975	2250'
SE NE Sec. 17, T.27S., R.9W.	Phillips Petroleum Co.	O.H. 1	Idle-Strat Test	—
NE NW Sec. 9, T.27S., R.9W.	Phillips Petroleum Co.	Roosevelt KGRA 9-1	Idle Dry Hole	6885'
SW NE Sec. 3, T.27S., R.9W.	Phillips Petroleum Co.	Roosevelt KGRA 3-1	Idle	2724'
SW NE Sec. 3, T.27S., R.9W.	Phillips Petroleum Co.	Roosevelt KGRA 54-3	Idle	2882'
NW NW Sec. 35, T.26S., R.9W.	Phillips Petroleum Co.	Roosevelt KGRA 12-35	Idle	—
SW NW Sec. 10, T.27S., R.9W.	Phillips Petroleum Co.	Roosevelt KGRA 13-10	Idle	—
NE NE Sec. 33, T.26S., R.9W.	Phillips Petroleum Co.	Roosevelt KGRA 82-33	Idle Disposal	—
SW NW Sec. 2, T.27S., R.9W.	Thermal Power-Natomas	Utah State 14-2	Idle	6108'
NW SW Sec. 15, T.27S., R.9W.	Phillips Petroleum Co.	Roosevelt HSU 25-15	Idle	—
NE NE Sec. 16, T.27S., R.9W.	Thermal Power-Natomas-O'Brien	Utah State 72-16	Testing	1254'
NE NW Sec. 33, T.26S., R.9W.	Phillips Petroleum Co.	O.H. 4	Idle-Strat Test	—
SE NE Sec. 28, T.26S., R.9W.	Phillips Petroleum Co.	O.H. 5	Drilling Strat-Test	—

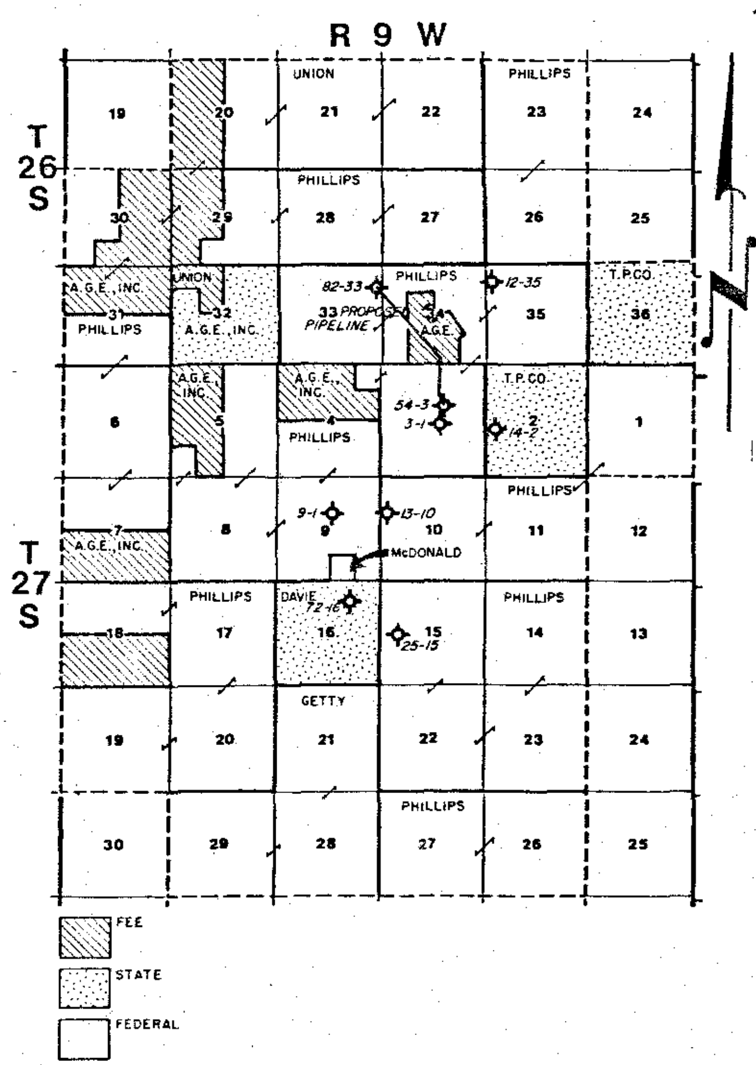

Fig. 7. Roosevelt Hot Springs Unit Area.

for testing. The initial testing at Well 54-3 used a separator to separate liquid and vapor phases so they could each be measured separately. The separator has a capacity of 1 million pounds per hour of total mass flow and it proved to be inadequate to handle the maximum well flow. At the other production wells, flow has been measured using Russell James (1966) method of steam-water measurement employing an orifice plate and a lip critical pressure measuring device.

The limiting factor on the duration of the flow tests is the disposal of the produced liquids. At present the reserve pits adjacent to the wells are used to contain the test fluids. During the 3.5 day flow test of Well 54-3, the liquids produced were discharged into the natural drainage system. It was an experiment designed to measure the effect that reservoir fluids would have on the native vegetation, and was allowed to proceed because the shallow groundwater in the area is similar in quality to the reservoir fluids. The discharge pipe was buried beneath riprap in the center of a large wash. After the test gullying was noted below the outlet pipe for several 100 feet downstream. A second result was the death of trees immediately adjacent to the channel, but not all

TABLE 3.

SELECTED WATER ANALYSES OF ROOSEVELT K.G.R.A.

	Roosevelt[1] Hot Springs	Roosevelt[1] Hot Springs	Roosevelt Seep	Roosevelt Seep	54-3	3-1
Date	11-4-50	9-11-57	5-9-73	8-15-75	8-26-75	5-25-75
Temperature (°C)	85	55	17	28	> 260	> 205
Silica (ppm)	405	313	76	107	560 +	560 ?
Calcium (ppm)	19	22	113	107	10.1	8.0
Magnesium (ppm)	3.3	0	17	23.6	0.24	0.01
Sodium (ppm)	2080	2500	2400	1800	2000	2437
Potassium (ppm)	472	488	378	280	410	448
Bicarbonate (ppm)	158	158	536	300	200	180
Sulfate (ppm)	65	73	142	70	54	59
Chloride (ppm)	3810	4240	3800	3200	3400	4090
Fluoride (ppm)	7.1	7.5	5.2	3.3	5.0	5.0
Nitrate (ppm)	1.9	11	TR	TR	TR	0.1
Boron (ppm)	–	38	37	29	29	25
Lithium (ppm)	–	0.27	–	17	19.0	20.0
TDS (ppm)	7040	7800	7506	5948	6442	7067
pH	–	7.9	8.2	6.43	6.5	6.3
[2] Na-K-Ca Geothermometer (°C)	295	285	247	239	294	273
Na-K Geothermometer (°C)	307	282	250	248	290	294

1. Mundorff (1970) 2. β = 1/3

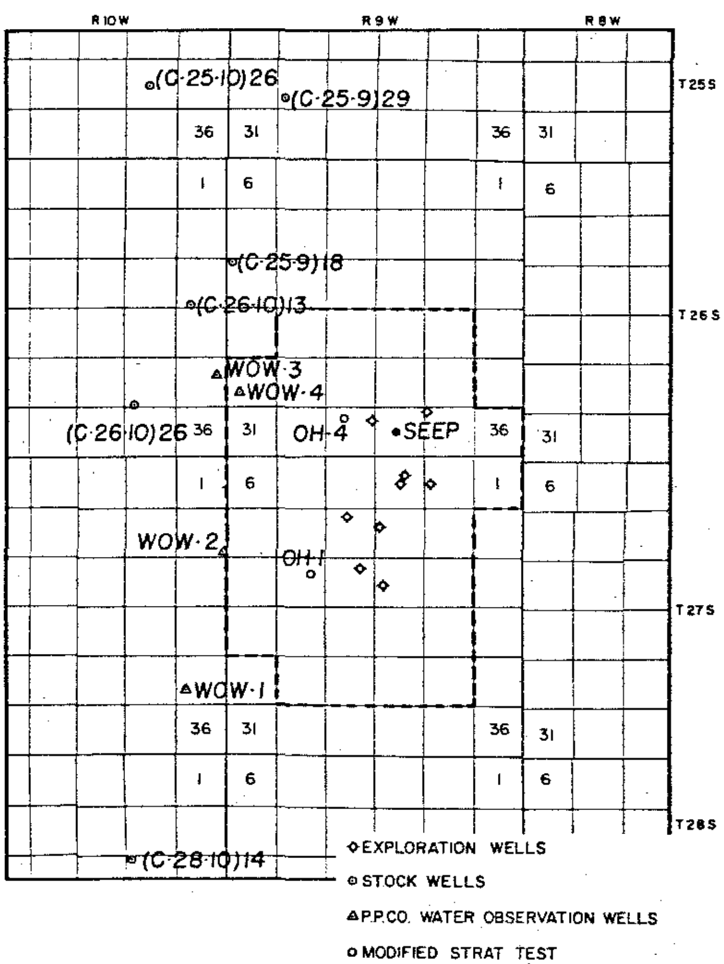

Fig. 8. Water Observation Well System in the area of the Roosevelt Hot Springs Unit.

trees were effected. A recent field check indicates that dead trees are juniper trees, but healthy pine trees are found next to dead junipers. A detailed study of the effect which this test has had on the environment has not yet been made, and until it is, it is unlikely that any further surface disposal will be permitted.

In order to acquire needed reservoir data, there is in preparation a plan for a long term flow test. The proposal calls for flow-testing Well 54-3 for a sustained period of up to six months to determine reservoir size and production characteristics.

The fluids produced at Well 54-3 will be piped through a centrifugal steam/water separator at the well site where the steam portion will be vented in the pit through an existing muffler. It will be necessary to construct approximately 1.4 miles of 10" pipe to connect Well 54-3 to Well 82-33 (Fig. 7). Well 82-33 will function as an injection well during the reservoir tests. The liquid portion from Well 54-3 will be piped to Well 82-33 using the produced pressure for injection into the well.

ACKNOWLEDGMENTS

The writers wish to acknowledge the contributions of Stuart Johnson, Robert Wright and Joe Beall in all phases of the exploration at Roosevelt. Permission to publish the paper has been generously granted by Phillips Petroleum Company.

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F

UTAH GEOLOGICAL AND MINERAL SURVEY

606 BLACK HAWK WAY
SALT LAKE CITY, UTAH 84108
(801) 581-6831

DONALD T. McMILLAN
Director

CALVIN L. RAMPTON
Governor

GORDON E. HARMSTON
Executive Director
Department of Natural Resources

5 May 1976

MEMORANDUM

TO: J.W. Gwynn

FROM: C.A. Petersen

SUBJECT: Phillips' Water Rights Hearing

On April 29, 1976, a hearing was called by Dee Hansen, State Engineer, to consider applications by Phillips Petroleum Company for the production of geothermal water. The hearing, which was held in the Beaver County courthouse, allowed Phillips to present their case and the protestants to reply.

Phillips used the opportunity to give a concise but very informative review of the Roosevelt Geothermal reservoir as they understand it and to show that production of geothermal waters will not affect the shallow aquifers used by agriculture.

According to Gary Crosby, Phillips spent some $400,000 over two years in exploration of the Roosevelt KGRA before deep drilling. The eight deep wells that they have drilled to date cost $3,410,000 and testing three of these wells cost $285,000. After other costs are added to these, Phillips has spent more than $4,500,000 on the Roosevelt area, not including land costs.

The reservoir is located east of the Dome fault. It consists of fractured granite, overlain by 1600 ft. of impermeable granite and Precambrian rocks. A cross section enetered into evidence showed the fractured granite extending to a depth of 5000' below sea level. Dick Lenzer, Project Geologist, stated that the reservoir is entirely within the boundaries of the KGRA, and furthermore is within the perimeter of the lands covered by the Phillips - Union unitization agreement.

The reservoir contains water at 506°F (263°C) and at pressures of 2250 lb/sq.in. The typical geothermal well is a flowing artesian well, with the piezometric surface several hundred feet above the land surface. About 12% of the water flashes into steam in the well, and another 8% flashes in the steam - water separator. One of the wells tested produced more than 1,200,000 lb/hr. of water and steam.

If mechanical restrictions are overcome, wells in the best part of the reservoir may produce 1,500,000 lb/hour of steam and water. This is ten times the average initial per-well mass flow rate at The Geysers.

Phillips expects that the field can support eight 55 MW generating capacity, or a total of 440 MW. The first unit of UPL's Huntington Canyon plant has a capacity of 430 MW, and The Geysers currently has a capcity of about 600 MW. Each 55 MW unit of Roosevelt would be supplied with the steam from 5,000,000 lb/hr. mass flow by 5 to 7 wells.

About 5 years would be required before plants could be online-one year from base line studies, two for environmental, and two for construction. The plant would cost $4 million, and the wells and pipelines would cost $20-25 million.

Reservoir Fluid

Dick Lenzer stated that the old Roosevelt Hot Springs and a presently flowing seep represent leaks from the reservoir. The total dissolved solids of this water is adequate for watering sheep and cattle. The water produced from the wells has a boron content ten times greater than that accepted by the most tolerant crops, and the sodium-adsorption ratio and salinity hazard of the water makes it totally unsuited for irrigation.

The reservoir water has undergone an oxygen isotope shift about equal to that observed at Steamboat Springs, Nevada.

At least 95% of the reservoir water is meteoric in origin. The area of recharge can't be defined at present, but is thought to be the highlands.

Some geothermal water leaks from the reservoir and flows as ground water into the Beaver Bottoms area of the Escalante Valley, where it mixes with the shallow ground water. It probably takes 700 years to reach the valley bottom from the Roosevelt area. If the section through which it flows is composed entirely of sand, the trip would take 300 years.

Ground water flow in the bottom of the Escalante Valley is to the north, away from the agricultural area, and the water exits at Black Rock. The trip from Beaver Bottons to Black Rock probably requires 10,000 years, and would take 4,000 years if the whole section were composed of sand.

Protesters

The South Milford Pumpers Association, Utah Power and Light and Thermal Power of Utah all indicated that they were satisfied by the Phillips efforts to define the mixing of geothermal water with shallow water and the program of observation wells. These parties have or probably will withdraw their objections to the Phillips applications.

Only one person, Victor Kaufman, voiced a concern over pollution of the ground water. Also, Kaufman gets his water from the springs at Black Rock, and didn't think that an observation well would be suitable to monitor changes in the spring. He seemed satisfied by the suggestion of installing a Weir at the spring to monitor it.

Carl
C.A. Petersen

CAP:af

BOUNTIFUL LIGHT AND POWER

GEOTHERMAL WELL DRILLING PROGRAM

By

R. M. Golbraith

The City of Bountiful Light and Power Company proposes to drill a geothermal well in the Roosevelt KGRA on Lease U 14990. This well will be drilled with similar equipment and techniques as have been used to successfully drill other geothermal wells in the area. If the first well is successful, three additional wells will be drilled.

The general sequence for drilling will be as follows: (1) Use a dry hole digger to 100 # feet and set and cement to surface 100 # feet of 20 inch conductor pipe; (2) Move in and rig up a conventional rotary drill rig; (3) Drill a 17 1/2 inch hole to 500 # feet with mud, blow out preventor and rotating head; Run a 13 3/8 inch casing to 500 # feet and cement it back to surface; (4) Drill a 12 1/4 inch hole with mud, blow out preventor and rotating head to 1100 # feet and run in and cement to surface 1100 # feet of 9 5/8 inch casing; (5) Drill with mud, blowout preventor and rotating head to 2000 # feet until a steam reservoir is encountered.

These casing depths are assumed in the basis of drilling histories in the area and may be greater or less than stated. The conductor pipe will not be less than 50 feet nor will the surface casing be less than 250 feet. The exact setting points will be dictated by the temperature of the circulating fluid. Generally the drilling mud will be cooled before circulation into the hole. When discharge mud temperatures can not be kept below 185 to 190°F casing will be set. Rapid increases in temperature generally occur just prior to hitting steam. A make up pit will be maintained to fill the hole as the drill string is withdrawn on every trip.

LOGGING

Bottom hole temperatures will be taken every 100 feet or once a day which ever is more frequent. Single shot surveys will be run every 100 feet. Temperature, resistivity, sonic velocity, density, natural gamma and caliper logs will be run at the 13 3/8 inch and 9 5/8 inch casing points and in the completed hole, temperature permitting.

No coring is planned but chip samples will be collected at 20 foot intervals for the entire length of the hole.

G

THE STATE OF UTAH

DEPARTMENT OF NATURAL RESOURCES
DIVISION OF STATE LANDS
105 STATE CAPITOL BUILDING
SALT LAKE CITY, UTAH 84114

CHARLES R. HANSEN
Director

July 8, 1977

City of Bountiful
Light & Power
198 South 200 West
Bountiful, Utah

Attention: Mr. W. Berry Hutchings

Dear Sir:

Pursuant to your request, please be advised that the Division of State Lands is a multiple-use land managing agency. The lands in the Roosevelt Hot Springs area owned by the Division of State Lands are managed for surface values as well as sub-surface values.

It is the understanding of the Division of State Lands that you are interested in the possible acquisition of a 40 acre tract of land in Section 9, Township 27 South, Range 9 West, SLM, which adjoins State-owned Section 16. This possible acquisition would be for the geothermal rights under a federal lease.

The need for rights of way, easements, or plant site arrangements are covered in our rules and regulations on surface use and are negotiated at the time of need. I am attaching a copy of these rules and regulations on surface use for your information. Our relationship with the regulatory federal agencies has been very cooperative regarding access, either ingress or egress, to one anothers land, if the proper steps are taken to provide this access in accordance with the rules and regulations.

If you have further questions, please contact me at the Division of State Lands.

Very truly yours,

Wm Lowell Johnson vp

WM. LOWELL JOHNSON
LAND SPECIALIST

WLJ:vp

Enclosure

United States Department of the Interior

BUREAU OF LAND MANAGEMENT

Utah State Office
University Club Building
136 East South Temple
Salt Lake City, Utah 84111

IN REPLY REFER TO
2800
(U-942)

JUL 8 1977

City of Bountiful Light & Power
198 South 200 West
Bountiful, UT 84010

Gentlemen:

This letter is to assure you that rights-of-way for tramroads, power lines and other purposes can be obtained over public lands that are presently subject to geothermal lease.

All such leases were granted under the authority of the Geothermal Steam Act of 1970 (30 U.S.C. 1001). Section 17 of the Act provides that the administration of the Act shall be conducted under the principles of multiple use management. This concept is defined in the Federal Land Policy and Management Act of 1976 (FLPMA) (43 U.S.C. 1701) at Section 103(a) to mean:

> [T]he management of the public lands and their various resource values so that they are utilized in a combination that will best meet the present and future needs of the American people. . . .

This authority permits the use of lands under geothermal lease for rights-of-way purposes, and while the existence of a geothermal lease (or any other lease or right-of-way over public lands, for that matter) could necessitate some alteration in the proposed location of a right-of-way, it could not likely preclude it entirely due to the requirements of multiple use management.

The authority for most rights-of-way over public lands is presently found in the FLPMA. A complete list of those types of rights-of-way authorized under this Act can be found at Section 501(a). We are enclosing for your convenience a copy of all pertinent laws and forms necessary to complete a proper right-of-way application. If you should have any questions please feel free to contact this office.

Sincerely,

Carol Shake

Chief, Lands Section

Enclosures:
- FLPMA
- Section 17, Geothermal Steam Act of 1970
- Fact Sheet - Rights-of-Way
- Circular No. 2384
- Form 1140-5
- USO 2800-10 (3)
- USO 2800-17

Fact Sheet - Rights-of-Way

On October 21, 1976, the President of the United States signed into law the Federal Land Policy and Management Act of 1976 which provides for the management, protection and development of the public lands. This act repealed numerous antiquated public laws and provided a new charter to BLM in the management of national resource lands.

Title V of this Act refers specifically to rights-of-way. Some of the highlights concerning rights-of-way are as follows:

1. The Act repealed all right-of-way statutes Except (1) The Mineral Leasing Act for the granting of oil and gas pipeline rights-of-way, and (2) Title 23, U.S.C. for the granting of Federal Aid Highways. All right-of-way grants are now discretionary.

2. The Act provides new authority for the granting of road rights-of-way to State and local governments now requiring applications and approval prior to construction. The Act repealed R.S. 2477.

3. The Act provides new authority for the granting of rights-of-way to Federal agencies under appropriate application. Right-of-way "notation" procedures under the principles of 44 L.D. 513 are no longer applicable.

4. The Act provides new authority for granting road rights-of-way to private parties for purposes other than mining and logging.

5. Right-of-way provisions of the Act applies both to BLM - administered public lands and to national forest lands. They do not apply to wilderness lands.

6. The Act requires the applicant to submit full disclosure of his plans, competition and ownership as that information relates to the right-of-way application.

7. The Act gives the Secretary the authority to grant rights-of-way across BLM lands in connection with timber harvest and provides for acquisition, construction, and maintenance under cost-sharing.

8. The Act provides for the common use of rights-of-way and the designation of corridors.

9. The Act requires that a right-of-way width be limited to no more than is necessary.

10. The Act provides that the duration of a grant or renewal be limited to a reasonable term in light of all circumstances concerning the project.

11. The Act provides for payment annually of the fair market value of the right-of-way except that advance payment for more than one year at a time may be required when the annual rental is less than $100.

12. The Act provides for the reimbursement to the United States for reasonable administrative and other costs incurred in processing the application and monitoring construction, operation, maintenance and termination of authorized facilities and for protection and rehabilitation of the lands involved.

13. The Act provides that the terms and conditions of the grant must comply with State and Federal environmental and safety standards and whichever standard is more stringent will govern.

14. The Act provides that a right-of-way is considered abandoned if not used for its intended purpose for any continuous 5 year period.

15. The Act provides that existing rights-of-way are nominally protected. The Secretary, with the consent of the holder, may replace an existing grant with one under the new Act.

UNITED STATES
DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY
Area Geothermal Supervisor's Office
Conservation Division, MS 92
345 Middlefield Road
Menlo Park, CA 94025

JUL 8 1977

W. Berry Hutchings
Bountiful City Light and Power
198 S. 200 West
Bountiful, Utah 84010

Dear Mr. Hutchings:

The following information per your telephone request is furnished.

Changes to Federal regulations both by Bureau of Land Management and U.S. Geological Survey are currently in review and about to be published in the Federal Register for public comment. These changes will delineate the means by which Federal lessees may acquire a permit to establish a power generating facility on Federal geothermal leases.

There are two different classes of power plants which may be permitted under the geothermal operating regulations which are administered by the Geological Survey. The first class of facility is a unit for commerical production powered by a single well and whose output is 10 MW net capacity or less. There could be any number of these on a single lease or unit.

The second class would be a research and demonstration project of 25 MW net capacity or less which may be operated by more than one well. The research and demonstration project would be limited to a project life of five years. If at the end of that time commercial production continues, it would be necessary to obtain an appropriate permit from the Bureau of Land Management.

All other classes of power plants would be authorized under a permit issued by the Bureau of Land Management. As well, rights of way for transmission corridors and similar ancillary equipment would be obtained through the Bureau of Land Management.

Drilling programs, plans of injection and other proposals may be prepared with the assistance and advice of the staff of the Area Geothermal Supervisor. Meetings with lessees are commonly held before an initial operation is proposed. Such meetings serve to provide the lessee or operator with background to enable them to prepare their initial plans. Details can then be attended to as the processing moves along.

Enclosed is a copy of the current geothermal regulations, GRO Orders and a draft copy of the changes to the operating regulations, 30 CFR subpart 270, under which a U.S. Geological Survey permit would be issued. I am certain that the Bureau of Land Management State Office in Salt Lake City will be more than happy to furnish a copy of their draft changes. If we may be of further assistance, please do not hesitate to call.

Sincerely,

Barry A Boudreau

Acting Area Geothermal Supervisor

Enclosures

H

GENERAL ELECTRIC

POWER SYSTEMS

SALES OPERATIONS

GENERAL ELECTRIC COMPANY, 5320 NORTH 16TH STREET, PHOENIX, ARIZONA 85016
Phone (602) 264-1751

June 3, 1977

Mr. Berry Hutchins
Director of Power Resources
City of Bountiful
Bountiful, Utah

Subject: 10 MW Geothermal Turbine

Dear Berry:

Attached is a conceptual design arrangement for a 10 MW "transportable" geothermal steam turbine-generator. While you might not require the base-mounting feature, this arrangement is the basis of our estimate of $190 per KW for the turbine-generator and accessories in the Equipment List. This does not include auxiliary equipment, condensers, cooling towers or switchgear. The total installed value of the complete plant has been estimated by a consulting firm at approximately $600 per KW.

An estimate of shipment for this turbine-generator unit is twenty (20) months.

If I can help in any way as you progress with the evaluation of your geothermal alternatives, please call.

Very truly yours,

Frank L. Battuello

F. L. Battuello
Senior Application Engineer

/f

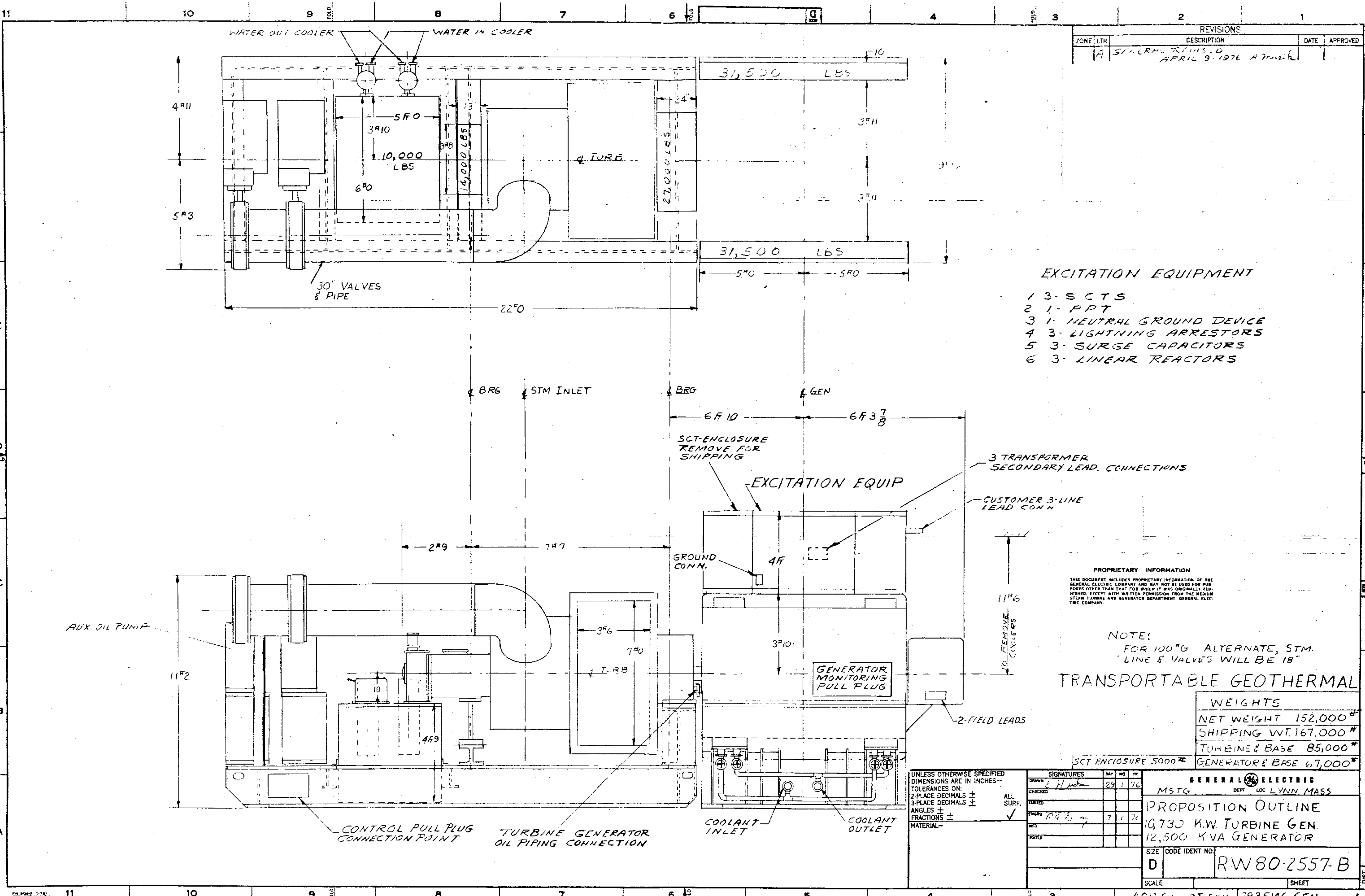
INTRODUCTION

A packaged transportable steam turbine-generator for the geothermal market to be located at the well head to serve as either a temporary or permanent electric power producer is proposed by the General Electric Company.

The following pages describe the equipment proposed to be furnished by General Electric Company, as well as, the connections and equipment required for the Purchaser to complete the plant.

The General Electric Company intends to furnish the steam turbine-generator equipment only. An architect engineer should be selected by the Purchaser to size and complete the plant layout for a specific site.

The proposed design of the steam turbine incorporates a number of unique features to make the unit adaptable for a range of well head steam conditions, condensing and non-condensing operation, highly packaged, transportable by truck to the site, with a very minimum of installation time.


REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
A GENERAL REVISED APRIL 9 1976
WATER OUT COOLER
WATER IN COOLER
31,500 LBS
31,500 LBS
10,000 LBS
14,000 LBS
27,000 LBS
℄ TURB
4 FT 11
5 FT 3
5 FT 0
3 FT 10
6 FT 0
3 FT 8
3 FT 11
3 FT 11
24"
13
10
5 FT 0
5 FT 0
30" VALVES & PIPE
22 FT 0
EXCITATION EQUIPMENT
1 3- S C T S
2 1- P P T
3 1- NEUTRAL GROUND DEVICE
4 3- LIGHTNING ARRESTORS
5 3- SURGE CAPACITORS
6 3- LINEAR REACTORS
℄ BRG
℄ STM INLET
℄ BRG
℄ GEN
6 FT 10
6 FT 3 7/8
SCT-ENCLOSURE REMOVE FOR SHIPPING
EXCITATION EQUIP
3 TRANSFORMER SECONDARY LEAD CONNECTIONS
CUSTOMER 3-LINE LEAD CONN
2 FT 9
7 FT 7
GROUND CONN.
4 FT
11 FT 6
TO REMOVE COOLERS
AUX OIL PUMP
11 FT 2
3 FT 6
7 FT 0
℄ TURB
3 FT 10
18
4 FT 9
GENERATOR MONITORING PULL PLUG
2-FIELD LEADS
CONTROL PULL PLUG CONNECTION POINT
TURBINE GENERATOR OIL PIPING CONNECTION
COOLANT INLET
COOLANT OUTLET
PROPRIETARY INFORMATION
THIS DOCUMENT INCLUDES PROPRIETARY INFORMATION OF THE GENERAL ELECTRIC COMPANY AND MAY NOT BE USED FOR PURPOSES OTHER THAN THAT FOR WHICH IT WAS ORIGINALLY FURNISHED, EXCEPT WITH WRITTEN PERMISSION FROM THE MEDIUM STEAM TURBINE AND GENERATOR DEPARTMENT, GENERAL ELECTRIC COMPANY.
NOTE:
FOR 100"G ALTERNATE, STM. LINE & VALVES WILL BE 18"
TRANSPORTABLE GEOTHERMAL
WEIGHTS
NET WEIGHT 152,000#
SHIPPING WT. 167,000#
TURBINE & BASE 85,000#
GENERATOR & BASE 67,000#
SCT ENCLOSURE 5000#
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES—
TOLERANCES ON:
2-PLACE DECIMALS ±
3-PLACE DECIMALS ±
ANGLES ±
FRACTIONS ±
ALL SURF.
MATERIAL—
SIGNATURES DAY MO YR
DRAWN 29 1 76
CHECKED
ISSUED
ENGRG 7 2 76
GENERAL ELECTRIC
MSTG DEPT LOC LYNN MASS
PROPOSITION OUTLINE
10,730 K.W. TURBINE GEN.
12,500 KVA GENERATOR
SIZE D CODE IDENT NO.
RW80-2557-B
SCALE SHEET
783E146 GEN

TURBINE GENERATOR EQUIPMENT LIST

The skid mounted, packaged, transportable geothermal turbine-generator set for indoor installation is shipped in four major pieces with additional equipment shipped separately for installation by Purchaser. The major pieces are as follows:

A. Turbine package

B. Generator package

C. Generator mounted excitation equipment

D. Excitation cubicle

The features and accessories of the turbine generator include:

A. Skid mounted turbine package for installation on flat concrete slab, controls pre-wired to a central pull plug for customer's control cubicle connection, and with steam and oil piping pre-assembled and oil pipe flushed in the factory. Accessories include:

1. Butterfly emergency inlet valve with open and closed position limit switches.

2. Butterfly control valve with open and closed position limit switches.

3. Main steam lead from emergency inlet valve to control valve to turbine inlet.

4. Emergency trip with manual trip and reset and solenoid trip.

5. Bolt type overspeed governor.

6. Shaft sealing system with air operated regulating steam seal valve and manually operated throttling valve venting to condenser or vacuum pump.

7. Speed governor - oil relayed type.

TURBINE GENERATOR EQUIPMENT LIST (Cont'd.)

8. Motor and hand operated synchronizing device with manual release for overspeed testing.

9. Lube and hydraulic oil reservoir built into the turbine base.

10. Float type oil level indicator with high and low level alarm and trip switches.

11. Twin oil coolers with transfer valve.

12. Shaft driven main oil pump.

13. Motor driven auxiliary oil pump.

14. Oil feed and return piping.

15. Flow oil sights (unlighted) for journal and thrust bearings.

16. Inlet oil strainers for each oil pump.

17. Pump test for local testing.

18. Pressure switches for automatic starting of auxiliary oil pump.

19. Vibration pick-ups on each bearing.

20. Dial thermometer and thermocouple for each journal and thrust bearing drain and oil line leaving oil coolers.

21. Well for customers lube oil temperature controller in oil line leaving coolers.

22. Low bearing pressure alarm and trip switches.

23. Hydraulic and bearing oil pressure gages.

24. Shaft driven tachometer generator.

25. Thrust failure trip device.

26. Shaft grounding brush.

27. Pneumatic main steam pressure transmittal.

TURBINE GENERATOR EQUIPMENT LIST (Cont'd.)

B. Generator package with feet for mounting on flat concrete slab at same elevation as turbine skid mounting, control and monitoring connections pre-wired to central pull plug location for customer's control cable connection, and with water and oil piping pre-assembled and oil pipe flushed in the factory. Accessories include:

1. Generator field, end shield supported on collector end and with shipping bracket on turbine end, assembled in the stator.

2. Collector housing and brush rigging (with constant pressure brush holders) shipped assembled and supported by the generator end shield.

3. Corner mounted, vertical air coolers with assembled water piping to and from coolers with shut-off (and flow regulating) valves at each cooler.

4. Six RTD's in stator winding.

5. One cold gas RTD for each cooler.

6. Liquid leak detector with alarm and trip contacts.

7. Bearing feed and drain piping assembled, pre-flushed, and piped to connection point to turbine skid.

8. Bearing vibration pick-up.

9. Bearing drain oil sight.

10. Dial thermometer and thermocouple for bearing drain line.

TURBINE GENERATOR EQUIPMENT LIST (Cont'd.)

C. Generator mounted excitation equipment shipped separately and mounted in the field on top of generator casing. Equipment includes:

1. Power Potential Transformer (PPT).

2. Three Saturable Current Transformers (SCT's).

3. Neutral grounding equipment.

4. Three lightening arresters.

5. Three surge capacitors.

D. Excitation Cubicle, free standing, 76" long x 60" deep x 90" high, for mounting indoors within 100 feet of generator and customer's turbine-generator control panel. Features and accessories include:

1. Field breaker.

2. Field discharge resistor.

3. Provision for polarity reversal.

4. Field ground detector.

5. Two field current shunts.

6. Field temperature indicator/retransmitter with alarm and trip contacts.

7. Automatic A-C voltage regulator with reactive current compensator.

8. Excitation start-up system (to be energized from Purchaser's d.c. supply).

TURBINE GENERATOR EQUIPMENT LIST (Cont'd.)

9. Meter panel with meters appropriate for servicing regulator equipment.

10. Maximum excitation limit.

11. Two (2) three phase, full wave rectifier bridge assemblies.

12. Isolating disconnects, manually operated, for each bridge assembly.

13. Thyrite resistor assembly connected across rectifier output terminals.

E. The following materials and parts are shipped separately for Purchaser's installation:

1. Thermal insulation and lagging for high temperature areas of steam piping and steam turbine.

2. Special maintenance tools including box sledging wrenches for bolts and nuts 1 1/2 inch in diameter and larger, casing guide pins, jacking bolts, generator field shipping bracket, steel generator gas gap shim for rotor assembly and protective non-metallic shim, rotor shoe for rotor assembly.

3. Ten (10) copies of instruction books.

4. Excitation voltage regulator transfer switch with Auto, Test, Manual and Start-Up positions.

5. Excitation transfer voltmeter.

6. Exciter manually operated regulator voltage set point adjusting unit.

7. Field breaker control switch and indicating lights.

TURBINE GENERATOR EQUIPMENT LIST (Cont'd.)

8. Control switch for d-c voltage regulator for control of generator field voltage with five indicating lights.

9. Vibration recorder and power supply with alarm and trip contacts.

10. Technical direction of installation (supplied at per diem rates at time of installation).

CONNECTION POINTS

Principal connections to the four major packages are as follows:

A. Turbine skid

1. Main steam lead.
2. Exhaust flange to condenser or atmospheric exhaust line.
3. Lube oil to and from Purchaser's oil conditioning system.
4. Lube oil to and from generator bearing.
5. Turbine steam lead and casing drain.
6. Water to and from each oil cooler.
7. Control wiring to pull plug for -
   - (a) Speed indicator
   - (b) Vibration (each bearing)
   - (c) Synchronizing motor
   - (d) Valve position limit switches
   - (e) Emergency trip solenoid
   - (f) Emergency trip limit switches
   - (g) Thrust failure trip
   - (h) Main steam thermocouple
   - (i) Bearing oil drain thermocouples
   - (j) Bearing feed thermocouple
8. Auxiliary oil pump motor power.
9. Pneumatic steam pressure transmitter.
10. Turbine-generator coupling.

CONNECTION POINTS (Cont'd.)

B. Generator package

1. Six stator winding RTD's.
2. Four cold gas RTD's.
3. Bearing oil drain thermocouple.
4. Bearing vibration pick-up.
5. SCT control (hand wired from pull plug to excitation equipment).
6. Thermostat for common cold gas temperature.
7. Liquid leak detector contacts.
8. Oil connection to turbine for generator bearing feed and drain.
9. Water to and from gas cooler manifold.
10. Field leads.
11. Six main leads (to excitation equipment).
12. Turbine-generator coupling.

C. Excitation equipment package

1. Six main leads to generator.
2. Three line leads.
3. Neutral connection.
4. SCT secondary leads.
5. SCT control leads (hand wired to generator pull plug).

CONNECTION POINTS (Cont'd.)

D. Excitation cubicle

1. SCT secondary (power leads).

2. Field leads (power leads).

3. Control leads via pull plugs

(a) SCT control
(b) Field ground detector
(c) High diode temperature
(d) Over-excitation alarm
(e) Transfer from auto to manual
(f) Start-up circuit
(g) Field breaker control and indicating lights
(h) Automatic regulator potentiometer
(i) Manual regulator control
(j) Transfer voltage
(k) Field amperes
(l) Field volts
(j) Instrument C.T.
(k) Two instrument PT's

CONTROL PANEL

Not included in the General Electric equipment package is the customer's control panel which should be located near or attached to the turbine-generator skid. The following is a suggested list of minimum functions and equipment to be included in the control panel. Unless otherwise noted, the equipment is to be provided by the Purchaser.

1. Speed indicator (by General Electric).
2. Vibration recorder with alarms and trip (by General Electric).
3. Synchronizing device control switch.
4. Frequency regulator (for isolated electrical system operation).
5. Turbine valve position indicating lights.
6. Emergency valve trip and reset push buttons and indicating lights.
7. Initial steam temperature.
8. Initial steam pressure.
9. Exhaust pressure gage.
10. Lube oil pump motor control switch and indicating lights.
11. Annunciator.
12. Bearing oil feed and drain temperature recorder with alarm and trip contacts.
13. Field temperature trip relay.
14. Thrust bearing failure trip relay.
15. Common cold gas temperature alarm and trip circuitry.
16. Generator protective relays.

CONTROL PANEL (Cont'd.)

17. Synchronizing panel.

18. VAR meter.

19. Armature voltage.

20. Armature amperes.

21. Wattmeter.

22. Stator (RTD) temperature trip relay.

23. Generator temperature indicator and transfer switch.

24. Liquid level trip relay.

25. Excitation equipment (by General Electric).

    (a) Start-up and transfer switch
    (b) Field breaker control switch
    (c) Automatic regulator potentiometer
    (d) Manual regulator voltage set point adjusting unit
    (e) Transfer voltmeter

I

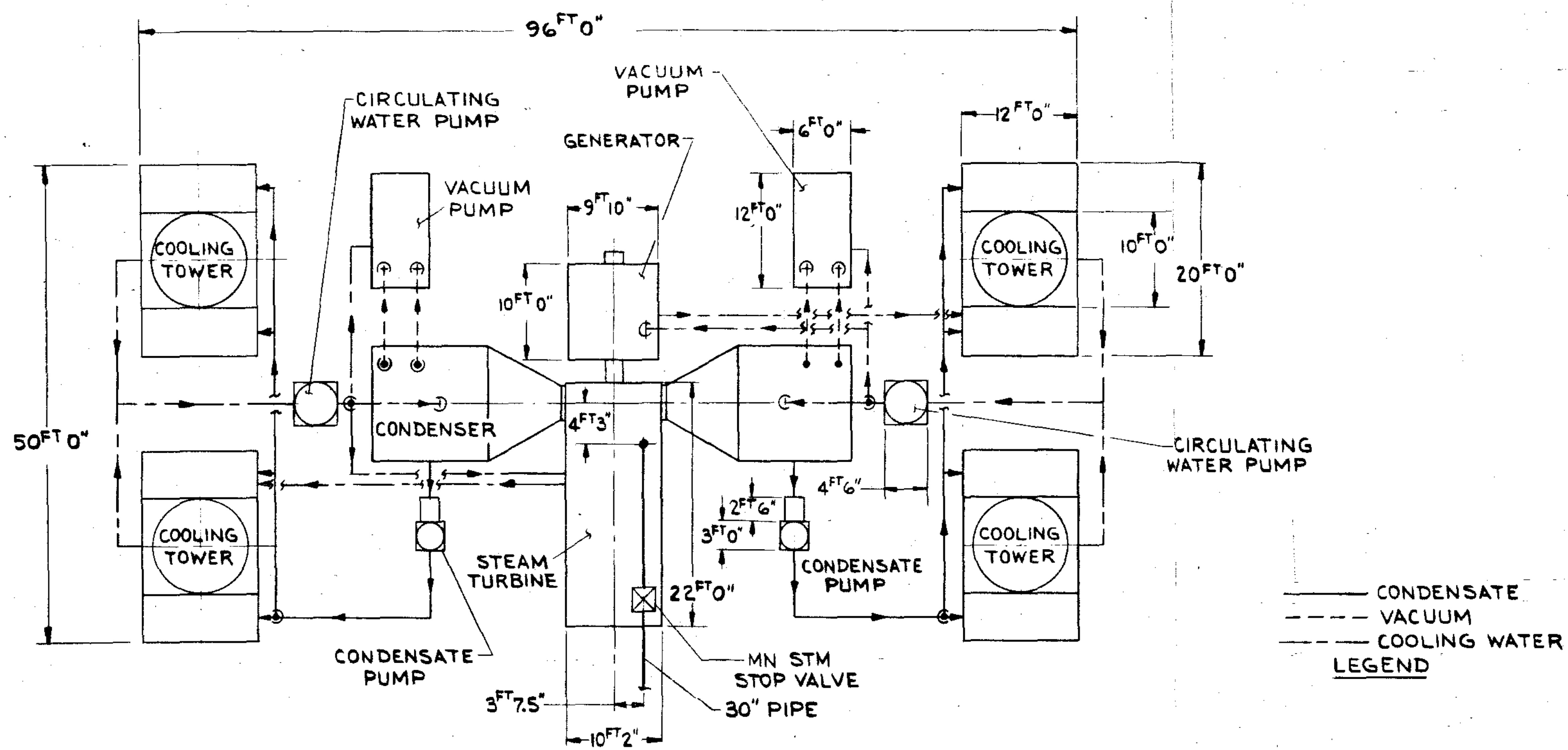
MATERIAL AND EQUIPMENT DESIGNED AND FURNISHED BY OTHERS

1. Site
2. Site preparation
3. Earthwork and piling
4. Condenser and condenser connection and expansion joints
5. Cooling towers
6. Condensate pumps and piping
7. Condenser blow-out diaphragm
8. Exhaust pipe to atmosphere
9. Foundations
10. Plant layout
11. Structural steel for building, if required
12. Building enclosure
13. Control panels
14. Bus or cable to electrical system
15. Generator breaker
16. Main and auxiliary transformers
17. Flash tanks
18. Flash tank shut-off valves (manual)
19. Main steam strainers

MATERIAL AND EQUIPMENT DESIGNED AND FURNISHED

BY OTHERS (Cont'd.)

20. Waste fluid disposal system
21. Turbine casing drain system and disposal
22. Condensate disposal system
23. Motor control center(s)
24. Cooling water system - generator and oil coolers
25. Lube oil and generator cold gas temperature controllers
26. Air supply system (instrument and steam seal control valves)
27. All site labor
28. Control and power inter-connecting cables and wiring
29. Instrument PT's and CT's
30. D.C. and A.C. auxiliary and control power systems
31. Steam seal vacuum pump if non-condensing
32. Lube oil conditioning system
33. Initial charge of lube oil and storage
34. Sole plates



NOTE:
Typical arrangement only for 10,730 kw unit. Smaller 5220 kw alternate unit would have only one side condenser. Overall dimensions are approximate for Purchaser to visualize total plot plan. For more definitive information concerning auxiliary equipment for turbine generator and dimensions, it is recommended an architect engineer be consulted.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES—
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TYPICAL PORTABLE GEOTHERMAL ARRANGEMENT

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UTAH GEOLOGICAL AND MINERAL SURVEY
606 BLACK HAWK WAY
SALT LAKE CITY, UTAH 84108
(801) 581-6831

DONALD T. McMILLAN
Director

CALVIN L. RAMPTON
Governor

GORDON E. HARMSTON
Executive Director
Department of Natural Resources

September 22, 1976

MEMORANDUM

TO: J.W. Gwynn

FROM: Carol Petersen

SUBJECT: Geothermal Short Course: "Geothermal energy and electric utilities - a background for decision."

The gothermal short course held at Snowbid on September 20 and 21 was generally considered to be informative and successful. There were more than 125 registrants, with more representatives from various electrical utilities present than at previous meetings. Three main topics were addressed: the characteristics of various known geothermal reservoirs, including their historic and projected electrical generating experience and capacity; the financing of geothermal field development and power plants, including the ERDA guaranteed loan program; and the way in which geothermal power plants must mesh with existing and planned electrical transmission facilities.

I. Geothermal Reservoirs

Several speakers made the point that as the geothermal energy used in a 55 MW electrical generating plant for 30 years is about equivalent to the yield of a 25,000,000 barrel oil field used for the same purpose, which shows how valuable a geothermal field can be.

Bob Greider of Chevron Oil has evidently changed his opinion about the eventual practicality of geopressured systems. He now says that economic conditions are approaching the point where large geopressured power plants may be feasible in the Gulf Coast area, if the huge quantity of water required can in fact be produced for 20-30 years and if the problem of ownership of the resource can be resolved. He pointed out that Tertiary basins exist in Wyoming and California (didn't mention Utah) and encouraged efforts on basic research.

A lucid explanation of geothermal reservoir engineering was given by Subir Sanyal, emphasising the kind of data required and the techniques used to figure out if a field will support a power plant for 30 years.

II. Financing and Legal Problems

The questions of whether geothermal resources are mineral, water, or sui generis is still unresolved; and therefore their ownership and tax status are still problematical. Cases in litigation in California will provide important precedents. Current betting is that geothermal resources will wind up with the owner of the mineral estate.

The relationship between surface, shallow ground water, and geothermal reservoirs causes uncertainties in many places. California and Oregon have a deal called a "certificate of presumption". This assumes that the geothermal developer is not interferring with surface and shallow ground-water rights, and he is free to proceed unless the contrary is proven.

The large sums of capital required to develop a good geothermal prospect and to build a power plant are difficult to raise in present market conditions. The ERDA geothermal loan guarantee program is supposed to assist in this. However, the loan program can't be used by the major oil companies, and small companies probably don't have the staff to satisfy the requirements of the loan program, so it's difficult to tell whether it will make a real difference.

Several representatives from utilities expressed concern about getting involved with power plants on federal lands because the federal leases call for readjustment of royalties every 10 years. They are also worried that long-term use of land for plant sites is inadequately assured, and that federal bureaucrats might shut down the field for environmental infractions, leaving the power plant high and dry. The utilities, who are naturally conservative, also worry about what happens if the field fails after a relatively short time (5-10 years) and would like contract clauses whereby the steam producer would compensate the utility in such an event.

As far as current costs go, Val Finlayson said that they are budgeting $435 per Kilowatt generating capacity for a dual inlet geothermal turbine plant. This compares with $365/kw for coal-fired units without SO_2 scrubbers, and $418/kw with scrubbers, but the latter cost is expected to go to $600/kw soon. The current average cost of electrical generating for UPL is 5.5 mil/kwh, and the cost for a mine-mouth coal-fired plant is 4.0 mil/kwh.

The 1975 cost for electricity at the Geysers was 6.35 mil/kwh, and is expected to be 13 mil/kwh in 1977. The costs at any future Utah geothermal plant are unknown but are thought to be competitive with coal-fired plants.

III. Electrical Transmission

Harry Haycock of UPL gave a few words of caution about proposed additions to the electrical grid - they must be carefully planned to be compatible with the rest of the system. There are large areas in the western U.S., especially Nevada, that have no suitable lines (larger than 115 KV) to hook into. Lines in the 345-500 KV range are very complicated, and might not be feasible to tap into.

Lines will be costly - $50-60,000/mile for a 230 KV line plus $1-2,000,000 for terminations.

The Milford area is lucky - there is a 138 KV line near Beaver that can be used in early stages.

Other speakers cautioned that utilities are budgeted and committed for five years in advance and a suddenly discovered large geothermal resource would probably suffer delays in being worked into the market for that reason if no other.

Carol
CAROL PETERSEN

CP:af

Bountiful City Light and Power

198 South 200 West Street
Bountiful, Utah 84010

801/295-9496

W. BERRY HUTCHINGS
DIRECTOR OF POWER RESOURCES

VAUN BETHERS
MANAGER OF OPERATIONS

June 27, 1977

Mr. J. C. Taylor, Vice President
Utah Power & Light Company
1407 West North Temple
Post Office Box 899
Salt Lake City, Utah 84110

Dear Mr. Taylor:

Bountiful is making a feasibility study on the purchase of a Federal geothermal lease now held by A. L. McDonald, Milford, Utah. The property under the lease is favorably located in the Federal Roosevelt Known Geothermal Resource Area (KGRA) about twelve (12) miles northeast of Milford. We are presently considering the installation of a ten (10) megawatt geothermal generating power plant at this site.

The Utah Power & Light Company has a 46 KV transmission line that extends through the area near the McDonald property. The transmission line terminates at the Sigurd Substation and the Cameron Substation. We would propose to tap this transmission line about mid-point between the existing Milford TV -- A.T.& T. tap and the Milford substation. The tap would be made in accordance to standard electric utility practices and at Bountiful's expense.

Our request for this service is being submitted enough in advance to allow sufficient time to meet with you to review our program and prepare a transmission service agreement. We would appreciate the opportunity of meeting with you at your earliest convenience.

Sincerely yours,

Berry

W. Berry Hutchings
Director of Power Resources

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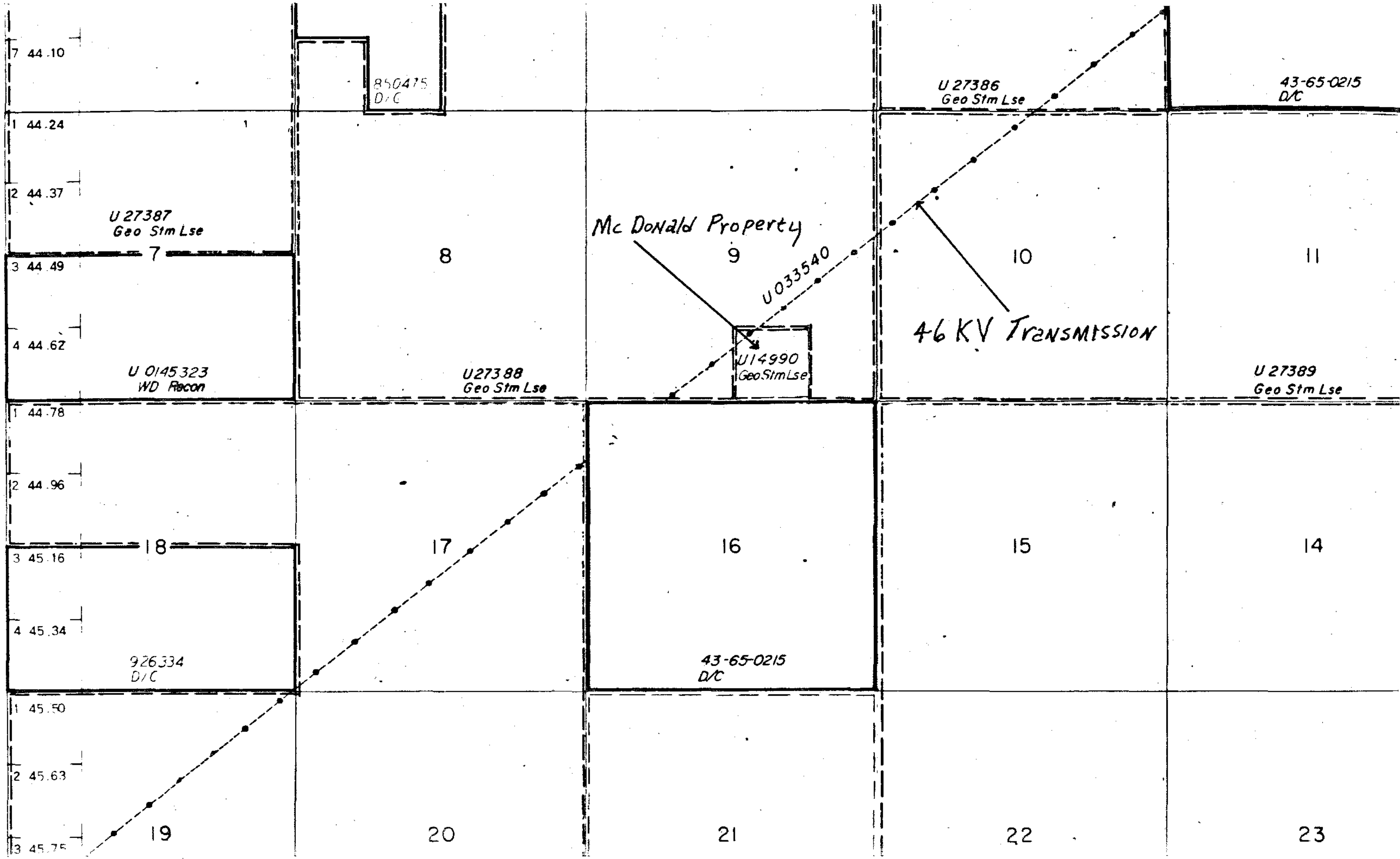

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Geothermal Energy and Electrical Power Generation

RONALD C. BARR
Earth Power Corporation, P.O. Box 1566, Tulsa, Oklahoma 74101, USA

ABSTRACT

The economics of electric power generation by means of fossil fuels and by means of geothermal energy are compared. This paper describes capital and fuel costs in some detail and touches on operating costs. Comparisons for nuclear fuels are not included due to the paucity of satisfactory data: capital costing for nuclear plants also does not lend itself to this comparison. Currently marginal or underdeveloped geothermal sources (such as hot dry rocks or low temperature, highly mineralized water) are not considered. Comparisons are restricted to oil, gas, coal, dry steam, and flashed steam—energy sources with which adequate experience has been gained—and also to binary cycles above a critical temperature. For comparison, the different sources are standardized according to British thermal units (Btu) per commodity unit of the energy source: coal, oil, gas, or geothermal fluid, assuming that the same amount of electricity (1 kWh) is generated for each 10 000 Btu regardless of source, assuming typical plant efficiencies. Data used are from The Geysers, Otake, and Cerro Prieto. Some conversions have been made to adjust the figures to a standard 110-MW generating unit, and to relate all costs to the same late-1973 level. For binary cycle possibilities, only reservoirs whose temperatures exceed 360°F (182°C) are considered commercial in this paper; the amount of hot water consumed per kWh increases markedly at lower temperatures. It is shown that under the conditions assumed, geothermal energy is commercially competitive and can reach profitable levels of operation.

INTRODUCTION

This paper will briefly describe the economics of electrical power generation and the economics of geothermal energy power generation based on production experience. The value of geothermal energy for power generation is compared to the value of oil, gas, and coal based on the assumption of a competitive price structure. The comparative value of geothermal energy may then be used to determine its potential profitability which in turn may be used to establish cost parameters for an exploration program.

Energy forms used commercially to generate electricity in North America are oil, gas, coal, nuclear, hydroelectric and geothermal. Fossil-fuel electrical power is generated in the United States by combusting oil, gas, or coal in a boiler which produces steam to drive a turbine. In a nuclear facility, a controlled nuclear reaction is initiated in a reactor which boils water to make steam to drive a turbine. A hydroelectric facility uses stored water to drive a turbine directly. Geothermal steam facilities use steam, or heat extracted from geothermal fluid, to drive a turbine or to heat a secondary fluid to drive a turbine.

Costs for the generation of electricity may be categorized as capital, operating, and fuel. This report will describe capital costs and fuel costs in some detail and will touch on operating costs. Fuel costs will be treated as costs of fuel delivered to the power generating plant, that is, inclusive of transporation and pipeline costs. From the point of view of the energy supplier the potential profitability of supplying fuel may be calculated by determining the market price for fuel less costs of extraction or production and transportation.

POWER GENERATION: CAPITAL COSTS

Capital costs often are expressed in terms of installed capacity; that is, a plant which will generate 100 000 kW of electricity is often referred to as a 100 000-kW plant or a 100-MW plant.

The output of a plant is commonly expressed in hours of output; that is, there are 8760 hr in one year. Table 1 shows a 100 000-kW plant's output as commonly expressed at various capacity factors in terms of kilowatt-hours of production per year.

Operating costs are generally quite small compared to capital costs and fuel costs and generally run from $0.0005, or 0.5 mills, per kWh to 1.0 mills per kWh. In other words, for a 100 000-kW plant operating at 70%, the annual operating costs over 1 year of production would amount to $350 000, that is, 700 000 000 kWh multiplied by $0.0005.

A range of present costs for utility construction has been obtained by reviewing announcements over the past year by the various utilities of their intentions to build new generating facilities, the type of facility to be constructed, and its cost. As shown on the next page, the costs for a nuclear plant are now $650 to $700/kW and $350 to $400/kW for a coal-fired plant.

The significance of the recent cost escalation is highlighted with the observation that the book-carrying cost for the approximately 360 000-MW generating capacity for the utility industry as a whole ranges from $75 to $125 per kW. When the construction of a new facility is announced and the cost is projected at an amount exceeding the book cost for the existing plant, rate increases or external financing must be obtained in an amount proportionate with the cost for the new plant as a percentage to that for the existing

Table 1. Power plant production.

Capacity (kW)	Operating rate (%)	Operating rate (hours)	Annual production (kWh)
100 000	90	7884	788 400 000
100 000	80	7000	700 000 000
100 000	70	6132	613 200 000

plant and the proportion of new plant capacity to existing capacity.

In reviewing announced construction plans over the last year, it is interesting to note that of approximately 47 new installations only one new oil-fired plant is anticipated (Table 2). One geothermal unit was announced, and the balance is fairly evenly divided between coal and nuclear units in terms of numbers of installations.

Recent cancellation and deferrals of new nuclear facilities reflect the increased cost situation perhaps more than they do environmental and safety considerations. We estimate that current projections showing increasing utilization of nuclear power are greatly exaggerated and will be replaced substantially by coal and, based on the issuance of leases by the Federal government and availability of exploration and development funds, geothermal.

POWER GENERATION: FUEL COSTS

Fossil Fuel Power Generation Costs

Fuel costs may be compared directly by determining plant efficiency and by establishing the British thermal unit (Btu) content of the specific fuel. A review of Part One of the National Power Survey published by the Federal Power Commission (FPC) in 1970 shows power generating data for various fossil fuel and nuclear facilities in the United States. The listing by plant of Btu required to produce 1 kWh of electricity illustrates the typical range of Btu consumption for coal, oil, and gas, as given in Table 3.

Table 2. Power plant construction announcements.

Date	Utility	Cost* Nuclear	Coal	Oil and gas
1973				
7/17	Commonwealth Edison	$545		
7/31	Pennsylvania Power Company		$303	
7/31	Detroit Edison		303	
10/12	Utah Power & Light		427	
11/9	Pennsylvania Power & Light	666		
11/16	Consumers Power Company (Michigan)	521		
11/27	Columbus & Southern Ohio Edison		293	
12/4	Philadelphia Electric			$266
12/4	Dayton Power & Light		333	
1974				
1/25	Alabama Power Company	$604		
1/29	Commonwealth Edison	545		
1/29	American Electric Power		323	
2/15	Iowa Public Service		417	
2/22	Long Island Lighting	568		
3/1	Niagra Mohawk Power		379	
4/19	Indiana-Michigan Electric Company	615		
5/17	Toledo Edison	673		
5/20	Rochester Gas & Electric	708		
5/25	New England Electric	695		

*Represents $/kWh installed. Data where plant capacity, type of facility, and estimated cost were reported taken from 19 out of 47 announcements as reported by Moody's Utility Service.

Table 3. British thermal units (Btu) required to produce 1 kWh of electricity.

Fuel	Low	High	Weighted
Oil	9333	17 651	10 500
Gas	9832	13 279	10 000
Coal	9836	15 033	10 500

The range of operating efficiencies varies with small units being less efficient and larger units being more efficient. While the age of the plants is not shown in the FPC report, we would guess that a similar situation exists; older plants are less efficient than newer plants.

The Btu content varies within the major fuel classifications of oil, gas, and coal. A constant, however, by definition, is that 3414 Btu is equivalent to 1 kWh. Therefore, as we look at the range of heat energy, or more practically the weighted average, it is most helpful to note that the operating efficiencies for the various fuels have a striking similarity. In other words, if we used a figure of 10 000 Btu as representative of power plant efficiency we would see that 1 kWh of electricity would be produced. We then have assumed that the same amount of electricity is produced for every 10 000 Btu of coal, gas, or oil consumed.

Nature has given us Btu contents in the physical quantities shown in Table 4. There are 42 gal of oil in a barrel, and 2000 lb of coal in one ton, the units commonly used in commodity transactions; gas is usually measured in thousands of cubic feet (MCF). Using the average heat exchange rates as shown above, we can use the standard commodity units to illustrate what comparable quantities may be required for electrical power generation (assuming 10 000 Btu required to produce 1 kWh). See Table 5.

It may be observed that in a nonregulated market, assuming similar plant construction costs, the delivered price for oil, gas, and coal would be based solely on Btu content and would be identical for the quantities shown above. Only nature's variances in quality of the specific fuel by unit would cause price differences.

Table 4. British thermal unit content.

Fuel	Quantity	High	Low	Common usage
Oil	1 gallon	152 000	126 000	145 000*
Gas	1000 ft^3 (MCF)	1 200 000	900 000	1 000 000
Coal	1 pound	14 000	10 000	12 500

*Used in this report is 142 857 Btu × 42 gal = 6 000 000 Btu/bbl oil.

Table 5. Comparable quantities of fuel required for electrical power generation.

Fuel	Quantity	Comparable Btus
Oil	4166 2/3 barrels	25 000 000
Gas	25 MCF	25 000 000
Coal	one ton	25 000 000

We have not considered nuclear fuel in the foregoing because we do not have data with which we would be satisfied, and capital costs are so different from plants using conventional fuel. Similarly, we have not allowed for varied sulfur contents in fossil fuel.

GEOTHERMAL POWER GENERATION COSTS

The costs of electrical generation using geothermal energy depends on the nature of the resource at the specific site where it is discovered. Geothermal resources in general may be classified as follows:

1. Dry steam.
2. Hot water with
   (a) Low temperature, low dissolved solids;
   (b) High temperature, low dissolved solids;
   (c) High temperature, high dissolved solids;
   (d) Low temperature, high dissolved solids.
3. Hot dry rocks.
4. Geopressured zones.

Production experience with dry steam and high temperature, low dissolved-solid hot water has proven the commercial profitability of the resource in these forms. While commercial success using hot water has to date used only flashed steam, progress on the binary cycle has advanced enough to consider it commercial. The classification of the binary system as commercial is significant because it permits utilization of hot waters in the high temperature—high dissolved solids category and reduces the low end of high temperature category from 466°F, where an economic level of flashing occurs, to 360°F, where the hot water may be used directly. Hot dry rocks, geopressured zones, and low-temperature geothermal systems (less than 360°F) are not discussed in this paper because of a lack of sufficient data.

Accurate cost breakdowns for dry steam are available from the Pacific Gas & Electric Company experience at The Geysers. Generation costs for hot water systems using "flashed" steam at Cerro Prieto, Mexico, and Otake, Japan, have been obtained from published industry sources. Costs for the binary cycle, using hot water directly, are projections by the Ben Holt Co. and are discussed separately. The capital cost for each type of plant will vary depending on the quantity of Btu that may successfully be recovered; that is, the amount of heat that is extracted and its relationship to the pressure and rate of flow, together with the quantity of dissolved solids and noncondensable gases.

In order to perform an analysis based on past experience, we have taken data from The Geysers, Otake, and Cerro Prieto and have made some conversions, first to adjust the figures to a standard 110-MW unit, and second, in the case of Otake, to relate the costs to a comparable late 1973 level (Table 6). The costs for The Geysers are used as a base and are shown herein in the exact quantities of funds spent as they appear in the Certificate of Application filed with the California Public Utility Commission by Pacific Gas & Electric Company for Unit 14 (due to come on stream in 1976).

The Otake figures have been taken from a 1970 paper published by the United Nations Symposium on the Development and Utilization of Geothermal Resources from Pisa in 1970. They are based on a 30-MW plant which went into operation in 1968. The cost budget experience for the 30-MW plant was used as a basis for construction of a 70-MW plant and reflects certain economies of scale. We have made a straight extrapolation from the 70-MW figure to 110 MW and have added 20% to reflect current costs. While the 20% may be on the low side, it does not take into account any additional economies of scale on the overall plant size. If, by way of example, the outside diameter of the cooling tower were expanded from 20 to 30 ft in order to handle a proportionately greater volume of steam, the costs would not escalate proportionately. The same would apply to the structure housing the plant, instrumentation, and controls.

In the case of Cerro Prieto the source material for the total costs, as reported in the February, 1974, Geothermal Hot Line published by the State of California, were originally shown as direct and indirect costs. They have been increased proportionately to reflect the increase to 110 MW from 75MW with no consideration for economies of scale. Rather than allocating indirect costs among the various accounts and then increasing each account to reflect the increase from 75 MW to 110 MW, the direct costs were doubled and then a charge of $2.521 million was allocated to plant overhead.

For the three cases studied we have grouped specific cost breakdowns for power production facilities. Drilling and pipeline costs and those other costs which would normally be associated with a steam supplier are not included. Overhead costs have been allocated equally between the power producer and the steam supplier. The accompany-

Table 6. Geothermal power capital costs for a 110 000-kW plant.

	Power plant	Costs in $ × 10³ Dry steam (The Geysers, California)	Hot water (Otake, Japan)	Hot water (Cerro Prieto, Mexico)
1	Condenser—cooling tower	0	4 322	1 600
2	Structures	1 838	2 651	2 960
3	Equipment (plant)	648	496	736
4	Turbo-generator	6 411	7 192	4 240
5	Electric equipment	1 167	3 366	960
6	Miscellaneous equipment	234	999	1 585
7	Engineering—instrumentation	1 012	1 010	960
8	Overhead	2 130	2 585	2 521
	Subtotal	13 440	22 621	15 562
9	Substation transformer	441	655	655
10	Transmission transformer	153	153	153
	Total	14 034	23 429	16 370
	Cost/kW installed	$ 127	$ 212	$ 148
	Fixed charges 17.3% ($000)	$ 2 427	$ 4 053	$ 2 832
	Operating expenses ($000)	250	375	375
	Total fixed ($000)	$ 2 677	$ 4 428	$ 3 207
	Cost/mill @ load factor (exclusive of fuel)			
	90% (106 × 7885 = 835,8MM kWh)	3.20	5.29	3.83
	80% (106 × 7000 = 742,0MM kWh)	3.60	5.96	4.32
	70% (106 × 6130 = 649,7MM kWh)	4.12	6.81	4.93

ing chart illustrates the range of capital costs for power generation using dry steam and steam flashed from hot water.

The projected costs for binary cycle electrical generation using geothermal hot water have been described by the Ben Holt Co., based on design work completed in California, at Niland and Heber in the Imperial Valley and at Mammoth in Long Valley. They have projected binary-cycle plant construction costs as a function of hot-water consumption and reservoir temperature. The higher capital costs for a binary cycle system are principally associated with the heat exchange system itself. These costs alone appear to increase plant costs approximately $100/kW-capacity over those for a dry- or flashed-steam facility.

While the Ben Holt Co. analysis shows the cost-reservoir relationship from 250 to 500°F (120 to 260°C) only those temperatures in excess of 360°F (182°C) are considered commercial in this study. The reasons for the 360°F cut-off are three-fold. First, the projected plant cost loses its competitive advantage over a coal-fired facility at temperatures lower than 360°F. Second, the number of wells for production and reinjection accelerate rapidly at lower temperatures. Third, the hot water consumption at 360°F is comparable to the minimum temperature of hot water flashed to steam or of dry steam considered necessary for commercial development.

These three factors, combined with a knowledge of present drilling costs, lead to the conclusion that the discovery of a reservoir with a minimum temperature of 360°F should prove to be commercially viable.

Comparative Energy Valuations

The conversion of geothermal energy to electricity has been demonstrated using dry steam and hot water flashed to steam. Development to date indicates that the binary cycle conversion of hot water to electrical energy will be demonstrated shortly. A method for pricing geothermal energy has been devised based on flow rates for geothermal wells and minimum temperatures. Dry steam wells at The Geysers produce 100 000 to 200 000 lb/hr steam, and hot water wells commonly produce 500 000 to 750 000 lb/hr. The minimum temperatures used are those where 20 lb/hr steam or 100 lb/hr hot water produce 1 kWh.

The dry steam at The Geysers enters the steam turbine at 100 psi and 373°F. The steam tables show that the total heat (enthalpy) of the steam is approximately 1200 Btu/lb. While The Geysers consumption is 18 lb/kWh, the literature often describes the amount as 18 to 20 pounds, leading to the "rule of thumb" that 20 lb/hr are required for 1 kWh, or as more commonly expressed, that a 100 000-lb/hr well will supply 5000 kWh. It may be noted that if 20 lb/hr are required to produce 1 kWh (3414 Btu by definition), then 24 000 Btu (20 lb multiplied by 1200 Btu/lb) are required for 1 kWh. The thermal conversion efficiency is therefore 14.22% (3414 ÷ 24 000). These parameters should hold true for dry steam in general.

The amount of steam which can be flashed from hot water is a function of temperature and has been reported by D. E. White in 1975; Table 7 summarizes White's results.

The temperatures of the hot water at Cerro Prieto are in the 550 to 600°F range. While the amount of hot water flashed is not reported, the Mexican government has stated that the steam consumption is 16.74 lb/hr. (It is generally felt within the industry that utilization at Cerro Prieto could be improved by 50% without additional wells.) At Otake, the amount flashed is believed to be 25.6%, thus indicating a temperature around 500°F.

Table 7. Amount of steam which can be flashed from hot water at given temperatures.

Temperature (°C)	(°F)	Amount flashed (%)
150	302	0
175	347	5.5
200	392	11.0
225	437	16.5
240	466	20.0
250	482	22.0
275	527	27.5
300	572	33.0

The Ben Holt Co. analysis for the binary cycle shows hot water consumption in pounds relative to temperature required to produce 1 kWh (Table 8). Note the significantly greater quantities of hot water required between 300 and 360°F and the rapid decrease in water consumption at the higher temperatures. While plant costs estimated by Holt within this range appear economically competitive ($400/kW at 300°F, $350/kW at 350°F, $310/kW at 400°F, and $250/kW at 500°F), the consumption of more than 100 lb/kWh generated does not appear to be commercial because of the significantly larger volumes of water and, therefore, the greater number of wells necessary to supply the plant.

Table 7 shows that at 460°F (238°C), hot water will produce a 20% flash to steam. For a hot water well flowing at a rate of 500 000 lb/hr, 100 000 lb/hr steam would be produced. Every 20 lb/hr will produce one kWh and 100 000 lb/hr will produce 5000 kWh. Similarly, a 500 000-lb/hr well supplying a binary cycle plant at 360°F will use 100 lb/hr hot water for 1 kWh and 500 000 lb/hr will provide for the generation of 5000 kWh.

A review of the Btu consumption of fossil fuel (10 000 Btu required to generate 1 kWh) and the useful heat content of dry steam, steam flashed from hot water, or hot water supplying a binary plant, leads to the observation that 2000 lb steam or 10 000 lb hot water produced over 25 hr will have an electrical output in kilowatt-hours which may be compared directly with fossil fuels. If 20 lb/hr are required for 1 kWh, given current conversion efficiencies for geothermal power production, then 2000 lb steam produced for 25 hr is equal to one ton of coal, 4.166 barrels of oil, or 25 MCF of gas. By adjusting the 20 lb/hr downward 4%, the 25-hr component is offset to a 24-hr factor. This produces a unit of measure for the sale of geothermal steam of 2000 lb/hr/day or simply a *ton/day of production*.

Table 9 is based on a ton/day for the generation of

Table 8. Hot water consumption relative to temperature required to produce 1 kWh.

Hot water (lbs/kWh)	Temperature (°F)
200	300
150	320
100	360
80	400
75	450
60	500

Table 9. Fuel prices based on power generation output.

bbl oil ($) (4 ¹/₆ bbl)	MCF gas (¢) (25 MCF)	ton coal ($) (one)	ton/day geothermal ($)* (one)
$ 1.00	$ .16	$ 4.16	$ 4.16
2.00	.33	8.33	8.33
3.00	.50	12.49	12.49
4.00	.66	16.66	16.66
5.00	.83	20.83	20.83
6.00	1.00	25.00	25.00
7.00	1.16	29.16	29.16
8.00	1.33	33.32	33.32
9.00	1.50	37.49	37.49
10.00	1.66	41.66	41.66
11.00	1.83	45.82	45.82
12.00	2.00	50.00	50.00

*The Btu prices are equivalent for oil, gas, and coal but are 41% for geothermal due to less efficient conversion to electricity.

Table 10. Well flows and geothermal revenues.

Hot water* (lb/hr)	Steam (lb/hr)	Ton/day	Revenues oil/TD† equivalents @ 80% capacity‡ $6/25.00	$8/33.32	$10/41.66
250 000	50 000	$ 25	$182 500	$243 236	$ 304 118
500 000	100 000	50	365 000	486 472	608 236
750 000	150 000	75	547 500	729 708	912 354
1 000 000	200 000	100	730 000	972 944	1 216 472

*Assumes 20% flash to steam or 100% utilization with binary cycle.
†TD = ton/day of geothermal steam.
‡Capacity @ 80% × 292 days.

geothermal energy and is shown with fossil-fuel prices. Because the natural gas is assumed to have 1000 Btu ft³, the price per thousand cubic feet MCF of natural gas with the decimal point moved one place to the right is equivalent to the cost in mills per kilowatt-hour for power generation fuel costs. Table 10 shows a range of well flows and corresponding revenues.

CONCLUSION

The costs of utilizing geothermal energy for electrical power generation have been shown for power plant construction and geothermal energy purchases. They are competitive with other forms of power generation. This paper, and an awareness of drilling costs, suggest that revenues from the sale of geothermal energy will lead to a profitable level of operations for the energy supplier sufficient to encourage the commercial exploration and development of geothermal energy, perhaps on a large scale.

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GEOTHERMAL POWER

THE "SLEEPER" IN THE ENERGY RACE

ROBERT LENGQUIST[1] with FRITZ HIRSCHFELD[2]

There may be a bright future ahead for geothermal power. It is relatively cheap, there are no safety problems, relatively few environmental headaches, and little new technology to develop or prove. The installation at The Geysers in northern California shows what can be done to harness this potential source of useful energy.

Approximately 90 mi (140 km) north of San Francisco—nestled in the rugged terrain of the Mayacmas Mountains—is the site of the world's largest commercial geothermal power complex. In a remarkably short time span—slightly more than 20 yr—the production of electricity at The Geysers has grown from 0 to 522 MW installed capacity; with units projected that will bring the total rating close to 1000 MW by the 1980s. Considering that this was accomplished entirely by private enterprise—without any government funding or support—and in the face of the militant environmentalist movement in California—it is quite an achievement!

Geothermal power derives from the elementary fact that there is considerable heat stored beneath the surface of the earth. If one accepts the premise that the planet Earth was formed as the result of a tremendous explosion/implosion in the solar system, that it was literally a ball of fire at the time of conception, and that it has been gradually cooling down ever since, then it follows that there is a temperature gradient between the outer layer of the earth and its core. Irrespective of theory, however, such observable phenomena as volcanos, geysers, fumaroles, hot springs, etc., prove beyond question that there is a substantial heat source encapsulated within our planet. But the exact nature of the energy—its quantity and quality, where it is located, and how it can be successfully tapped—these are areas of geological investigation that are still in their infancy.

In certain respects we are no better off than the peoples of antiquity. For example, we watch with the same awe and fear as the ancient Romans did the periodic volcanic eruptions of Vesuvius, and we cannot control or even accurately predict the upheavals of this millenium-old crater. And in the realm of superstition, the mythology of Hades has managed to survive the scientific method and lives on in religious folklore as the "fires of hell." It is little wonder, therefore, that when William Bell Elliott, hunting grizzly bears in the Mayacmas hills in the spring of 1847, stumbled on The Geysers and heard the loud noise of steam escaping through narrow fissures, smelled the sulfurous fumes, and saw clouds of water vapor shooting high in the air, his first thought was that he had discovered the "gates to the Inferno"!

Today there is a credible explanation for The Geysers. Volcanic activity within the last 3 million yr has brought magma or molten rock within 5 to 10 mi (8–16 km) from the earth's surface. Water contained in the fractures and formations of the near surface rocks is heated by the cooling magma. Sufficient pressure is generated by the

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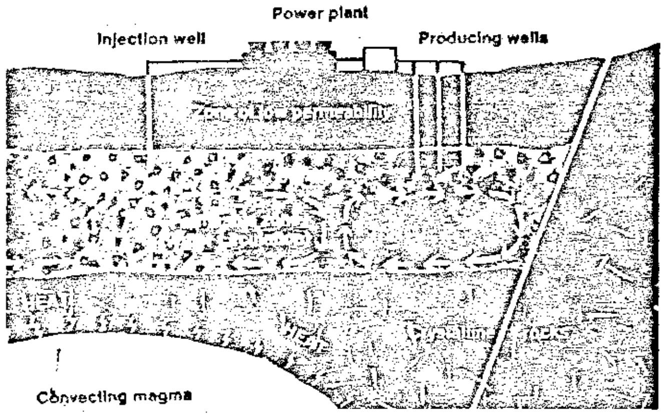


Earth tremors more than 60 million yr ago caused fissures to open in the crust and brought magma — a molten mass — 5 to 10 mi (8–16 km) from the earth's surface. Water contained within fractures in the near surface rocks is heated by the cooling magma. When such a reservoir is tapped by drilling, pressure is released. This permits hot water or steam to flow to the surface, which then may be used to generate electricity.

trapped water vapor to cause jets of steam to break through the thin layer of crust and escape in small quantities to the atmosphere. These were the manifestations that caught the attention and fired the imagination of Elliott back in 1847. Of course, when such a reservoir is tapped by drilling, much greater quantities of steam will flow, forced out by the subterranean pressures. Geologists are now attempting to ascertain whether underground waters replace that which is being drawn off as steam. This is one of the more crucial questions, and the answer will obviously help to determine the long-term value of geothermal power.

During the century following Elliott's discovery the therapeutic virtues of The Geysers, rather than its potential as a source of energy, were being touted:

THE GEYSERS is properly called "The Eighth Wonder of the World," "Nature's Gift to California," "The Carlsbad of America," and "The Tourists' Paradise." Here our Creator has provided every thing needed to cure the ills of humanity. Here are the most heavily laden RADIO-ACTIVE Mineral Waters in the World . . . . The Hot Magnesia water cures stomach and intestinal disorders, the Liver Spring cures all liver disorders, the Kidney Spring for all kidney troubles, Sulphur and Iron Springs to build up your health in general.

And among the visitors who patronized "The Eighth Wonder of the World," as noted in an old hotel register, were the likes of: . . . General Grant, William McKinley, Theodore Roosevelt, Mark Twain, Horace Greeley, Garibaldi, J. Pierpont Morgan, the King of England . . .

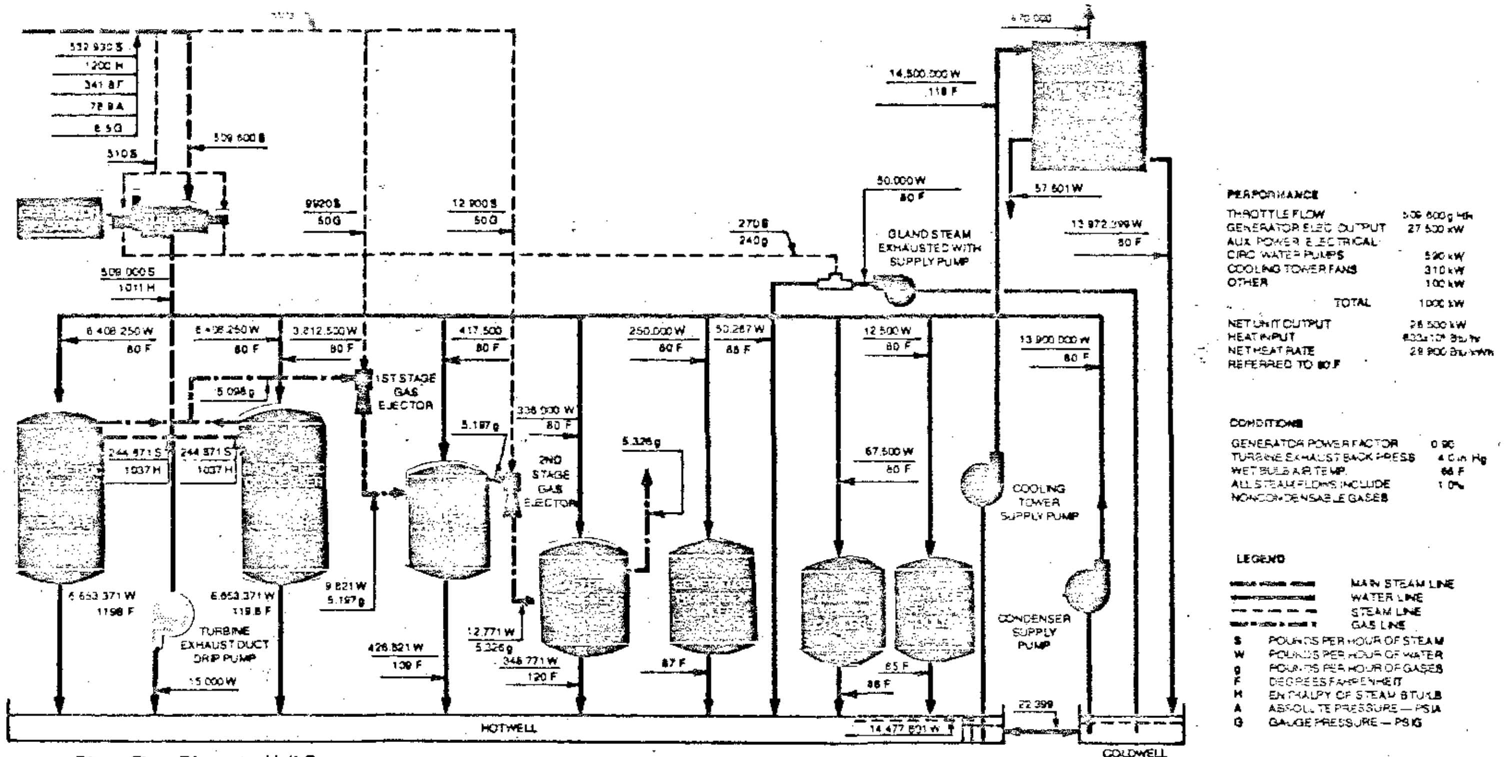
In the meantime, while the "beautiful people" frolicked in California, a pioneer venture in geothermal power was being pursued on the other side of the globe. Appropriately enough in Italy—where the Roman aristocracy also used to luxuriate in their hot thermal baths—it was decided to develop these thermal sites for the practical purpose of generating electricity. The first geothermal power station in the world went on-stream at Larderello (between Rome and Pisa on the western side of the Apennine Range) in 1904. By the late 1930s, capacity had increased to 100 MW; and the present installed capacity of all Italian geothermal power plants is over 400 MW. Dry steam flows from 181 wells in the Larderello region with an average production per well of about 50,000 lb/hr (23 t) at 302°F (150° C) with shut-in pressure of 73 psi (5 atm) and power station pressure of 62 psi (4.2 atm). The upper limits of steam production of the Larderello fields have probably been reached (they've been worked continuously for over 70 yr) but there are at least nine more promising thermal areas lying along a 500-km (300-mi) zone in the Apennines in central Italy. These prospects are now either being extensively explored or in various stages of development.

Exploration, Imagination, Exploitation

When the tourist phase at The Geysers had run its course (apparently the health cures did not live up to their advance billing) a group of enterpreneurs moved in in the early 1920s and drilled eight shallow wells, ranging in depth from 154 ft (47 m) to 636 ft (194 m). Rigs using the cable tool concept (then called churn drills) were employed to bore the holes. The exploration program did prove that large quantities of dry steam were available and that it was feasible to harness this energy to produce electricity. A small 250-kW generator was actually installed, and driven by a noncondensing reciprocating engine, it furnished electric power for a local resort hotel. However, because of the plentiful supply of cheap electricity from conventional hydroelectric and fossil-fuel plants, there was no economic incentive to invest further capital in the development of geothermal power at The Geysers, even though the Italians had already amply demonstrated that geothermal energy could be a commercially competitive factor.

Again The Geysers lay dormant. The resort lapsed into a state of decay. Only an occasional hiker or weekend motorist visited this out-of-the-way spot. Fortunately, it fell to an imaginative and competent lumber merchant from Los Angeles, Mr. B. C. McCabe, to revive interest in The Geysers as a geothermal project. Although "Mac" McCabe has no formal engineering training and no past association with the power business, he was stimulated by the geothermal challenge and he set out to prove that it offered a profitable opportunity for the utilities and a sound investment for himself. Risking his own money, McCabe leased from The Geysers Development Company—a private firm holding title to much of the property)—approximately 3620 acres (1460 hectares) of land along Sulphur Creek, a stream that serves as a runoff channel for the area. The initial well drilled by McCabe's operating entity, Magma Power Co., was called Magma No. 1 and was completed in 1955 to a depth of 817 ft (249 m.). The flow rate of dry stream was roughly 150,000 lb/hr (68 t) at a wellhead pressure of 100 psig (7 kg/cm^2).

An old associate of McCabe's, Dan A. McMillan, Jr., was tempted to join the action. He, too, formed his own vehicle—Thermal Power Co.—and Magma and Thermal then agreed to share equally in the leasing and drilling expenses as well as in the anticipated profits of the combined undertaking. By 1957, six wells had been drilled at The Geysers, with depths running from 527 ft (161 m) to 1414 ft (431 m). By December of that year



Plant Flow Diagram. Unit 3.

flow tests had been made on four of the completed wells.

Enter P.G.&E.

At about this time McCabe and McMillan began looking around for a customer to purchase their steam. Representatives of one of the largest utilities on the West Coast, Pacific Gas and Electric Co., were invited to visit the site and to review the results to date. P.G.&E. conducted its own independent studies and tests and became convinced that there was at least enough steam available at The Geysers to justify a substantial capital investment that could be safely amortized within a period of 30 yr. A contract was signed on October 30, 1958 whereby P.G.&E. committed itself to install a 12,500-kW turbine-generator operating on the condensing cycle; and Magma and Thermal obligated themselves to supply steam at the turbine steam strainer inlet at the rate of 235,000 lb/hr (107 t) and at a pressure of 100 psig (7 kg/cm^2). The contract also provided that additional units could be added as: (1) steam became available; (2) there was need for the power generated; and (3) it could be economically produced in comparison with other sources of power.

The first 12,500-kW unit went on-line in April of 1960. This turbine-generator had been functioning for 42 yr for P.G.&E. in a standard fossil-fuel steam generating plant using steam at an inlet pressure of 250 psig (17 kg/cm^2). The turbine was already on the way to the scrap heap when it was decided to salvage it for duty at The Geysers. The blading of the rotor and stator sections was rebuilt for the use of steam at an inlet pressure of 100 psig (7 kg/cm^2). Now the "old war-horse" still performs faithfully, operating at 85 psig (6 kg/cm^2) with a back pressure of 4 Hg absolute, and exhausting to a barometric condenser with cooling water supplied by a mechanical induced draft cooling tower.

Starting with 1960, the following units have been installed at The Geysers:

Unit No.	Start-up	Cap. MW	RPM	Inlet psig.	Exh. Press. Hg abs., in.	Gen. Cool.
1	1960	12	1800	85	4	air
2	1963	14	3600	65	4	air
3	1965	28	3600	65	4	hydrogen
4	1968	28	3600	65	4	air
5	1971	55	3600	100	4	hydrogen
6	1971	55	3600	100	4	hydrogen
7	1972	55	3600	100	4	hydrogen
8	1972	55	3600	100	4	hydrogen
9	1973	55	3600	100	4	hydrogen
10	1973	55	3600	100	4	hydrogen
11	1975	110	3600	100	4	hydrogen
		522 Total Capacity				

The stated capacities are total generator capabilities. The plant auxiliaries consume approximately 4 percent of the generator output, with the remaining 96 percent being delivered into the transmission grid for P.G.&E. customer use. Units 12 through 15 are in the planning stages. Unit 12 will be operating in 1978 with two 55-MW turbine-generators producing a total output of 110 MW. Unit 13 will add another 135 MW; Unit 14, 110 MW; and Unit 15, 60 MW. Therefore, if these projections fully materialize, there will be 937 MW worth of geothermal power flowing from The Geysers within the coming decade.

The principal advantage of the geothermal steam cycle is the elimination of the boilers. With the low quantity of noncondensable gases in the steam at The Geysers, it is economical to condense the steam. About 30 percent of the cost of the plant is in the condensing system and about double the power can be obtained by using a condensing turbine instead of one with atmospheric exhaust.

The plant cycle for Unit 3 is shown in the accompanying diagram. The cycle for Unit 4 is the same except the steam flow to the turbine is 1.2 percent greater because the generator is air-cooled instead of hydrogen-cooled. Also, the cooling water for the generator is to air-coolers instead of hydrogen-coolers. The flows in the plant cycle for Units 1 and 2 are about half those of Unit 3.

The noncondensable gases in the steam require a large-size gas ejector on the condenser compared to the normal air ejector called for with a conventional unit. There is a two-stage steam jet gas ejector utilizing about 4 percent of the total steam flow. The gases were ejected to the atmosphere high above the barometric condenser so that the hydrogen sulfide in the noncondensable gases would be diluted to reduce ground-level concentrations to an acceptable figure. The off-gas is now discharged into the cooling tower structure to mix with chemical solutions for abatement of hydrogen sulfide.

The geothermal steam has entrained in it subsurface rock particles and dust plus noncondensable gases totaling about 0.20–0.50 percent by weight of total mass flow. The table below is a typical example of the steam conditions relative to noncondensable gases, etc.:

Composition, Percentage by Weight of Total Flow

	H_2	CO_2	N_2	CH_4	H_2S	NH_3	Total
Steam	0.005	0.280	0.004	0.020	0.016	—	0.325
Condensate	—	0.090	—	—	0.014	0.025	0.129
Total	0.005	0.370	0.004	0.020	0.030	0.025	0.454

During initial stages of well flows, the noncondensables may represent as much as 1 percent of total mass flow, but will subside to some 0.5 percent or as low as 0.20 percent in just a few months' time.

Environmental Problems

The hydrogen sulfide is probably the main culprit that has exercised the environmentalists—and perhaps with good cause. H_2S has a strong pungent odor—not unlike rotten eggs. Although it is not known to be harmful at the present concentration levels to humans, animals, or vegetation, its obnoxious smell makes its presence highly undesirable. As of last year, The Geysers were pumping close to 25 tons of H_2S daily into the air; and, while the region is sparsely settled, nevertheless there are small communities scattered throughout the area. It seems that when the wind blows from the right direction, some of the neighboring townsfolk get a whiff of hydrogen sulfide gas. The locals have quickly learned that even the slightest complaint of pollution brings the full and immediate wrath of the environmentalists down upon the heads of the offenders. Lawsuits, injunctions, court hearings, and regulatory agencies are all mobilized and there is literally no place left to hide! The best defense generally is prompt compliance. By installing pollution control equipment at The Geysers and by carefully sealing off leakages, the H_2S output to the atmosphere has been brought down to about 20 tpd. Further measures should make it possible to reach a goal of 5 tons—an amount that everyone apparently agrees that they can live with.

The other environmental problems could be coped with more expediently. Take the complaint of Mrs. Faye Dewey, for instance—an elderly lady who is the proprietress of the sole tavern/general store in the vicinity of The Geysers. Mrs. Dewey resented the roaring noise created when the wells are allowed to blow freely to the atmosphere. This noise is often deafening—somewhat like living next to Niagara Falls—especially when the sound echoes off the steep walls of the canyon. Every effort was made to ease Mrs. Dewey's discomfort. Vents were capped when not in use and the operators were instructed to hold down the decibels as much as possible. The good-neighbor policy has helped to keep this problem within bounds.

Dumping wastewater containing ammonia into Sulphur Creek also became a "no-no" when it was learned that even slight amounts of this toxic substance killed off the fish population.

An ongoing program was instituted in 1973 to landscape those sites that were deformed or scarred by drilling and construction activities. Replanting trees and shrubbery, terracing, and the removal of unnecessary structures and eyesores has gone a long way to restore or maintain some of the area's natural beauty.

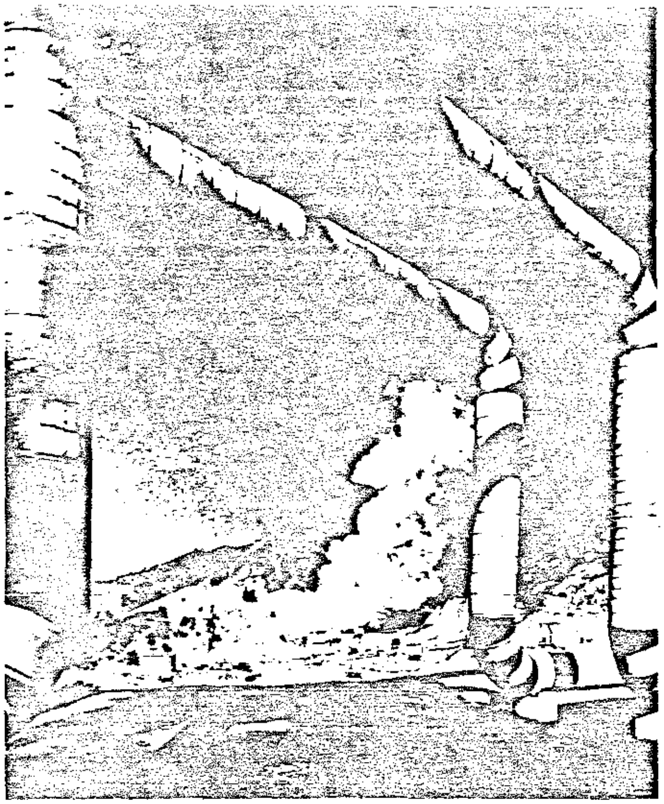
The corrosive effects of the noncondensable gases have called for certain precautions to be observed in the selection of materials used at The Geysers. Again, the chief villain is H_2S, which has a voracious appetite and affinity for anything containing copper. Aluminum, stainless steel, epoxy-coated asbestos cement, and cast iron have served as substitutes for copper in condensate lines, underground piping, gas and oil cooler tubes, and cooling tower hardware. Exposed copper in the plant is either tinned or protected by coatings to prevent damage by the hydrogen sulfide in the atmosphere. To avoid using copper commutators required by rotating exciters, static excitation systems are employed. Meters and relays pose special problems. Meters with platinum taut-band suspensions have successfully replaced meters using conventional copper-alloy springs. Relays with special proprietary corrosion resistant provisions have proven equally satisfactory.

Geothermal Steam Characteristics

The differences between a geothermal power plant compared with a fossil-fueled thermal installation—apart from the fact that there is no boiler—lie in the characteristics of the geothermal steam. These characteristics can be divided into physical and chemical components. The chemical properties have already been mentioned. The principal physical feature is the huge volume of geothermal steam that must be processed to produce 1 kWh of electricity. This means, for one thing, large steam lines and larger quantities of cooling water that have to be handled for each generated kilowatt-hour. An idea of the comparative statistics is illustrated in the table tabulating side-by-side data from Units 3 and 4 at The Geysers with the equivalent information from a conventional P.G.&E. power plant (Units 6 and 7 at the Moss Landing Power Plant):

Power Plant Comparisons

	Geysers 3 or 4	Moss Landing 6 or 7
Unit Size, MW	28	750
Inlet Stm. Press., psig	65	3675
Inlet Stm. Temp., °F	342	1000
Lb Stm./kWh	18.54	6.68
Ratio of Stm. by Wt.	2.78	1
Inlet Stm. Vol., cu ft/lb	5.8	0.193
Ratio of Stm. by Vol.	30	1
Ratio cu ft of Stm./kWh	83.4	1
Cooling Water, gpm/kW	1.03	0.41
Net Heat Rate, Btu/net kWh	23,900	8300



Expansion loops carry geothermal steam from wells drilled to a depth of more than 1½ mi (2.5 km) to Pacific Gas and Electric Co.'s plant at The Geysers in Sonoma County, Calif. The plant is located about 90 mi (140 km) northeast of San Francisco.

Since there is no boiler which needs to be fed with condensate, a less expensive direct contact or barometric condenser is adequate. The cooling water in this type of condenser mixes with the steam exhausted from the turbine and condenses it. The mixture of condensate and cooling water could be dumped if a large river were handy from which to draw a supply of cooling water, but then only if dilution was sufficient to prevent heat and/or toxic pollution. However, this not being the case at The Geysers, cooling towers are required. Part of the condensate—about 75–85 percent of the water being added from the turbine unit—is evaporated, and the remainder overflows to a reinjection disposal system. The amount of evaporation is determined by the atmospheric conditions. No make-up is needed from external water sources and the circulating water becomes essentially condensate. The overflow keeps the buildup of chemicals in the water from the noncondensable gases to a low limit.

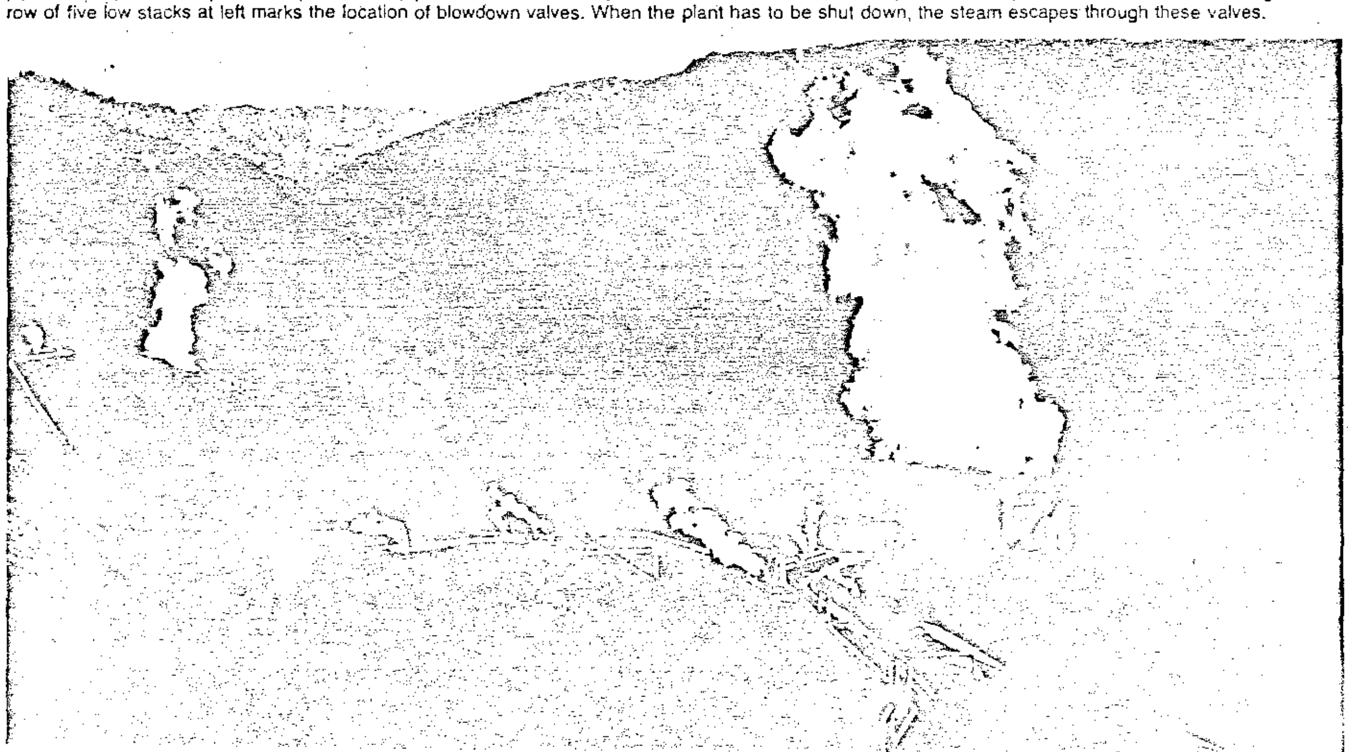
Geothermal steam coming from the wells is passed through in-line separators to prevent fine sand and rock particles from reaching the turbine blades and causing damage or serious erosion. Each well, therefore, is equipped with an in-line centrifugal separator. A second separator, installed in the steam line of each turbine near the turbine room, acts as a backup separator and final cleanup of the steam before it enters the turbine. According to the contractual arrangements, the steam suppliers are responsible for providing acceptably clean steam to the power plant.

Economics

It has been commercially practical to generate power from geothermal steam at The Geysers because it can be produced economically in comparison with power from other sources in the P.G.&E. system. The capital cost at The Geysers is $132/kW in Units 9, 10, and 11. Future installations are expected to average in the neighborhood of $250/kW. By comparison, large coal-burning plants run $300–400/kW; and nuclear plants are $500–600/kW. Also, lower operating and maintenance costs are experienced because there is no boiler to operate and the units are designed to function unattended.

Operating personnel are present during each of the three 8-hr shifts per day. Maintenance personnel and office staff are present during the 8 a.m. to 4 p.m. shift. The units have been installed in pairs so that the cost of the second unit tends to be less per kilowatt because most of the cost of the site development work was ab-

Units 3 and 4, shown here, went into commercial operation in 1967 and 1968, respectively. They brought plant capacity to 82,000 kW. In the foreground are steam pipes with expansion loops. The loops allow the pipe to contract when the plant has to be shut down and to expand on startup. The steam condensate rising from the row of five low stacks at left marks the location of blowdown valves. When the plant has to be shut down, the steam escapes through these valves.



sorbed in the overhead for installing the first unit.

The thermal efficiency of a geothermal unit is considerably less than that of a conventional steam boiler unit because it uses natural steam which has low pressure and little superheat. The net thermal efficiency of Unit 3 at 28,000 kW is about 14.3 percent. The plant is still economical, however, because of the lower cost of natural steam.

One of the outstanding features of this project is the resultant conservation of fuel oil. The kilowatt-hours generated in 1975, some 3.37 billion, represents about 5,500,000 bbl of fuel oil. This is based on a heat rate of 10,000 Btu average heat rate in a modern fossil fuel fired steam-electric power station. From April 1960 through June 1976, the total generation represents the conservation of about 24,800,000 bbl of fuel oil. The steam is paid for on the basis of the amount of electrical energy that is actually delivered to the P.G.&E. system. For the first two units, for example, the price paid for the steam was 2.5 mills/kWh. For the additional units, the cost is calculated each year on the basis of the weighted average of (1) 2.5 mills/kWh, adjusted for current fuel costs and the best heat rate for fossil units compared with December 1958 (later agreed to 1968 values) fuel costs and best heat rate; and (2) the average nuclear fuel costs. For 1966, the payment for energy from additional units was 2.55 mills/net kWh; and in 1967 it was 2.27 mills/net kWh. The 1976 rate is 11.35 mills, which includes 1/2 mill for water injection services.

The following table shows the principal costs for the first four units installed at The Geysers:

	Units 1 and 2	Units 3 and 4
Gross Generating Capacity, kW	26,000	56,000
Total Capital Cost of Power Plant	$3,800,000	$6,900,000
Cost per Gross kW	$146	$123
Total Capital Cost of Transmission Line	$215,000	$310,000
1967 Energy Cost, Mills/kWh	2.5	2.27
Total Estimated Cost Delivered to System at 90% Capacity Factor Including Transmission, Mills/kWh	5.65	4.71

Operating Procedures

Inflation has clearly manifested its presence. The estimated costs of additional units are now in the area of $250/kW. Steam wells, gathering system, roads, and other supporting facilities will add about another $175/kW, resulting in a total capital cost of approximately $425/kW. The principal difference in operating procedure for the geothermal units of The Geysers is the practice of shutting down the plant every few months for a few hours as a trip test, so that a functional test of the plant's automatic protection features can be carried out. On conventional units, these tests are performed as part of an on-line testing program during maintenance outages. The shutting down of the geothermal units provides an opportunity to do preventive maintenance on those parts of the electrical switchgear that are subjected to the corrosive attacks of the hydrogen sulfide in the atmosphere, which has been a primary maintenance problem. This type of servicing is the only practical method of preventing an operating failure of the electrical switchgear and its components. This has been upgraded considerably by housing much of the sensitive instrumental control devices in a filtered air environment.

The annual capacity factor of the geothermal units has varied over a range of 70 to 96 percent since 1960. This is approximately the same as the unit availability—because the units are normally operated either at their maximum rating or else they are shut down for maintenance. None of the units is classified as standby.

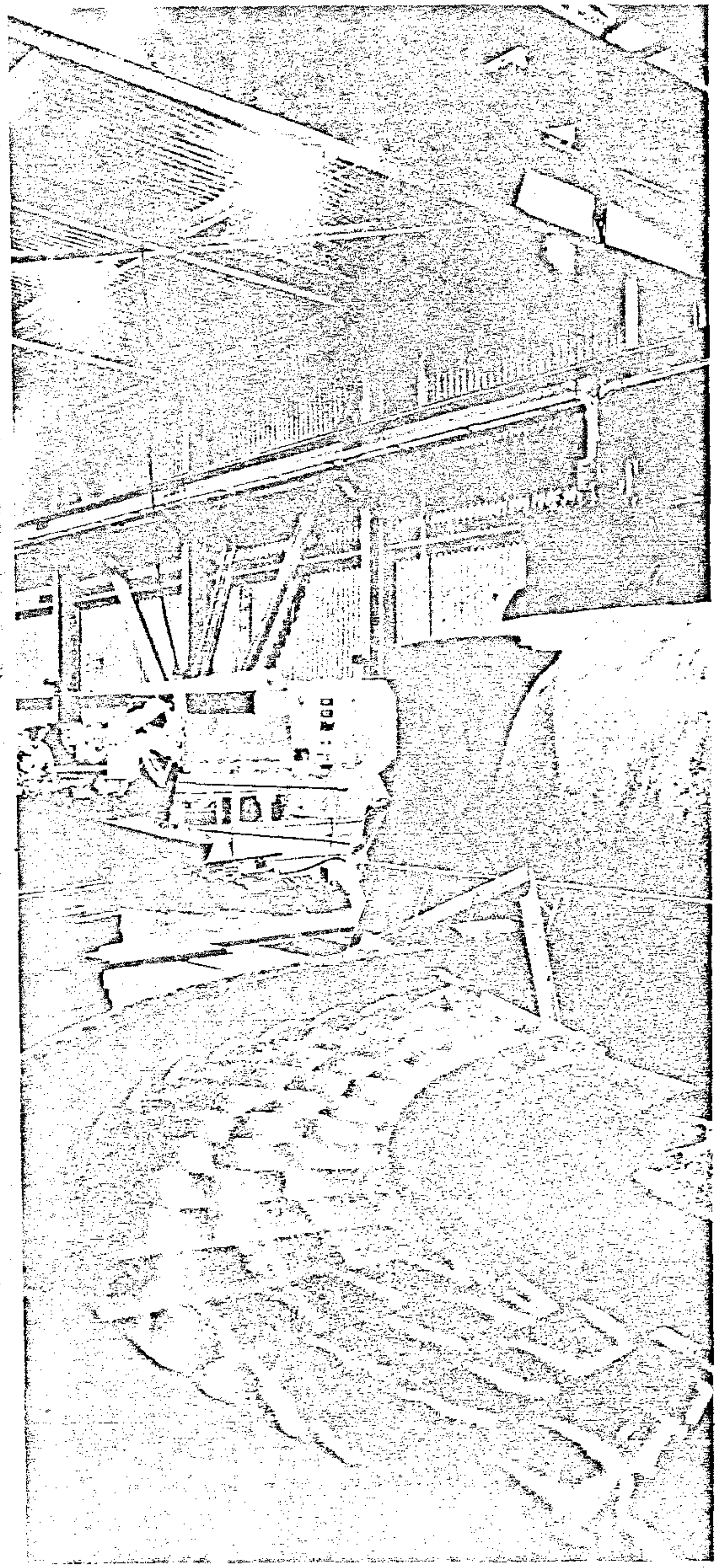
During turbine overhauls, the upper casing is removed and the turbine is dried out to inhibit corrosion. The only corrosive effects that have been noted in the turbine itself have been at the shaft seals—which had to be replaced with corrosion-resistant stainless steel. Experience has confirmed that with the proper selection of materials designed to withstand the corrosive atmospheric conditions—i.e., H_2S—plant maintenance problems are similar to those prevalent in conventional power plant equipment.

The same modern drilling rigs that are common in oil and gas fields are employed to drill holes to the steam-producing zones at The Geysers. Depths presently range from 4000 ft (1200 m) to 10,000 ft (3000 m). Some of the earlier wells of the 1950s were as shallow as 500 ft (150 m). The wellbores are cased to the depths necessary to reach into the graywacke formation, which is a rock type hard enough to support fractures. The fractures then act as conduits for the steam. The wellbore is open hole (uncased) from the bottom of the casing to the final depth. In drawing steam from underground, care must be taken to avoid sudden shocks (like turning a valve on or off too abruptly) in the closed system. Such changes might create a reverberating effect that would cause damage to the subterranean formations.

Completed wells come in at about 75,000 to 350,000 lb/hr (34 to 159 metric tons/h) at a wellhead pressure of roughly 125 psig (8.8 kg/cm^2). Shutoff pressures average 475 psig (33.4 kg/cm^2) with a temperature in the neighborhood of 465°F (240°C) corresponding to an enthalpy of approximately 1204 Btu (669 cal/kg). Design pressures at the turbine strainer inlets are 65, 85, and 100 psig (4.6, 6.0, and 7.0 kg/cm^2) at an enthalpy of about 1200 Btu (667 cal/kg) and with superheats of 59, 52, and 50°F (15, 11, and 10°C) respectively.

Most of the turbine-generators used at The Geysers have come from Toshiba of Tokyo. General Electric Co. has been the successful bidder for Unit 13 (135 MW) and Unit 15 (60 MW), while Units 5 to 11, now in service, are Toshibas. Units 12 and 14 (110 MW), now on order, are also being made by Toshiba.

As the operations at The Geysers have grown in size and scope, they have become more institutionalized. In June 1967, Magma Power Co. and Thermal Power Co.—as joint ventures—entered into an agreement with the Union Oil Co. of California. In effect, Union Oil has taken over the responsibility of operating and managing the geothermal wells that are sending steam to P.G.&E.'s power stations. The greater resources of Union Oil have also enabled the partners to expand the steam production rates to keep pace with P.G.&E.'s planned schedule of adding 100 MW of annual capacity from 1971 onward. During Magma Thermal's period of operation, lease holdings had increased to about 4500 acres (1800 hectares)—and, when combined with Union Oil's 9500 acres (3800 hectares) this made a grand total of approximately 15,000 acres (6000 hectares). The overall holdings have, in the meantime, grown to encompass more than 20,000 acres (8000 hectares). But that has not deterred the competition! On the contrary—the smell of success, as usual, has spurred rivalry!



Workman uses a 25-ton bridge crane to move a main geothermal steamline into position at Unit 7 of Pacific Gas and Electric Co.'s Geysers Power Plant. In the foreground near the generator is part of the turbine blading for the unit. Units 7 and 8, housed in this building, both have net generating capacities of 53,000 kW. They went into commercial operation in 1972.

Coming: Lots of Competition

Since at the moment the developed area in the region of The Geysers is approximately 7 mi long and 2.5 mi wide (11 × 4 km), and it is anticipated that future outstep wells will considerably enlarge the area of proven development, there is lots of room for newcomers. Pacific Energy Corp. has already drilled wells on its lease holdings with a sufficient steam output to support a 60-MW power plant. Aminoil U.S.A. (formerly Burmah Oil & Gas), Shell, Geo-Kinetics, and McCulloch are among those busy exploring and enlarging their respective holdings. Nor is it likely that P.G.&E. will long retain its present exclusive use of the geothermal steam on the power generating side of the business. Other utilities and municipalities are considering the establishment of their own generating facilities at The Geysers while contracting to purchase steam from any or all of the above-mentioned producers.

There have been other changes as well. Mr. McMillan—one of the original entrepreneurs—passed away and the Thermal Power Co. was recently sold to the Natomas Co. in San Francisco. Mr. McCabe—the true visionary—is still active, and his enthusiasm for the development of geothermal energy has helped stimulate corporate enterprises to invest in and develop this relatively new energy industry.

What about the global scene? There are known geothermal areas in countries ranging from Iceland to New Zealand. The Russians, the Japanese, the Mexicans, the Italians, and others are actively engaged in pursuing geothermal energy programs. In the search for low-cost energy, geothermal power offers a quick and attractive solution.

As was stated earlier in this article, the geologic understanding of geothermal energy is in its infancy; and so is the commercialization of geothermal power. Perhaps it is valid to draw an analogy with the discovery of oil in Pennsylvania over 100 yr ago. There, too, it was surface seepage of oil that first attracted attention. As was the case at The Geysers, the early wells that were drilled in the Pennsylvania oil fields were shallow and primitive (by modern standards). Then gradually, as the art of discovering oil fields became more sophisticated and predictable, so did drilling and pumping techniques. It can fairly be said that the mastery of the geology paved the way for the petroleum industry as we know it today. Maybe geothermal energy will evolve along a parallel path. If, once again, the geologists can find the answers to locating steam-bearing subterranean formations, then the rest is a foregone conclusion. The power companies stand ready and waiting to put the geothermal steam to work. In this respect, the experience at The Geysers in California speaks for itself.

K

UTAH GEOLOGICAL AND MINERAL SURVEY

606 BLACK HAWK WAY
SALT LAKE CITY, UTAH 84108
(801) 581-6831

DONALD T. McMILLAN
Director

CALVIN L. RAMPTON
Governor

GORDON E. HARMSTON
Executive Director
Department of Natural Resources

5 May 1976

MEMORANDUM

TO: J.W. Gwynn

FROM: C.A. Petersen

SUBJECT: Phillips' Water Rights Hearing

On April 29, 1976, a hearing was called by Dee Hansen, State Engineer, to consider applications by Phillips Petroleum Company for the production of geothermal water. The hearing, which was held in the Beaver County courthouse, allowed Phillips to present their case and the protestants to reply.

Phillips used the opportunity to give a concise but very informative review of the Roosevelt Geothermal reservoir as they understand it and to show that production of geothermal waters will not affect the shallow aquifers used by agriculture.

According to Gary Crosby, Phillips spent some $400,000 over two years in exploration of the Roosevelt KGRA before deep drilling. The eight deep wells that they have drilled to date cost $3,410,000 and testing three of these wells cost $285,000. After other costs are added to these, Phillips has spent more than $4,500,000 on the Roosevelt area, not including land costs.

The reservoir is located east of the Dome fault. It consists of fractured granite, overlain by 1600 ft. of impermeable granite and Precambrian rocks. A cross section enetered into evidence showed the fractured granite extending to a depth of 5000' below sea level. Dick Lenzer, Project Geologist, stated that the reservoir is entirely within the boundaries of the KGRA, and furthermore is within the perimeter of the lands covered by the Phillips - Union unitization agreement.

The reservoir contains water at 506°F (263°C) and at pressures of 2250 lb/sq.in. The typical geothermal well is a flowing artesian well, with the piezometric surface several hundred feet above the land surface. About 12% of the water flashes into steam in the well, and another 8% flashes in the steam - water separator. One of the wells tested produced more than 1,200,000 lb/hr. of water and steam.

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UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
SAN FRANCISCO OPERATIONS OFFICE
1333 BROADWAY
OAKLAND, CALIFORNIA 94612

May 27, 1977

Dear Geothermist:

In case you did not know it, we signed the first Geothermal Loan Guaranty on May 6, 1977. The guaranty was for a loan of $9.03 million by the Bank of America to the Republic-1975 Geothermal Energy Drilling Program. On Sunday, May 8, the first well drilled with funds made available through the GLGP was "spudded."

At the closing ceremony, which was presided over by Don Reardon, Acting Manager of SAN, and attended by Charles Fullerton, Vice President, Bank of America, and Robert Rex, President of Republic Geothermal, Inc., the Bank of America presented ERDA a check for $27,442.00 - the first year's user fee -- and a check of $2,250,000 to Republic-1975 -- the first disbursement in Milestone 1.

A copy of the news release is enclosed (for your information).

In approving this application, ERDA had to make the following Findings and Determinations:

1. Application complies with GLGP Regulations (10 CFR 790);
2. Project will not have a significant affect on the quality of the human environment;
3. The risks are acceptable;
4. Project is consistent with the goals and objectives of P.L. 93-410;
5. Overall probability of success is 63% or higher; and
6. There is a reasonable assurance that the loan will be paid off.

When Acting Administrator Robert Fri approved this application, several important principles were established, including:

1. ERDA will share both the financial and technological risks of developing this important resource with the lenders and borrowers;

2. ERDA will encourage, to the maximum extent practicable, participation by commercial lenders if the interest rates are reasonable (approximately 120%-125% of floating prime appears to be a maximum acceptable rate at this time).

3. ERDA will, on a case-by-case basis and where appropriate, allow equity participation on a 25/75 ratio throughout disbursements (i.e., we will not necessarily require the full 25% to have always been spent prior to any disbursements, nor will we allow any disbursements such that the government's risk at any point in time is greater than 75% of the project's cost); and

4. ERDA will foster the development of normal borrower-lender relationships.

We are currently processing the following applications:

PROJECT	LOCATION	LENDER	APPLICATION $M
Dry Creek Exploration (GRI w/Chevron Oil)	Geysers, CA	Bank of America	$ 7.500
GeoCal (GeoProducts)	Honey Lake, CA	Bank of Montreal	2.269
CU I Venture (GKI/McCulloch)	Beryl & Lund, UT Brawley, CA	Bank of Montreal	6.326
Southern Calif. Public Energy Corporation (City of Burbank)	Roosevelt Hot Springs, UT, and other sites	Dean Witter & Co.	25.00
Geothermal Food Processors, Inc.	Brady Hot Springs, NV	Nevada National Bank	3.460
Diablo Exploration, Inc.	New Mexico	Kidder, Peabody, Inc.	21.80
		TOTAL	$ 66.335

A number of other recent developments at the Federal level have very exciting potential for the geothermal industry. These include the President's National Energy Plan (NEP), proposed amendments to P.L. 93-410 passed by the House Science and Technology Committee, and a bill introduced into the House of Representatives by Congressman Barry Goldwater entitled "The Geothermal Steam Act Amendments of 1977."

In the NEP, the President has proposed a tax deduction for intangible drilling costs comparable to that now available for oil and gas drilling. Furthermore, "Additional funding will be provided to identify new hydrothermal sources which could be tapped for near-term generation of electricity and for direct thermal use. The Government will also support demonstration of direct, non-electric uses of geothermal energy for residential space conditioning and industrial and agricultural process heat in areas where this resource has not previously been exploited."

Several amendments to P.L. 93-410 were passed by the House Science and Technology Committee on May 11, 1977, which enhance the GLGP. Some highlights include:

1. Would allow guaranty to cover 75% of total costs of a non-electric or self-generation project when located near a geothermal resource predominantly for the purpose of using geothermal energy or its economic viability is dependent upon the performance of the geothermal reservoir;
2. Would raise the guaranty limits from $25 million to $50 million per project for non-electric applications and up to $100 million for electric applications, and from $50 million to $200 million per borrower;
3. Would allow interest differential payments for guaranties on taxable borrowing by states, municipal utilities or other political subdivisions of states, or Indian Tribes;
4. Would pledge the full faith and credit of the United States to the payment of guaranties;
5. Would allow interim payment of principal and interest to avoid defaults on worthwhile projects; and
6. Would provide for borrowing authority by the Administrator to rapidly meet default payments.

On May 5, 1977, Cong. Goldwater introduced a bill entitled "The Geothermal Steam Act Amendments of 1977." A few of the highlights are:

1. Would increase the per State acreage limitation on a geothermal leasehold from 20,480 to 51,200;
2. Would provide a statutory scheme to insure that geothermal leases will have access, on an equitable basis, to any transmission lines or rights-of-way for transmission lines on public lands in the general area of their leasehold; and

3. Would provide for environmental assessments in phases on federal geothermal leases.

In conclusion, several important strides have been taken which could enhance the development of the geothermal industry. One of these is the approval of the first loan guaranty application. However, the continued viability of the GLGP is still very much in question. With only seven applications received having a total of some $75.4 million versus an authorization of $200 million for FY 1977 and a request by ERDA for another $200 million in FY 1978, there are important voices asking two key questions:

1. Does the industry really want and/or need the GLGP? and
2. Does the industry really need $200 million per year?

To these questions, satisfactory answers can only be formulated based on numbers supplied by the industry.

Furthermore, if you have any suggestions on how we can improve the program - our procedures, the guidelines, etc., please let us know immediately.

It's up to you.

Sincerely,

Mark N. Silverman, Director
Office of the Geothermal
Loan Guaranty Program

Enclosure:
SAN News Release
No. 7747

FACT SHEET

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
GEOTHERMAL LOAN GUARANTY PROGRAM

Legal Basis:	Geothermal Energy Research, Development and Demonstration Act of 1974 (P.L. 93-410)
Purpose:	Accelerate commercial development of geothermal energy by private sector through minimizing financial risk to lending agencies.
$ Limit:	Single Project - $25 Million Single Borrower - $50 Million Also -- 75% of aggregate cost of project but may be 100% of loan.
Interest:	Not to exceed Administrator's determination (with Secretary of Treasury) of "reasonable" and "prevailing."
Terms:	Up to 30 years or expected life of physical assets, whichever is less.
Location:	Project in U.S., territories or possessions.
Termination:	September 3, 1984, but guarantee agreements and interest assistance contracts in effect at that time will remain in effect.
Guarantee Fee:	It is expected that no more than 1 per cent annually on average outstanding loan value, may be passed to borrower; however, a firm fee will be determined at a later date.

Controls and Restrictions: Detailed in Federal Register of May 26, 1976, pages 21433-21440.

1. Information concerning lender the borrower.
2. Information on project.
3. Interest assistance by ERDA.
4. Default authority by ERDA.
5. Permissible costs defined - criteria (financial considerations).
6. Expenses not allowable.
7. Environmental considerations.
8. Reports required and access to reports to other agencies.
9. Servicing the loan.
10. Visit access.
11. Withdrawal of guarantee.
12. Security (borrower's assets).
13. Patents and proprietary rights.
14. Escrow and interest.

Who Administers: The Administrator of ERDA; however, the Manager of SAN has been delegated the responsibility of processing all applications for geothermal loan guarantees from throughout the United States. After review and analysis of the application, the Manager will recommend approval or disapproval to the Administrator. Additionally, SAN has the responsibility of monitoring all loan guarantees throughout the life of the guarantee.

Where to Obtain Information: San Francisco Operations Office (SAN) of ERDA. Attention: Mark N. Silverman, 1333 Broadway, Oakland, CA 94612. Telephone: (415) 273-7881.

Publication Date:
May 4, 1977

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

Division of Geothermal Energy

GEOTHERMAL ENERGY

Request for Expression of Interest for a

Geothermal Demonstration Power Plant

INTRODUCTION AND PURPOSE

The Energy Research and Development Administration (ERDA) is requesting an expression of interest (REI) from organizations desiring to participate in a demonstration project for the utilization of geothermal energy for electric power generation. The demonstration will be a commercial-size plant constructed and operated under realistic industrial conditions. The intent is to demonstrate to industry that electric energy can be generated economically from liquid-dominated geothermal resources in an environmentally and socially acceptable manner. Successful demonstration will reduce the uncertainties that attend the utilization of geothermal resources for power production and will thereby advance the realization of geothermal energy as an option for meeting national energy needs. The expression of interest is intended to obtain information about who is interested in geothermal exploitation and their capabilities for conducting a demonstration project.

INTENDED DEMONSTRATION PROJECT

ERDA plans to initiate a commercial-scale (50 megawatts electrical or greater) demonstration project in Fiscal Year 1978. Joint industry and government funding of construction and operation of the project is anticipated. The project will be located at a site where reservoir development work is already underway in order to accelerate geothermal development in the near term.

The plant is intended to demonstrate commercial generation of electric power using a high-temperature, low-to-moderate salinity resource with a binary fluid, flashed-steam or a fossil-geothermal hybrid conversion cycle. Target date for power-on-line is 1982 or earlier.

M

PHILLIPS 66

PHILLIPS PETROLEUM COMPANY
DEL MAR, CALIFORNIA 92014
BOX 752 714 755-0131

NATURAL RESOURCES GROUP
Energy Minerals Division
Geothermal Operations

June 3, 1977

Mr. Berry Hutchings
City of Bountiful Light & Power
198 South 200 West
Bountiful, UT 84010

Dear Berry:

Following up on our telephone conversation, I have thought of some aspects of operating on a small lease which I will put down here for what it might be worth. First, if the option is exercised, the price per acre will exceed the present record by a factor of more than three. Secondly, I have wondered what City of Bountiful might do about reinjection of residual water, amounting to possibly as much as 2850 barrels per hour.

It is not my intent here to evaluate the geothermal potential of the lease, except to say that I think we both recognize that it is favorably situated. The location, however, is astride the Dome fault, and drilling in the fault zone is a risky business; and, dealing with such problems as might be encountered, can be a costly business.

I don't know what reservoir engineers will finally decide is an optimum well spacing to produce the field. There is a good chance, however, that it will not be less than 40 acres. The U. S. Geological Survey has the authority to impose a well spacing scheme on all operators in the field, if in their view, they feel a certain well spacing extracts the optimum amount of the resource.

Sincerely yours,

Gary W. Crosby
Exploration Director

GWC/skb

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