Fred Dunn

PROPOSAL
FOR
SOUTH BRAWLEY GEOTHERMAL POWER PLANT
CONCEPTUAL DESIGN

PREPARED FOR
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

AUGUST 21, 1981
Z- 81003 - 20

ROGERS
Engineering • San Francisco

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Proposal

For

SOUTH BRAWLEY GEOTHERMAL POWER PLANT CONCEPTUAL DESIGN

Prepared for

**STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES**

By

ROGERS ENGINEERING CO., INC.

**AUGUST 21, 1981
Z-81003-20**

ROGERS ENGINEERING CO., INC.
ENGINEERS & ARCHITECTS
111 PINE STREET
SAN FRANCISCO, CALIF. 94111, TEL. (415) 986-6546

In reply refer to:
Z-81003-20

21 August 1981

State of California
Department of Water Resources
P. O. Box 388
Sacramento, California 95802

Attention: Mr. Bruce D. Johnson

Subject: Proposal for South Brawley Geothermal Power Plant
Conceptual Design - In Reply to Your Request of 21 July 1981

Dear Mr. Johnson:

Rogers Engineering Co., Inc., is pleased to submit its qualifications to assist the Department of Water Resources in formulating a conceptual design for a commercial power plant utilizing the available geothermal resources in the South Brawley area.

As shown in our proposed organizational chart for this project, we have assembled acknowledged geothermal experts to assist in evaluating and analyzing the data which is to be developed for the reservoir at South Brawley. These experts will make an important contribution in evaluating the existing data and preparing a list of additional information which will be required for the feasibility study of the power plant. We are specifically interested in the data which has been substantiated by the producer with respect to the performance of the reservoir and its assessment. For this area of activity we have retained Dr. William E. Brigham of Stanford University.

Rogers will provide the overall consulting project coordination as well as specific inputs into areas of optimization of the geothermal processes and economics of produced power at the power plant bus.

Our recent successful completion of the power plant at Brawley for Southern California Edison indicates our capabilities in geothermal power plant design as well as our abilities to deal with the local conditions in the Imperial Valley. Thus we can be uniquely responsive to your needs on this project. We hope to have the opportunity to work with you on this interesting and challenging geothermal energy development in South Brawley.

We shall be pleased to meet with you at your convenience to discuss details of this proposal and provide any amplifications or clarifications.

Very truly yours,

ROGERS ENGINEERING CO., INC.

H. Rogers, Jr.
President

HR:bg

Rogers

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1.0 INTRODUCTION

Rogers Engineering is pleased to present this proposal to the California Department of Water Resources for assistance in the development of a conceptual design for the geothermal electrical generation plant in the South Brawley Prospect, Imperial County, California. This proposal presents a comprehensive and logical approach to the preparation of a power plant conceptual design which most effectively utilizes the available resource being developed by MCO Holdings, Inc. As the engineering firm who designed the first commercially operating geothermal power plant in the Imperial Valley, Rogers is most eager to assist DWR in this project.

1.1 Objectives

The primary objectives of this proposed work are as follows:

1. Formulate a power plant conceptual design using an analysis that will result in a facility that best utilizes the available geothermal resource and minimizes the busbar cost of generating electricity.
2. Identify any additional data needs regarding the reservoir.

Secondary objectives are:

1. Analyze the potential for mineral recovery and marketing and/or waste heat utilization.
2. Address pertinent environmental and socioeconomic issues, including regulatory requirements.

1.2 Description of Resource

The drilling of exploratory wells in an area south and east of Brawley, California by MCO Holdings, has resulted in the discovery of a high temperature zone which may possibly support one or more commercial power plants. The wells are located in the Mercer unit which is south of Keystone Road and east of Dogwood Road outside Brawley. The existing Environmental Impact Report indicates there are currently permits for four wells in this area.

To our knowledge, the closest well to the Mercer wells is a well recently drilled by TRW, Inc. for Holly Sugar. The well appears to have been unsuccessful. However, other well drilling by Occidental Geothermal, Chevron, and Phillips Petroleum in the South Brawley area indicate the possibility of a sizeable resource below 11,000 feet.

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Initial well flow tests on McCulloch's Mercer 2-28 well from a zone between 11,600 and 12,910 feet resulted in sizable flow rates at well-head conditions exceeding 400°F and 300 psia. Further drilling and well tests have been completed but have not yet been made available for study. These data, when provided, will serve as the basis for an initial reservoir evaluation once a contractor has been selected to conduct the studies outlined in the Request for Proposal.

1.3

Study Approach

Rogers Engineering Co., Inc. is organized on the Project Management concept. All projects are assigned to a Project Manager whose responsibility it is to see that a project is completed on schedule and within budget utilizing the best possible talent. This project management approach involves task definitions and budget and time allocations for each task to insure that the primary and secondary objectives of the project are attained. Periodic reviews are carried out to insure that each task is proceeding according to schedule and budget and each task is interfaced properly with other tasks. These reviews are also designed to assure real time responsiveness to the specific needs of the Client.

Additionally, throughout this project, it is understood that basic project decisions will be the responsibility of the DWR Project Manager, with advice and consultation as requested from the Rogers' Project Manager and Rogers' consultants. Although this project is designed to end once power plant conceptual design studies are completed, Rogers is interested in working with DWR to develop the best possible condition for the ultimate completion of an operating and reliable power plant.

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2.0 QUALIFICATIONS OF STUDY TEAM

2.1 Rogers Engineering Co., Inc.

This proposal offers a capable and experienced team who have designed at least 7 operating geothermal electric power plants in the world, to assist the Department of Water Resources in realizing their goal of electrical generation using geothermal energy from the Imperial Valley. Good power plant design resulting in reliable power generation doesn't just happen; it is the cumulative result of firsthand knowledge of the geothermal resource, sound engineering practice, and experience developed from other similar projects.

Rogers Engineering and their consulting team of Dr. William Brigham, Emerald Exploration Consultants, Inc. and Radian Corporation represent such a team. Rogers has been in the geothermal business since 1961. They designed the following operating geothermal power plants: Krafla in Iceland, Southern California Edison plant at Brawley, the HGP-A Well-head Generator on Hawaii, the first two 110 MW power plants in the Philippines (preliminary design), The Geysers Units 5 and 6 (partial design) and 7 and 8. They have conducted resource exploration, reservoir development and power plant design studies at Tiwi and Los Banos in the Republic of the Philippines, Costa Rica, El Salvador, Iran, Turkey and at numerous U. S. locations such as Roosevelt Hot Springs, the Salton Sea, and Marysville, Montana. In fact, by the end of 1980, Rogers had been associated with the installation of over one-third of the capacity of the world's geothermal power plants. Activities of Rogers Engineering in the above projects have included not only engineering design but also equipment procurement, construction management, operator training, start up, and supervision.

This experience can be directly applied at the liquid-dominated high temperature resource at the South Brawley Prospect. All of the operating geothermal power plants Rogers has designed use liquid-dominated resources except The Geysers units. The SCE Brawley plant which went into operation in 1980 was the first flashed steam unit in the U. S. The producer of the resource, Union Geothermal, was responsible for the steam flash and cleaning process.

In addition, the high temperature South Brawley resource is conducive to a double-flash design which was pioneered by Rogers. Steam generation at two separate pressures uses more of the available heat energy than could be made available with a single flash separation. Rogers designed the first double-flash units at Tiwi, Krafla and the proposed Costa Rica facility.

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2.2

Consultants

To support the engineering design efforts of Rogers, the assistance of Dr. William Brigham, Emerald Exploration Consultants, Inc. and Radian Corporation have been added to offer a complete capability in geothermal system development. Their expertise in reservoir engineering and geothermal resource development will be very useful in recommending ways to most effectively define and evaluate this South Brawley resource.

Dr. William Brigham is a Professor and Associate Chairman of the Petroleum Engineering Department, Stanford University. He has had extensive experience in geothermal and oil and gas reservoir engineering, and has published widely in these fields. He brings firsthand knowledge to the project in reservoir development and production techniques for the Imperial Valley.

Emerald Exploration Consultants, Inc. offers professional expertise in three areas: geophysics, geochemistry and environmental analysis. Roger Smith, Arnold Orange and Ernest Berkman are experienced exploration geophysicists; Andrew Alpha adds his expertise in geochemistry.

Radian has provided expertise in environmental, health, socioeconomics or engineering activities in all the Imperial Valley geothermal resource areas from the Salton Sea to Cerro Prieto. Their breadth of geothermal understanding therefore allows them to provide a significant advocacy role in Imperial Valley geothermal considerations. Radian Corporation conducted the entire socioeconomic data gathering and analysis for the Heber Binary Geothermal Power Plant EIS. Radian continues to be active in the SDG&E Heber Project from a corrosion engineering standpoint which demands a thorough knowledge and awareness of the plant's ambient environment and cooling water sources and chemistry. Radian has also analyzed geothermal fluid samples from the Woolsey #1 well (near the Salton Sea resource) for their potentially hazardous hydrogen sulfide and ammonia noncondensable gases, mercury and other heavy metals. In addition to conducting the ambient air and noise monitoring at DOE's first geothermal-geopressured well, Radian has conducted and written many environmental assessments for geothermal development projects including the application and acquisition of an EPA/NPDES permit for a geothermal surface discharge. For specific geothermal power plants in the Imperial Valley, Radian has conducted a preliminary analysis and modeling plan to analyze the environmental effects of noncondensable gas discharges from the 10 MW SCE Brawley Geothermal Power Plant as well as a failure analysis of the Magma Binary Power Plant turbine.

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The study team organized to conduct the work scope outlined in the following paragraphs is diagrammed in Section 5.0. The final section (8.0) lists resumés of all key Rogers and consultant personnel and includes additional background material on the study team's qualifications.

2.3

Conflict of Interest Statement

Rogers Engineering Co., Inc. is a privately held California corporation providing professional engineering services. Rogers Engineering does not have a financial, contractual or other arrangement with a business entity or individual which provides services, products or materials to the California Department of Water Resources. Also, Rogers Engineering does not hold any direct or indirect interest in real property which is associated with the Department's geothermal program. To the best knowledge of Rogers Engineering, consultants retained to assist Rogers Engineering in this study do not have arrangements or interest of the nature described above.

Rogers

3.0 WORK ELEMENTS OF THE STUDY

In order to meet the objectives outlined in Section 1.1, five work elements are necessary as outlined below.

- 3.0.1 System Analysis and Optimization - a systematic study of existing data and comparison of all reasonable alternatives in order to select the optimum resource utilization and power plant design.
- 3.0.2 Power Plant Conceptual Design - development of the main features and equipment for a power plant which meets the needs of a 55 megawatt, base load, 30 year life geothermal electric power plant. All design information necessary to proceed to final design will be included as an end product of this work element.
- 3.0.3 Geotechnical Assessment - development of a plan for providing the necessary geothermal resource data to insure optimum final design of the power plant.
- 3.0.4 Integrated Resource Use Assessment - a study of alternative and additional uses of the geothermal resource.
- 3.0.5 Environmental and Socioeconomic Assessment - a study of issues that may affect the environmental and social acceptability of this power plant.

Rogers

3.1 System Analysis and Optimization

Rogers Engineering believes that any successfully operating power plant in the Imperial Valley must satisfy three basic criteria: (1) the electricity generated by geothermal energy must be competitive in cost with other power generation, (2) the geothermal resource must be effectively utilized to insure maximum productivity, and (3) the power plant must satisfy the environmental constraints that exist in the area. We feel that the environmental criteria deserve equal attention based on experience in the Imperial Valley and at other geothermal fields. Current development at The Geysers certainly doesn't suffer from resource availability or financing difficulties, but is being slowed by environmental problems. The same will be true in the Imperial Valley unless issues such as water resource availability and brine disposal are fully addressed.

Therefore, we propose to select optimal features of a power plant design and energy supply system based upon these three basic criteria. The selection process will proceed according to Steps 3.1.1 to 3.1.7 described below. As you will note, the heart of the optimization process is the initial specification of a baseline conceptual design which Rogers feels is near optimal, based upon our past experience and available knowledge of the South Brawley resource. By starting the selection process with a baseline conceptual design, the whole system analysis is much simplified and less time consuming. This baseline conceptual design is of a 55 MWe base-loaded plant with double flashed steam flows, surface condenser, and evaporative cooling tower.

We intend to compare alternative design features to this baseline conceptual design to find the optimum system. One major alternative we feel is very important involves the method of heat rejection. If cooling water supplies are not available in the Imperial Valley, dry air cooling will be needed. We present this option as a major element of our system analysis task.

Steps 3.1.1 to 3.1.7 are described below:

- 3.1.1 The initial step will be to meet with the Department of Water Resources to determine their specific needs for electrical generation, with respect to timing and capacity. These needs will govern the system analysis.
- 3.1.2 Secondly, a meeting with MCO Holdings, Inc. will be held to obtain all available information on the wells and the resource, and to determine what MCO's plans are with regard to the development of the resource.

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3.1.3 Based upon data collected in the above meetings, and the three basic criteria described above, a complete list of detailed criteria of an optimal plant design and resource development will be constructed.

Only a partial list of detailed criteria are listed here. As stated earlier, these criteria will most likely fall into one of three categories: cost, resource productivity, or environmental acceptability.

Cost

- Financing options available to DWR
- Investment in resource exploration
- Cost of geothermal energy supplied
- Taxation and insurance
- Equipment and operating cost
- Power plant life, capacity, cost, efficiency and availability

Reservoir Productivity

- Reservoir size needed to sustain production
- Reservoir recharge and life
- Quality of steam (or liquid) provided with regard to temperature, salinity, noncondensable gases, total dissolved solids and suspended solids
- Decline of productivity over time
- Constancy of production

Environmental Acceptance

- Gaseous emissions
- Liquid waste disposal
- Water resource availability
- Subsidence and induced seismicity

Maximum effort will be made to compile an accurate, complete, and definitive list of criteria that will be useful in comparing system alternatives.

3.1.4 A baseline conceptual design of a geothermal power plant and energy supply system will be developed. This design will serve as a baseline for comparison with other possible designs. With the information available from the Department of Water Resources and MCO Holdings, Inc., Rogers feels certain design features can now be selected as near optimal without extensive analysis. Assuming that the resource developer provides a clean, reliable flow of steam to the plant and adequate cooling water is available, the features listed below will most likely result in a minimum cost, maximum resource utilization power generation facility. These features are illustrated in Figure 1 and described below:

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- This resource appears to produce high temperature, high pressure brine, pointing to the selection of a flashed steam plant over a binary cycle design. In addition, a double-flash design will be superior in thermodynamic performance to a single flash. The second flash can result in over 50% more electrical generation for the same well mass flow rate as a single flash. Therefore the baseline design includes the expansion of a high pressure and a low pressure steam stream through a double pressure entry turbine.
- The power plant is rated at 55 MWe gross capacity to assure lower cost due to availability of standard components that have been developed for other geothermal power systems.
- Power plant is assumed to be base-loaded.
- The resource developer provides flashed and separated steam at two different pressures to the power plant, thus clearly dividing responsibilities of the parties between energy supply and electrical generation. In this baseline design the resource developer is also responsible for liquid waste disposal. This type of arrangement has evolved as a standard one, and has tended to equalize risk-sharing.
- The power plant electrical system ends at the switchyard for the purposes of these studies.
- Evaporative cooling is employed for heat rejection, assuming the availability of acceptable cooling water.
- Minimal use of steam condensate in the power plant is assumed in order to satisfy reinjection requirements.
- Steam jet ejection is employed for removal of noncondensable gases from the steam condenser. Noncondensable gases are assumed to be less than 1% by weight.
- The use of polishing steam separators for each entering steam stream is assumed.

3.1.5

Design features different from those in the baseline conceptual design will be selected for comparison. These design features will reflect reasonable alternatives for power generation at South Brawley. As stated in the introduction to Section 3.1, a major alternative is dry air cooling which may be necessary if cooling water supplies are inadequate. This design feature in addition to others, is listed below.

Rogers

- Alternative heat rejection methods will be analyzed including dry air cooling, combination wet/dry cooling and floating cooling. Dry air cooling is an especially important heat rejection option since water supplies in Imperial Valley in the near future will be severely limited if not nonexistent. Even though this heat rejection method will result in capital costs higher than those for the baseline conceptual design, Rogers feels that cost effective designs can be accomplished. Because of its importance, a full economic and technical comparison of dry air cooling with evaporative cooling will be made. A schematic of this cooling option is shown in Figure 2. Note that a limited amount of auxiliary cooling is still provided by an evaporative cooling unit since dry air cooling cannot sustain sufficiently low temperatures for hydrogen and oil coolers. Also note that the turbine design will be different from that used for the baseline design, since the turbine back pressure must be allowed to fluctuate with dry air cooling. Environmental implications of the heat rejection method selected are discussed later in Section 3.5.
- Single and triple flash designs.
- Extension of power plant operator's responsibility to include the separation and clean-up of steam using various desalination processes.
- Alternative plant capacities, loads, efficiencies and lifetimes will be selected to determine the most appropriate values.
- Alternative plant financing options will be assessed, as requested by DWR.
- Integration of alternative energy uses will be evaluated as a part of the geothermal system, according to Section 3.4.
- The baseline plant is assumed to be a single unit that can be designed for expansion. Expansion options will be considered (such as expansion of the plant from 55 to 110 MWe).
- Alternative liquid waste disposal methods including partial re-injection and replacement fluid streams.
- Varying brine temperatures, pressures, salinities and chemistries will be considered for their impact on the design. Alternative steam pressures and noncondensable gas contents will also be studied.

Rogers

- Depending upon the division of responsibility between the power plant operator and the resource developer, options for cleaning the steam may be a necessary part of this analysis. Rogers will use its experience and the experience of others in examining these alternatives.

3.1.6 Several analytical tools including computer models will be employed to compare all selected plant options against the baseline design, using the list of criteria from Step 3.1.3. Four analytical tools to be used are listed below:

- A computer program which computes the thermodynamic efficiency, required steam flow rate and power output.
- A computer program which accurately computes power plant cost.
- An extensive cost data base developed over the past twenty years on reservoir exploration and development, and power plant design, construction and operation.
- An in-depth knowledge base available through our consultants to predict the impact of various power plant designs on the development and productivity of the reservoir.

3.1.7 On the basis of these comparisons, an optimal power plant design which best meets the established criteria will be selected. This selection will be reviewed with the Department of Water Resources to insure compatibility with their goals.

The Rogers Project Manager will direct the efforts of this work element, with assistance from the geotechnical consultants, and Rogers' personnel in the following disciplinary fields: economic analysis, engineering, chemistry and process analysis, and environmental analysis.

Rogers

3.2

Power Plant Conceptual Design

A conceptual design will identify all major features and equipment in the power plant. The various aspects to be included in the power plant design are listed below. Dependent on the design selected, some of these items may not need to be included.

- (1) Geothermal fluid preparation and transmission
- (2) Process flow diagrams
- (3) Turbine-generator system including controls and materials
- (4) Heat rejection system
- (5) Electrical system
- (6) Auxiliary Systems, including auxiliary cooling water system, turbine-generator lubricating oil system, instrument air system, fire protection system, water treatment systems, and noncondensable gas removal system.
- (7) Controls and instrumentation
- (8) Environmental control systems (especially H₂S abatement)
- (9) Structures and access roads
- (10) Liquid waste disposal system
- (11) Plant start up and operational characteristics
- (12) Future expansion plans
- (13) Permitting requirements
- (14) Design and construction schedule
- (15) Plant layout

The team to complete this work element will consist of the Rogers' Project Manager, and Process, Chemical, Mechanical, Electrical, Civil, Instrumentation, Architectural and Environmental Engineers.

Rogers

3.3

Geotechnical Assessment

Rogers Engineering and its consultants, Dr. William Brigham and Emerald Exploration Consultants will first examine all existing information on the South Brawley Prospect and review the resource development plans of MCO Holdings, Inc. In addition, the well tests conducted after this work is underway will be monitored. Based on these reviews and observations a number of recommendations will be made.

- A recommendation for additional wells or well tests will be made if the data is insufficient to assure adequate resource quantity and quality, or if tests results are inadequate.
- All available reservoir and resource data will be reduced to provide the needed information to complete power plant final design and to ready the resource for full utilization.
- A list of geotechnical criteria will be provided to Work Element 3.1 for use in system analysis and optimization.
- Recommendation will be made to DWR for the development of a sales agreement position with the resource developer.
- A recommendation for additional geophysical surveys and well coring, will be made if warranted, to help in reservoir characterization.

Some important considerations that will need to be addressed to properly develop the geothermal reservoir are as follows:

- Location and depth of recharge (reinjection)
- Rate of resource production (constant well flow rate or constant power output)
- Replacement well scheduling and location
- Prevention of premature cold water breakthrough
- Subsidence

Since the South Brawley resource appears to be at depths exceeding 11,000 feet, flow from the producing formation will most likely be primarily governed by fractures, not by intergranular permeability as in the case of shallower systems like Heber. This will affect all of the considerations above, since flow patterns will cease to be essentially homogeneous and be governed by fracture patterns. Adequate knowledge of the resource is necessary to prevent direct communication between a production and injection well via a fracture, but allow sufficient communication for water recharge.

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Additional tests and surveys that may be necessary to properly characterize the resource are listed below:

- Well deliverability tests
- Pressure build-up tests
- Interference tests
- Surface and downhole geophysical surveys, especially resistivity
- Well coring to determine stratigraphy and heterogeneity
- Develop plan to use tracers for reservoir flow characterization during plant start-up.

It should be noted that, while Rogers and its geotechnical consultants will review geotechnical data, monitor tests and make recommendations to DWR, this proposal does not include direct involvement in any field work.

In summary, this work element is designed to assure that DWR's best interests are served with respect to resource development and utilization, especially with regard to the reliable supply of high quality energy. It is also designed to help integrate resource considerations with power generation aspects so that an optimal geothermal system design can be generated.

The Rogers Project Manager will direct this work element, with technical support by Dr. William Brigham and by Emerald Exploration Consultants, Inc.

Rogers

3.4

Integrated Resource Use Assessment

The Department of Water Resource's primary interest in the utilization of this resource is directed toward the generation of electricity. However, if it is technically and economically feasible, DWR is interested in an integrated use of the resource. Possible options that warrant study are:

- Mineral extraction and marketing
- Waste heat utilization
- Spent brine utilization

Mineral extraction from geothermal brines has had a colorful history in the Imperial Valley, with only limited financial success. The primary problem seems usually to revolve around the unfavorable concentration of undesirable constituents in comparison with the marketable minerals. Improved desalination processes could reverse this trend, and make the mining of minerals such as silver, copper, lead and zinc more profitable, as well as the production of compounds like potassium chloride. These processes will be re-examined to identify changes in the technology or mineral markets (e.g. price fluctuations or large increase in demand), and to determine whether further investigation is warranted.

Numerous uses of waste heat are possible in the Imperial Valley. There are currently underway market surveys on this very topic, and the results of this work will be most helpful in determining whether there is an advantage to DWR to consider this integrated use of the resource. Four general applications have been identified thus far: agriculture, aquaculture, food processing and ethanol production. These will be investigated.

Spent brine utilization is a difficult topic since it involves one of the Valley's biggest potential problems: water resource quality and availability. Since water shortages are already severe in the Valley, one might see a real advantage to surface use of the spent geothermal fluids. Two other problems arise if this is done however; (1) the brines are often very saline and could contribute to further salinity increases in the Salton Sea, and (2) the less than total reinjection of the brines could cause land subsidence, upsetting the Valley's delicate gravity irrigation system.

These alternatives will be investigated to determine if there are advantages to the Department of Water Resources in integrating the use of the resource. Since this work element is directed toward a secondary objective, a nominal effort will be expended in comparison to other, primary work elements.

Rogers

The Rogers Project Manager will complete this task with the assistance of Chemical and Process engineering, an Economic Analyst, and an Environmental Analyst from Radian Corporation.

Rogers

3.5

Environmental and Socioeconomic Assessment

Pertinent environmental and socioeconomic issues will be evaluated to meet the following objectives:

- (1) Provide a basis for an environmentally sound resource production and power plant conceptual design.
- (2) Recommend needed pre-operational environmental monitoring such as water quality, subsidence and air quality. (Care must be exercised to take advantage of numerous existing studies).
- (3) Recommend a DWR position on environmental impact assessment.
- (4) Provide an outline of a long term plan for water resource management.

Item (4) above is included since Rogers feels that the issues of water quality and availability may be of paramount importance to decisions on future industrial activities in the Valley. This is obviously where the heat rejection option of dry air cooling enters, as discussed in work element 3.1.

The following environmental, public health, and socioeconomic issues will be investigated as a part of this study to meet the above objectives:

Environmental Issues

Gaseous emissions
Cooling water supplies (and the lack thereof)
Solid waste disposal
Spent brine disposal
Subsidence
Induced seismicity
Water quality impacts
Salton Sea level and salinity

Public Health Issues

Release of hydrogen sulfide, ammonia, mercury and benzene
Well flow releases
Noise

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Socioeconomic Issues

Population growth

Effects on unemployment

Increased income

Shift of interest groups from agricultural to include power generation

The Rogers Project Manager will be assisted by Environmental Analysts from Radian Corporation in conducting this work element.

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4.0

SCHEDULE

A 320-day schedule for completion of this study is shown in Figure 3. The schedule indicates the duration of each major work element, and the completion of a draft report within 270-days after initiation of the study.

ROGERS ENGINEERING CO., INC.
ENGINEERS & ARCHITECTS
111 PINE STREET
SAN FRANCISCO, CALIF. 94111

FIG. 3

Z-81003-20

AUG. 21 1981

PRELIMINARY SCHEDULE

PROJECT : SOUTH BRAWLEY GEOTHERMAL
POWER PLANT - CONCEPTUAL DESIGN

STATE OF CALIFORNIA
DEPT. OF WATER RESOURCES

NO. OF DAYS — 0

50

100

150

200

250

300

320

SYSTEM OPTIMIZATION

SYSTEM ANALYSIS

CONCEPT DESIGN SELECTION

CONCEPTUAL DESIGN

GEOTECHNICAL ASSESSMENT

REVIEW EXISTING DATA

RECOMMEND ADDTL STUDIES

INTEGRATED USE ASSESS.

ENVIRONMENTAL ISSUES

DRAFT REPORT

REPORT REVIEW

FINAL REPORT

Rogers

5.0

PROJECT ORGANIZATION

A corporate organization chart for Rogers Engineering is shown in Figure 4. The study team selected for this study is shown in Figure 5, and includes personnel from Rogers and its consultants. The personnel indicated will be assigned study work elements in consonance with their individual area of expertise and to the extent required by the study. Other technical support will be assigned as required.

Fred Dunn will be the manager of this study. Mr. Dunn has over thirty-five years of experience in all phases of engineering design and project management of electric power and other facilities. He has managed or been engineer in charge of the design of numerous geothermal power plants including the 3 MWe HGP-A wellhead generator, 60 MWe plant in Krafla, Iceland, 10 MWe plant in Brawley, California, and two 110 MWe plants at The Geysers. Mr. Dunn is also very experienced in well testing and drilling of geothermal resources.

Supporting Mr. Dunn as consultants will be Dr. William Brigham, Emerald Exploration Consultants, Inc., and Radian Corporation.

Resumés of all key personnel assigned to the project are presented in Section 8.0 of this proposal.

NOTES:

- (1) CHAIRMAN ENGINEERING REVIEW BOARD.
- (2) MEMBER ENGINEERING REVIEW BOARD.
- (3) ENGINEERS, DESIGNERS, DRAFTSMEN AND CONSTRUCTION MANAGERS ARE ASSIGNED TO PROJECTS BY THE MANAGER OF DEPARTMENTS AND THE RESPECTIVE DEPARTMENT CHIEFS.

**CORPORATE
ORGANIZATION CHART** Fig. 4

ROGERS ENGINEERING CO., INC.
ENGINEERS ARCHITECTS

APPROVED BY *HR*

DATE 7 27 81

Rogers

PROJECT ORGANIZATION - Figure 5
South Brawley Geothermal Power Plant Conceptual Design
State of California, Department of Water Resources
Z-81003-20
August 1981

Rogers

6.0

REPORTING

The following reports are proposed for communication of study results to the Department of Water Resources.

- (1) A monthly administrative report will be provided, reporting progress against milestones, costs incurred and manpower expended.
- (2) Six (6) copies of a draft report at the end of the study period will be provided and will include the results of all work elements and supporting information.
- (3) Within ten (10) days after the study period ends, an oral presentation of the draft report will be made to the Department of Water Resources.
- (4) Within twenty (20) days after the Department has reviewed the draft report, Rogers will provide six (6) copies of a final report and one (1) reproducible print of all drawings. Prints will be Dupont Company Cronoflex, or equivalent.

The final report format will be as requested in the Request for Proposal:

- (1) The draft and final reports shall be concise and contain summaries preceding supporting information.
- (2) Tables and graphs will be utilized where possible and appropriate.
- (3) The draft and final reports shall be bound and presented on 8 1/2 x 11 inch sheets. Substantial amounts of supporting data that are pertinent to the report shall be included as appendices.
- (4) Plant layout and process drawings shall be submitted in full size (24 x 36 inch) transparencies and shall be reduced to either 8 1/2 x 11 inch or 17 x 11 inch sheets and included in the report.

Rogers

7.0 COST

7.1 General

This section presents the estimated costs for Rogers Engineering Co., Inc. and its consultant team to carry out the foregoing scope of work.

The unit costs of services by individual category rates for Rogers Engineering personnel are shown in Section 7.2, "Suggested Contract". The detailed estimate of the costs for the component tasks, including the associated consultants, are shown in tabular form in Section 7.4.1, "Technical Services Personnel Cost". Direct expenses are estimated in Section 7.4.2, and total estimated costs are summarized in Section 7.4.3.

7.2 Suggested Contract-Rogers Engineering Co., Inc. (Prime Contractor)

7.3 Subcontractors to Rogers Engineering Co., Inc.

7.3.1 Radian Corporation for Environmental Studies

7.3.2 Emerald Exploration Consultants, Inc. for Geophysical and Geochemical Studies and Analysis

7.3.3 Dr. William E. Brigham for Reservoir Assessment Studies and Analysis

7.4 Cost Estimate

Rogers

AGREEMENT BETWEEN

CLIENT: California State Department of Water Resources

AND

ROGERS ENGINEERING CO., INC. - ENGINEERS - ARCHITECTS

FOR PROFESSIONAL SERVICES. DATED: _____

Rogers

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Rogers

This AGREEMENT made as of the _____ day of _____ in the year Nineteen Hundred and _____ by and between _____

(hereinafter called the Client) and Rogers Engineering Co., Inc., Engineers-Architects, (hereinafter called ROGERS).

WITNESSETH, that whereas the Client intends to have certain services rendered under the terms of this agreement, these services shall commence after receipt from the Client of a letter of authorization, purchase order, or similar written order. These authorizations, outlining the specific project requirements and addenda thereto shall become an integral part of this Agreement (hereinafter called the project).

SECTION 1 - RESPONSIBILITIES OF ROGERS

1.1 Professional Services

ROGERS agrees to perform professional services in connection with the project as authorized.

1.2 Client's Representative

ROGERS will serve as the Client's professional engineering-architectural representative in those phases of the project authorized and will give consultation and advice to the Client during the performance of these services.

1.3 Designation of Project Representative

ROGERS will designate a representative who will be responsible for the preparation and coordination of all work assigned to ROGERS on the project.

1.4 Project Coordination

ROGERS' representative will coordinate all project work with Client's designated representative who will provide definition of project work and scope of services to be performed in accordance with Client's written authorizations.

1.5 Quality of Services

ROGERS will perform and be responsible for the quality and accuracy of services in accordance with generally accepted professional engineering and architectural practices.

Rogers

SECTION 1 - RESPONSIBILITIES OF ROGERS - Continued

1.6 Client's Standards and Procedures

ROGERS will comply with Client's established standards and procedures as requested if they are in accordance with generally accepted professional engineering and architectural practices and standards.

1.7 Project Reporting

During the progress of the project, ROGERS will make periodic man-hour reports and project progress reports in accordance with the Client's requirements.

SECTION 2 - CLIENT'S RESPONSIBILITIES

The Client will:

2.1 Project Requirements

Provide full information as to his requirements for the project.

2.2 Designate Authorized Representative

Designate in writing a person to act as Client's representative with respect to the work to be performed under this Agreement; and such person shall have complete authority to transmit instructions, receive information, interpret and define Client's scope of work and policies and decisions with respect to materials, equipment elements and systems pertinent to the work covered by this Agreement.

2.3 Available Data and Access

Assist ROGERS by placing at its disposal all available information pertinent to the project including previous reports and any other data related to design and construction of the project and obtain access to required areas to perform services under this Agreement.

2.4 Timely Review and Decisions

Examine all drawings, studies, reports, sketches, estimates, specifications, proposals and other documents presented by ROGERS and Client shall render in writing decisions pertaining thereto within a reasonable time so as not to delay the work of ROGERS in accordance with established schedules.

Rogers

SECTION 2 - CLIENT'S RESPONSIBILITIES - Continued

2.5 Notice of Defect

Give prompt written notice to ROGERS whenever the Client observes or otherwise becomes aware of any defect or problems relative to the project.

SECTION 3 - PAYMENT FOR SERVICES

3.1 Services of Project Personnel

ROGERS will be paid for the time of project personnel engaged directly on the authorized projects in accordance with the Fee Schedule - Attachment "A".

3.2 Personnel Engaged on Projects

Services of personnel under Paragraph 3.1 shall mean those engaged directly on the project including, but not limited to, engineers, architects, consultants, designers, draftsmen, specification writers, estimators, purchasing agents and computer personnel.

3.3 Computer Services

If computer services are required for any authorized project, these services will be reimbursed to ROGERS at cost.

3.4 Outside Services

If ROGERS is authorized by the Client to use outside services, these will be reimbursed at cost.

3.5 Travel Time

ROGERS' project personnel's travel time, during normal working hours for any authorized travel, will be compensated on the basis of the Fee Schedule - Attachment "A".

3.6 Reimbursable Expenses

Client shall reimburse ROGERS for actual costs of reimbursable expenses. Reimbursable expenses shall mean the actual expense of transportation and subsistence of project personnel when traveling in connection with the project, toll telephone calls and telegrams, reproduction of reports, drawings and specifications and similar project related items.

Rogers

SECTION 3 - PAYMENT FOR SERVICES - Continued

3.7 Invoices

ROGERS will submit invoices to Client once a month. Monthly statements will include complete weeks only. Invoices are payable upon receipt unless otherwise agreed. Reimbursable expenses and outside services shall be fully substantiated with proper documentation. All invoices are subject to Client's audit.

SECTION 4 - GENERAL CONSIDERATIONS

4.1 Termination

Services furnished under this Agreement may be terminated by either party by seven days' written notice in the event of substantial failure to perform in accordance with the terms hereof by the other party through no fault of the terminating party. If so terminated, ROGERS shall be paid as provided in Section 3 for the work performed to the date of termination.

4.2 Ownership of Documents

All documents, including original drawings, estimates, specifications, field notes, and data, are instruments of service and will remain the property of ROGERS. The Client may, at his expense, obtain a set of reproducible record prints of drawings and copies of other documents. However, ROGERS may agree to transfer the above-named original documents should extenuating circumstances of Client require them.

4.3 Patent Rights

The patent rights to all inventions, discoveries, processes and improvements conceived by ROGERS' employees during the course of development of Client's project and related thereto, are assigned and conveyed to the Client for exclusive ownership thereof.

4.4 Protection of Restricted Data

All information and data relating to a project assigned to ROGERS by the Client is treated as confidential and every effort is made to preclude disclosure of the information, data, conceptions, processes, drawings, prints, etc., to persons other than those actually assigned to or supervising the project. Confidential or secrecy agreements will be executed if required by Client or a special provision be made under Section 5.

Rogers

SECTION 4 - GENERAL CONSIDERATIONS - Continued

4.5 Estimates

Since ROGERS has no control over the cost of labor, materials or equipment, or over the Contractor's methods of determining prices, or over competitive bidding or market conditions, the estimates of construction costs provided, when applicable, are to be made on the basis of experience and qualifications and represent ROGERS' best judgment as a design professional familiar with the construction industry, but ROGERS cannot and does not guarantee that bids or the Project construction cost will not vary from cost estimates prepared.

4.6 Arbitration

All claims, disputes and other matters in question arising out of, or relating to, this Agreement or the breach thereof shall be decided by arbitration in accordance with the Construction Industry Arbitration Rules of the American Arbitration Association then obtaining. This agreement so to arbitrate shall be specifically enforceable under the prevailing law.

Notice of the demand for arbitration shall be filed in writing with the other party to this Agreement and with the American Arbitration Association. The demand shall be made within a reasonable time after the claim, dispute or other matter in question has arisen. In no event shall the demand for arbitration be made after the date when institution of legal or equitable proceedings based on such claim, dispute or other matter in question would be barred by the applicable statute of limitations.

The award rendered by the arbitrators shall be final, and judgment may be entered upon it in any court having jurisdiction thereof.

4.7 Insurance

ROGERS shall secure and maintain such insurance as will protect it from claims under the Workmen's Compensation Acts and from claims for bodily injury, death, or property damage which may arise from the performance of its services under this Agreement.

Rogers

SECTION 4 - GENERAL CONSIDERATIONS - Continued

4.8 Successors and Assigns

The Client and ROGERS each binds itself and partners, successors, executors, administrators and assigns to the other part of this Agreement and to the partners, successors, executors, administrators and assigns of such other party, in respect to all covenants of this Agreement; except as above, neither the Client nor ROGERS shall assign, sublet or transfer their interest in this Agreement without the written consent of the other. Nothing herein shall be construed as creating any personal liability on the part of any officer or agent of any public body which may be a party hereto, nor shall it be construed as giving any rights or benefits hereunder to anyone other than the Client and ROGERS.

SECTION 5 - SPECIAL PROVISIONS

The Client and ROGERS mutually agree that this Agreement shall be subject to special provisions as attached which together with the provisions hereof and the related authorizations to be provided to represent the entire agreement between the Client and ROGERS; they may only be altered, amended or repealed by a duly executed written instrument.

In witness whereof the parties hereto have made and executed this Agreement the day and year first above written.

ROGERS ENGINEERING CO., INC.

By _____

Title _____

Date _____

CLIENT

By _____

Title _____

Date _____

Rogers

ATTACHMENT "A"

FEE SCHEDULE FOR BASE CONTRACT

CONSULTING ENGINEERING & ARCHITECTURAL SERVICES

BY

ROGERS ENGINEERING CO., INC.

NOTE: This Fee Schedule is valid for the year 1982

The following schedule of rates is established as the basis for charges for services furnished by project personnel. This schedule is subject to adjustment in the event significant increases in salary costs are experienced by ROGERS but, in any case, such adjustment will be submitted for Client's concurrence in ample time to the effective date of any such rate changes.

<u>Project Personnel Classification</u>	<u>Rates per Hour</u>
Principals	\$65.00
Project Manager	\$58.00
Senior Engineer II/Senior Architect II	\$55.00
Senior Engineer I/Senior Architect I/Senior Designer II	\$50.00
Engineer II/Architect II/Senior Designer I	\$45.00
Engineer I/Architect I/Designer II	\$38.00
Designer I/Draftsman	\$30.00
Computer Key punch and Verifying, Engineer's Aides and Project Stenographers	\$18.00

NOTE: Rogers' project personnel's travel time, during normal working hours for any authorized travel will be compensated on the basis of the Fee Schedule above.

ROGERS ENGINEERING CO., INC.

CLIENT

By _____

By _____

Title _____

Title _____

Date _____

Date _____

7.4 Cost Estimate

7.4.1

21 August 1981

TECHNICAL SERVICES PERSONNEL COST

<u>Par. No.</u>	<u>Task Description</u>	<u>Rogers Engineering Prime Contractor</u>	<u>Radian Corp. Environmental</u>	<u>Emerald Exploration Geology & Geophysics</u>	<u>Wm. Brigham Reservoir Assessment</u>	<u>Total</u>
1.0	System Optimization					
1.1	System Analysis	H. Rogers, Jr. F. Dunn J. H. G. Stuart R. Walter B. Fraser H. I. Rogers W. Bott 1,048 hrs. @ \$54.30*	M. Conover 16 hrs. @ \$38.*	R. Smith 15 hrs. @ \$50.*	W. Brigham 16 hrs. @ \$75.	\$ 59,530
1.2	Conceptual Design Selection	H. Rogers, Jr. F. Dunn J. H. G. Stuart R. Walter B. Fraser H. I. Rogers 464 hrs. @ \$54.30	M. Conover 16 hrs. @ \$38.	R. Smith 16 hrs. @ \$50.	W. Brigham 8 hrs. @ \$75.	27,203
2.0	Conceptual Design	H. Rogers, Jr. F. Dunn J. H. G. Stuart R. Walter B. Fraser W. Bott F. Prendergast D. Brewer W. Lindsay H. I. Rogers 2,088 hrs. @ \$54.30	M. Conover K. Strom 16 hrs. @ \$38.	A. Orange R. Smith 16 hrs. @ \$50.	W. Brigham 8 hrs. @ \$75.	115,386

7.4.1 (Cont'd)

Par. No.	Task Description	Rogers Engineering Prime Contractor	Radian Corp. Environmental	Emerald Exploration Geology & Geophysics	Reservoir Assessment	Total
3.0	Geotechnical Assessment					
3.1	Review Existing Data	F. Dunn B. Fraser R. Walter W. Bott 168 hrs. @ \$54.30	M. Conover T. Grimshaw 48 hrs. @ \$38.	R. Smith E. Berkman A. Alpha 48 hrs. @ \$50.	W. Brigham 32 hrs. @ \$75.	15,746
3.2	Recommend Additional Studies	F. Dunn B. Fraser R. Walter W. Bott 352 hrs. @ \$54.30	M. Conover T. Grimshaw K. Strom 96 hrs. @ \$38.	R. Smith A. Orange E. Berkman A. Alpha 96 hrs. @ \$50.	W. Brigham 48 hrs. @ \$75.	31,161
4.0	Integrated Use Assessment	H. Rogers, Jr. F. Dunn B. Fraser J. H. G. Stuart P. Walter H. I. Rogers F. Prendergast W. Bott D. Brewer 322 hrs. @ \$54.30	M. Conover T. Grimshaw 32 hrs. @ \$38.	A. Orange A. Alpha 32 hrs. @ \$50	W. Brigham 16 hrs. @ \$75.	21,501
5.0	Environmental Issues	F. Dunn B. Fraser R. Walter 80 hrs. @ \$54.30	M. Conover K. Strom T. Grimshaw 144 hrs. @ \$38.	A. Orange A. Alphas 32 hrs. @ \$50.		11,416

7.4.1 (Cont'd)

Par. No.	Task Description	Rogers Engineering Prime Contractor	Radian Corp. Environmental	Emerald Exploration Geology & Geophysics	Wm. Brigham Reservoir Assessment	Total
6.0	Draft Report	H. Rogers, Jr. F. Dunn B. Fraser J. H. G. Stuart R. Walter D. Brewer H. I. Rogers W. Lindsay F. Prendergast W. Bott 350 hrs. @ \$54.30	M. Conover T. Grimshaw K. Strom 152 hrs. @ \$38.	A. Orange R. Smith E. Berkman A. Alpha 144 hrs. @ \$50.	W. Brigham 80 hrs. @ \$75.	37,981
7.0	Report Review	H. Rogers, Jr. F. Dunn B. Fraser J. H. G. Stuart R. Walter H. I. Rogers 280 hrs. @ \$54.30	M. Conover T. Grimshaw K. Strom 32 hrs. @ \$38.	A. Orange R. Smith A. Alpha 32 hrs. @ \$50.	W. Brigham 16 hrs. @ \$75.	19,220
8.0	Final Report	H. Rogers, Jr. F. Dunn B. Fraser J. H. G. Stuart R. Walter H. I. Rogers 280 hrs. @ \$54.30	M. Conover T. Grimshaw K. Strom 32 hrs. @ \$38.	A. Orange R. Smith A. Alpha 32 hrs. @ \$50.	W. Brigham 16 hrs. @ \$75.	19,220
TOTAL SERVICES PERSONNEL COST						\$358,364

*Hourly Rate is a weighted average of individual rates. See Section 7.2 for individual rates.

7.4.2

DIRECT EXPENSES

Rogers Engineering Co., Inc.:

Travel:

San Francisco - Sacramento	24 Round Trips @ \$ 50.	\$ 1,200
San Francisco - El Centro	12 Round Trips @ 220.	2,640
Per Diem: 100 Man-days @ \$50.		5,000
Communication: 12 Months @ \$250/Mo.		3,000
Computer		2,500
Reports		2,000
Miscellaneous		<u>1,660</u>

Subtotal

\$18,000

Radian Corporation:

Travel and Per Diem

9,000

Emerald Exploration Consultants:

Travel and Per Diem

9,000

Dr. W. Brigham

Travel and Per Diem

4,000

Total Direct Expenses

\$40,000

7.4.3

Summary of Project Costs

Total Services Personnel Cost	\$358,364
Total Direct Expenses	<u>40,000</u>
Total Estimated Project Costs .	\$398,364

Rogers

8.0

RESUMÉS AND GENERAL QUALIFICATIONS

Resumés of Rogers personnel and the geotechnical consultants are included in this Section, in addition to brief descriptions of a number of geothermal projects conducted by Rogers Engineering.

Rogers

8.1

Resumés

Rogers Engineering Co., Inc.

Herbert Rogers, Jr.
Fred D. Dunn
Ronald A. Walter
H. I. Rogers
John H. G. Stuart
Bruce Fraser
William W. Lindsay
Frank Prendergast
Winston F. Bott
Donald R. Brewer

Dr. W. E. Brigham, Consultant

Emerald Exploration Consultants, Inc.

Roger D. Smith
Arnold S. Orange
Ernest Berkman
Andrew Alpha

Radian Corporation

Marshall F. Conover
Kenneth A. Strom
Thomas W. Grimshaw

Rogers

HERBERT ROGERS, JR.

POSITION

Chairman of the Board and President

EXPERIENCE

Mr. Rogers, as President, is responsible for overall administration of both the overseas and domestic operations for Rogers Engineering Co., Inc. In this capacity, he actively supervises the planning of projects, with particular attention to contract negotiations and project financing arrangements with financial institutions, both local and international.

Since founding his firm in 1946, Mr. Rogers has maintained a keen interest in the solution of special problems and new technology areas where the state-of-the-art is not yet clearly defined or well developed. This has resulted in the growth of a nucleus of highly skilled and creative engineers within the firm, which has been responsible for the successful completion of a number of unusual projects.

ROGERS entered the geothermal resource field in 1961, when it was in its infancy and sophisticated methods of utilization were being developed. Some nineteen years later, ROGERS has participated in, and is continuing in, the development and utilization of geothermal resources at locations in the United States, Iceland, Costa Rica, Iran, Turkey, the Republic of the Philippines and Hawaii.

By the end of 1980, ROGERS had participated in the engineering of over one-third of the capacity of the world's geothermal-electric generating plants. ROGERS engineers have developed a system for controlling the deposition of solids from highly mineralized geothermal fluids. This research resulted in U. S. Patent No. 3,782,468, "Geothermal Hot Water Recovery Process and System".

Mr. Rogers participated in the preparation of a portion of the Hickel Geothermal Report as Co-Chairman of the Geothermal Utilization Panel. He is a former member of the Board of Directors of the Geothermal Resources Council.

Under the direction of Mr. Rogers, the firm has successfully completed a diversity of projects for major industrial firms on the West Coast, all branches of the armed forces, U. S. Government Agencies, and the governments of the Philippines, Thailand, and Guam.

Rogers

HERBERT ROGERS, JR. (Page 2)

EXPERIENCE

Power systems projects, under Mr. Roger's direction, have included design and supervision of the installation for geothermal, thermal-electric, diesel-electric and hydroelectric generating plants, both in the United States and overseas. The engineering of the associated electrical transmission and distribution systems has also been a major part of the firm's operations, including the design of several hundred step-down substations ranging in voltage from 220 kV to 4.16 kV.

Rogers Engineering, under the supervision of Mr. Rogers, has actively participated in the engineering design for petroleum and chemical processing facilities; and also for bulk handling systems for asphalt and petroleum, including military and commercial airport hydrant refueling systems.

EDUCATION

Polytechnic College of Engineering, Bachelor of Science in Electrical Engineering, 1937

REGISTRATION

Registered Electrical Engineer, California

MEMBERSHIPS

The Engineers Club of San Francisco, Institute of Electrical and Electronic Engineers, Illuminating Engineering Society, The World Trade Club, Geothermal Resources Council

Rogers

FRED D. DUNN

POSITION

Vice President

EXPERIENCE

Mr. Dunn has over thirty-five years of experience in all phases of engineering design and project management of electric power, industrial, and process facilities for public utilities, industrial complexes and government installations, in both domestic and international applications.

As a firm principal in charge he has been responsible for the supervision of the preparation of feasibility studies, economic analyses, and conceptual, preliminary, and final design for a multitude of projects in the fields of electric power generation and distribution, steam generation and distribution systems, petroleum products storage and transfer facilities, and miscellaneous chemical process and industrial manufacturing plants.

On electric power generating projects Mr. Dunn has performed as firm principal and/or engineer in charge for preparation of design and construction drawings for (a) four hydroelectric power plants (120 MW each); (b) a major heavy fuel-fired total energy diesel-electric plant (50 MW); (c) several geothermal electric power generating plants including a single wellhead unit (3 MW) in Hawaii, a two unit (30 MW each) 60 MW plant in Iceland, a single unit 10 MW plant in California's Imperial Valley, two 2-unit (55 MW each) 110 MW plants at PGandE's Geysers geothermal power plants in California; and (d) a number of small diesel-electric stations (5 MW +) and standby and emergency power installations for utilities and government installations.

In the geothermal field, Mr. Dunn has been directly involved in the performance of a geothermal well testing and report program for a geothermal well in California's Imperial Valley; preparation of well drilling contracts and procurement of drilling accessories and tools for a well drilling program in the Philippines; preparation of numerous studies and publications on geothermal conversion systems and gathering and injection systems analyses and evaluations; and in development of feasibility studies, preliminary designs and cost estimates for numerous geothermal power generating plants.

Mr. Dunn's background also includes environmental engineering and pollution abatement studies and projects for H₂S abatement at geothermal power plants, solid and gaseous waste incineration, industrial fume control and chemical and industrial waste treatment facilities.

EDUCATION

University of Nevada, Bachelor of Science, Mechanical Engineering

REGISTRATION

Professional Mechanical Engineer, California, Nevada, Arizona and Montana

MEMBERSHIP

Consulting Engineers Association of California

Rogers

RONALD A. WALTER

POSITION

Senior Mechanical Engineer

EXPERIENCE

Mr. Walter has ten years of experience in the conduct of research, development and engineering studies associated with energy resource utilization. In eight of these years, work has been primarily in the development of geothermal energy resources. Activities and responsibilities in geothermal energy have included:

- program manager at a National laboratory responsible for geothermal energy research projects in resource exploration, power plant design, production economics, environmental impacts, geochemical interactions and reservoir engineering.
- project manager for development of a computer model simulating the operation of a geothermal power plant. This model includes thermodynamic, mechanical, chemical and financial considerations. Direct steam, flashed steam, binary fluid cycle and total flow plant designs were modeled.
- conducted power plant optimization studies for a variety of geothermal power plant design and operating conditions.
- studied environmental impacts associated with geothermal energy development, including gaseous effluents, liquid and solid waste disposal, subsidence and induced seismicity.
- developed monitoring instrumentation systems for binary fluid cycle power plants designed to detect adverse chemical and material performance changes.

Mr. Walter's experience in other energy technology projects include the development of improved methods for mechanical transport of solid materials at high pressures during coal gasification processes, development of a laser doppler velocimeter, design of a self-contained instrument for detection of rock movement in underground mines, and the design and testing of a high speed non-contact examination system for detecting flaws in ammunition casings. He worked for two years on the development of improved dry and wet/dry cooling tower designs for nuclear and fossil-fuel power plants. In this project, Mr. Walter conducted comparison studies on advanced extended surface designs for heat rejection, developed advanced wet/dry cooling tower designs, designed and managed the installation of a Water Augmentation Test facility to test advanced wet/dry designs, and conducted optimization studies on a variety of wet, wet/dry, and dry heat rejection systems.

Rogers

RONALD A. WALTER (Cont'd)

EDUCATION

M. S. Degree in Mechanical Engineering, Oregon State University,
1976

B. S. Degree in Mechanical Engineering, University of Nebraska,
1971

REGISTRATION

Engineer-In-Training Certificate - Mechanical Engineering,
State of Nebraska

MEMBERSHIPS

American Society for Mechanical Engineers

Geothermal Resources Council

International Society for Geothermal Engineering

Rogers

H. I. ROGERS

POSITION

Senior Electrical Engineer
Vice President

EXPERIENCE

Mr. Rogers has had extensive experience in the electric utility and computer applications fields. He has professional experience in planning, engineering design, economics, systems analysis, management of projects, and construction management.

Geothermal experience includes: project management, construction management, specifications, design criteria, capital and operating cost determinations, cost of electric power, project financing and overall economic analysis.

Electric Utility experience has been gained in consulting to and being an employee of investor owned, municipal and government owned systems. He has conducted and participated in field investigations, technical studies, and implemented electric system improvements and expansion projects to meet existing and future system load requirements. In planning the system requirements, his experience has included the total utility electrical situation from load development through transmission line design, routing and planning; economic evaluation of generation methods resources to coordinate with load characteristics and demand. Electric utility technical analysis includes: load flow, short circuit, and transient stability studies. Distribution work has been in operations, planning and design.

Economic Study experience includes: power supply contracts, wheeling agreements, rate structures, engineering economic alternatives, generation operating cost alternative comparisons, utility plant appraisal, project capital costs, cost of power and international project financing.

Computer Applications experience includes: system analysis and program writing in electrical and mechanical engineering, economics, business accounting, finance, public utility technical studies and critical path project scheduling.

Legal Research in the utility field relating to administrative and statute law of government power projects, regulatory commissions (FPC, CPUC, CERDC), and contractual regulations. This information was utilized in engineering and economic work.

Rogers

H. I. ROGERS (Cont'd)

EDUCATION

Whitman College 1959-62, Walla Walla, Washington
Arizona State University, BSE 1964, Tempe, Arizona
University of Santa Clara, MSEE 1970, Santa Clara, California
Stanford University, 1976, Utility Economics, Stanford, California

REGISTRATION

Professional Electrical Engineer, California

MEMBERSHIP

Institute of Electrical and Electronic Engineers - Power Society
Consulting Engineers Association of California
Geothermal Resources Council

Rogers

JOHN H. G. STUART

POSITION

Senior Staff
Mechanical Engineer

EXPERIENCE

Mr. Stuart's professional career embraces more than thirty-five years experience in the operation, maintenance and design of geothermal and fossil fuel electric generation plants, marine propulsion equipment and aerospace test facilities.

He was Lead Start Up Engineer and Project Manager for the start up and commissioning of the Brawley 10 MW Geothermal Power Plant (owned by Southern California Edison Co.) in Imperial County, California. He was responsible for the training of the plant operating personnel.

Mr. Stuart's experience in geothermal power plant design covers the evaluation of conversion of Pacific Gas and Electric Co.'s Unit 1 thru 12 conversion to comply with the California environmental requirements; the bid evaluation for the Heber, Imperial County's 50 MW geothermal power plant (Southern California Edison Co.) turbine-generator and brine flasher units; design of steam flasher test facility in Costa Rica; and Project Manager for the Salton Sea 10 MW geothermal power plant, Feasibility Report (Southern California Edison Co.) in Imperial County, California.

For the Krafla Geothermal Power Plant in Northern Iceland, Mr. Stuart served as project engineer, and in this capacity developed the design and carried it through to completion. His work included preparation of specifications and procurement documents, evaluation of bids, monitoring vendor submittals and progress and providing support to the construction effort, both from the home office and through considerable time spent at the project site. Additionally, Mr. Stuart was in residence at the site throughout the start-up period and made significant contributions to this phase of the project as well as training of the permanent operating staff. The Krafla project consists of two 30 MW steam turbine-generators with turbines of the double flow mixed pressure condensing type.

Mr. Stuart was mechanical discipline engineer for the preliminary design of the Tiwi 110 MW geothermal power plant in the Philippines and was involved in the specification preparation, and bid evaluations covering the main and auxiliary equipment.

Mr. Stuart was successively senior construction engineer, facility design engineer, supervisor of facility design and construction, and senior research engineer with Lockheed Missile and Space Co., Sunnyvale, California, and was responsible for the design, instal-

Rogers

JOHN H. G. STUART (Cont'd)

lation and test of several facilities for aerospace vehicle, ocean vehicle and missile development. Test facilities included very high pressure-high flow gas and hydraulic equipment, cryogenic, vacuum, power equipment, and high pressure/temperature deep sea simulator. Project work included development work on DSRV high pressure joints and development work on "clean sweep" oil suck recovery equipment for ocean systems.

Prior to joining Lockheed, Mr. Stuart was technical assistant, mechanical, with Pacific Gas and Electric Co. and was responsible for planning and economic analysis for the turbine-generator and boiler overhaul and maintenance program for the entire Pacific Gas and Electric system of seven million kilowatts installed capacity.

His experience includes service with the Calcutta Electric Supply Corp. in India as boiler and turbine house superintendent in three steam-electric power plants where he was responsible for operation, maintenance and construction for over five years.

Mr. Stuart's professional career began with seven years service in the Royal Navy with assignments including chief engineer officer and inspector of naval machinery.

EDUCATION

University of Dublin, Trinity College
B. S. Mechanical Engineering
M. S. Mechanical Engineering

University of London, Imperial College
Diploma in Generation, Distribution and Utilization of
Electric Power

Hartnell College, Salinas
Industrial Electronics

REGISTRATION

Chartered Mechanical Engineer
Great Britain

MEMBERSHIPS

Member, Institution of Mechanical Engineers
Electrical Power Engineers Association
American Society for Metals
American Vacuum Society

Rogers

BRUCE FRASER

POSITION

Chief, Chemical & Process Department

EXPERIENCE

Mr. Fraser has over forty years experience in all phases of process and power plant design, construction, start-up, production operations, process improvements, and air and water pollution abatement.

He is responsible for process engineering in the design of geothermal power production facilities including standards for well testing and evaluation; heat and materials balance for power cycle diagrams and process flow diagrams; evaluation of turbine condensers and noncondensable gas removal systems; application and evaluation of environment abatement processes applicable to the disposal of geothermal waste water and noncondensable gas including H_2S ; and application of Rogers' process system for handling calciting geothermal waters.

He is also responsible for evaluation of turbine condenser heat sink systems including: dry cooling systems (radiators), mechanical draft cooling water towers, cooling ponds and canals, river, lake and sea water circulation.

Mr. Fraser provided process engineering services on the Geysers Units 7 and 8 and the Krafla, Iceland 60 MW geothermal power plant. Most recently, he has directed or performed process design for 10 MW and 3 MW geothermal power plants including H_2S abatement for the latter.

His experience in pollution abatement projects includes:

Removal of chlorine, sulfur chlorides and sulfenyl chloride from the exhaust air system of a semi-works fungicide plant and from a similar full-scale fungicide manufacturing facility, plus additional disposal of liquid chlorinated sulfur compounds via dual liquid gas incineration and a flue gas scrubbing unit.

A field survey and plan to handle industrial wastes at Sharpe Army Depot, involving degreasing, chromate stripping and solvent removal units, and a similar, but more comprehensive plan for the Riverbank Army Ammunition Depot including waste water clarification, sludge dewatering and disposal and thermal reduction.

The collection and disposal of relief vent gases from petroleum processing which included a liquid interceptor and vent stack with smokeless flare.

Design of a process to remove H_2S from turbine exhaust steam at PGandE's Geysers' Power Plant.

Rogers

BRUCE FRASER (Cont'd)

Mr. Fraser was the technical adviser for a coal gasification conceptual design program for Lawrence Livermore Laboratory (LLL). This project involved process engineering consulting services for optimum system control design to provide maximum safety for equipment and personnel during the operation of LLL's steam/oxygen injection test for in-situ coal gasification experiment at the Hoe Creek, Wyoming test site.

EDUCATION	B. S. in Chemical Engineering, University of California
REGISTRATION	Professional Chemical Engineer, California
MEMBERSHIPS	American Chemical Society Instrument Society of America

Rogers

WILLIAM W. LINDSAY

POSITION

Senior Staff Electrical Engineer

EXPERIENCE

Over twenty-seven years of professional experience in electrical engineering has provided Mr. Lindsay with a background in planning, design and project management for power systems for public and private utilities and industrial firms both in the United States and abroad. Over thirteen years of experience has been in the Philippines, Thailand, Laos and Iceland.

Mr. Lindsay performed as a resident construction advisor and the electrical start-up engineer for the 60 MW Krafla geothermal plant in Iceland requiring his presence at the project site for extended periods of time. He performed similar construction and start-up services for a 10 MW geothermal plant located at Brawley, California.

Mr. Lindsay's experience in geothermal design includes, in addition to the above, responsibility for the design of the electrical systems relating to the steam supply and treatment system for the 10 MW geothermal power plant at Brawley. He also had design responsibility for the electrical systems for a 3 MW wellhead geothermal power generating plant on the island of Hawaii including on site supervision and start-up operations.

As Chief Electrical Engineer in Rogers' Manila office, Mr. Lindsay was responsible for field investigation, design, preparation of specifications and purchase orders, contract negotiations and field inspection for industrial and marine facilities, power plants, overhead and underground distribution, substations and high voltage transmission in the Philippines.

As project engineer for Rogers in Thailand, he conducted field surveys and prepared feasibility studies for rehabilitation and extension of distribution systems in Northern Thailand. He was also engaged in sub-transmission and distribution system planning and design for the power system in the City of Bangkok, including preparation of procurement specifications and evaluation of equipment bids. Also included in his responsibilities were supervision of electrical design, equipment procurement and construction supervision for a 10 MW diesel plant and a 12.5 MW steam electric generating plant, together with related 69 kV transmission and substation facilities.

Rogers

WILLIAM W. LINDSAY (Cont'd)

Mr. Lindsay has designed electrical power and control systems for a roofing plant and airport fueling and lighting systems. Additionally, he has spent over five years in planning, design supervision, preparation of specifications and purchase orders, and bid analyses for industrial power and control systems for various petrochemical facilities in California, Texas, Louisiana, British Columbia, and Australia. His experience also includes design of hydroelectric power plants and high voltage substations.

EDUCATION	B. S. in Electrical Engineering, University of California
REGISTRATION	Professional Electrical Engineer, California
MEMBERSHIP	Institute of Electrical and Electronic Engineers

Rogers

FRANK PRENDERGAST, AIA

POSITION

Assistant Vice President
and Project Manager, Architecture

EXPERIENCE

Mr. Prendergast has had a wide range of experience in the design of industrial, commercial, and residential buildings. He is responsible for the architectural design of major building structures for the firm. Recent design work has included programs for geothermal power plants in California and Hawaii.

Project architect assignments for Rogers have included diverse development programs, namely: A major research and development center for Del Monte Corporation, Walnut Creek, California; a bag manufacturing plant and regional office for St. Regis Paper Co., Union City, California; various industrial and maintenance buildings at military installations throughout California; a complex facility for the United States Navy at Pearl Harbor; several structures for Pacific Gas and Electric Company; a 50 MW diesel generation power plant for Anamax Mining Co., Sahuarita, Arizona; and geothermal power plants for Pacific Gas and Electric Company, and National Power Corporation, Tiwi, the Philippines.

As Project Manager he was responsible for a maintenance area planning and development study for the Golden Gate Bridge and Highway District; a headquarters fire station and sheriff's substation for valley of the Moon Fire Protection District; a bag manufacturing plant for Bemis Company, Union City, California, an enological research center for United Vintners, Inc., and an industrial plating shop for the U. S. Army Corps of Engineers.

Prior to his association with Rogers, Mr. Prendergast was engaged in the design of bank buildings for the Royal Bank of Canada and the Bank of America. For the Royal Bank of Canada, Montreal, he was assistant to the Chief Architect and had overall project responsibility from design concepts through preparation of drawings, coordination with associated engineers, site supervision of construction and final responsibility for the interior furnishings. He was also employed by a large architectural firm in the Bay Area involved primarily in the design of apartment build-

Rogers

FRANK PRENDERGAST, AIA (Cont'd)

ings, townhouses, office buildings and custom residential work. This assignment covered full responsibility in all planning, design and construction phases, including major apartment and townhouse complexes and design essays in environmental planning.

EDUCATION	University of London, Sir John Cass School of Art, and University of Cambridge, Department of Estate Management
REGISTRATION	Registered Architect, California, Hawaii
MEMBERSHIP	American Institute of Architects

Rogers

WINSTON F. BOTT

POSITION

Geothermal Development - Well Drilling Advisor
- Project Manager

EXPERIENCE

Thirty-two years diversified professional experience with principal emphasis in the energy field starting as a designer with successive assignments as field engineer, construction superintendent, drilling manager, exploration manager and project manager.

In April, 1980, Mr. Bott rejoined the staff of Rogers Engineering Co., Inc. and since then has served as Project Coordinator for the Costa Rica geothermal program. This work included the final reporting of the successful exploration and test well drilling phase, and the preliminary planning and feasibility study for development drilling, gathering system and reinjection well system.

During 1979-80 Mr. Bott served as Project Coordinator on the staff of PB-KBB, Inc., consulting specialists in the field of solution mining and construction of underground storage caverns by the solution-mining process. Mr. Bott coordinated projects including: drilling wells for solution mining of salt in bedded salt and shale formations; hydraulic fracturing of bedded salts; a report detailing the state-of-the-art in the field of feedwater treatment with additives to effect the in-situ (underground) purification of the solution-mined salt product; a proposal to DOE for a research program to develop a variety of stimulation techniques for the in-situ production of natural gas from coal deposits.

During 1977-78 Mr. Bott was designated as Drilling Supervisor for the Instituto Costarricense de Electricidad for their geothermal exploration program. He furnished guidance and advice on drilling specifications, drill site engineering, contractor solicitation and selection, drill rig inspection and mobilization, and contract administration.

Concurrently with the above assignment during 1977-78 Mr. Bott was Project Manager for geothermal exploration for the Ministry of Energy of Iran. Mr. Bott performed contract administration at the home office and in Iran, and coordinated the work of scientific subcontractors in the fields of geochemistry, geology, volcanology and photo-geology.

Rogers

WINSTON F. BOTT (Cont'd)

Mr. Bott managed the drilling of an exploratory well for the Marysville Geothermal Project, sponsored by the National Science Foundation, which was completed in 1974. On this project, Mr. Bott handled all local, state and federal government agency contracts and supervised drafting of an environmental impact report. He also supervised the preparation of contracts and specifications for the deep-hole drilling and for all site preparation. As drilling manager, he had full charge of drilling strategy and drilling supervision, and administered all contracts.

Mr. Bott has maintained a close contact with the drilling industry through the years as the inventor of a specialized safety device for which he holds a patent, and which is used by major oil well drillers throughout the world.

Prior experience has included: seismic exploration with a major oil company; construction supervision of refinery projects; area engineer on the construction management staff of a nuclear project; and other civil, process, and industrial projects.

EDUCATION

University of Missouri, Bachelor of Science in Civil Engineering
Tau Beta Phi and Phi Kappa Phi Member

REGISTRATION

State of Texas, Civil Engineer
State of California, Civil Engineer

Rogers

DONALD R. BREWER

POSITION

Senior Control Systems Engineer

EXPERIENCE

Mr. Brewer has over thirty years of experience in the analysis, design and application of instrumentation and control systems for the process, industrial, transportation, and food processing industries.

His experience in design of instrumentation and control systems includes analyses of AC and DC power systems and subsequent design and application of controls for transportation systems, design and application of control devices and systems for machine tools and hydraulic presses, injection molding machines, and aluminum extrusion presses. He also designed systems and controls for completely automated fluid product handling systems for the dairy, food, beverage and pharmaceutical industries.

As control systems engineer for the Rogers' Krafla Geothermal Electric Project in Iceland, Mr. Brewer designed the instrumentation and control system, prepared instrument specifications, evaluated quotations and recommended suppliers, and provided supervision for the preparation of installation drawings. He provided on-site supervision of the installation of the system and served as control system start up engineer including training of operating staff.

In Rogers' capacity as consultant to PGandE, Mr. Brewer prepared basic instrumentation and control philosophy for the major systems in Geysers Units 16 and 17. His most recent assignments have been as control systems project engineer for the Brawley geothermal power plant now in operation in southern California and the HGP-A Geothermal project in Hawaii. Rogers has design, procurement, operator training, construction management and start up responsibilities for both of these plants.

Mr. Brewer assisted in the preparation of instruction manuals, the training of operators and maintenance men and start-up supervision in these plants.

EDUCATION

B. S. in Electrical Engineering, University of Wisconsin

REGISTRATION

Registered Control Systems Engineer, California
Registered Professional Engineer, New York State

W. E. BRIGHAM

EDUCATION

September 1946 - June 1947 Burlington Jr. College, Burlington, Iowa
Iowa State Univeristy, Ames, Iowa
B. S. - Chemical Engineering, June 1950

September 1954 - August 1958 University of Oklahoma, Norman, Oklahoma
M. S. - Chemical Engineering, June 1956
Ph.D. - Chemical Engineering, June 1962

PROFESSIONAL
EXPERIENCE

June 1950 - September 1951
and
October 1953-September 1954 S. C. Johnson and Sons (Johnson's Wax), Racine, Wisconsin
Pilot Plant Engineer studying the processing of wax, resin and varnish products.
(The two year hiatus here was for military duty in the USMC).

September 1958 - June 1971 Continental Oil Co., Production Research Division, Ponca City, Oklahoma. Held a series of technical and supervisory positions. Professor and Associate Chairman of the Petroleum Engineering Department, Stanford University. Major interests are geothermal, and oil and gas reservoir engineering. Has published widely and consults for both government and industry in these fields. Research interests include geothermal engineering, enhanced recovery of heavy oil, reservoir mixing theories, new well test techniques, and other transient flow and oil and gas recovery phenomena.

June 1971 - Present

PROFESSIONAL
SOCIETY
ACTIVITIES

Member, SPE of AIME, 1958-present
SPE Transactions Editorial Committee, 1966-1967
SPE Monograph Committee, 1968-1972
SPE Distinguished Lecturer, 1968-1969
SPE Ferguson Medal Committee, 1971-72, Chairman, 1973
Session Co-Chairman, "Geothermal Operations", SPE Regional Meeting, Bakersfield, California, November 9-10, 1972

W. E. BRIGHAM (Cont'd)

Program Co-Chairman, SPE Regional Meeting, San Francisco,
April 3-5, 1974

SPE Program Committee, "Fluid Mechanics and Oil Recovery Processes",
1973-75

SPE Technical Coverage Committee, 1980-81

Vice Chairman and Chairman, Golden Gate Section SPE of AIME,
1975-77

Geothermal Resources Council-1977 - present

PUBLICATIONS
AND PATENTS

There are over 86 publications and patents on the subjects mentioned above. These are mostly on reservoir mechanics and secondary recovery.

Rogers

EMERALD EXPLORATION CONSULTANTS, INC.

ROGER D. SMITH

POSITION

Exploration Consultant

EXPERIENCE

Mr. Smith has been involved with various technical aspects of geophysical engineering, geothermal, and petroleum exploration since receiving his Masters Degree in Geophysics in 1973. Specific research was done in geothermal exploration techniques for this degree. Mr. Smith has broad experience in a wide range of geophysical methods and a strong geologic background particularly in the Rocky Mountain and Offshore Alaska areas.

Independent Exploration Consultant associated with Emerald Exploration Consultants, Austin, Texas. Involved with all phases of Exploration Consulting and Project Management for the petroleum and geothermal industries.

Geotronics Corporation - Austin, Texas: SENIOR GEOPHYSICIST-GEOTHERMAL PROJECTS INTERPRETATION AND CLIENT DEVELOPMENT. Primarily responsible for the interpretation of magnetotelluric data as pertaining to the geothermal industry and the marketing of services and surveys. Interpretation functions include development of the data package to fit the needs of a specific project, computer modeling, integration with available geological and geophysical data, final report preparation, and its presentation. Several recent projects have included large portions of the Northwest Overthrust Belt of Idaho as a Geothermal and Petroleum Providence. Involvement within the Geothermal Industry has included many of the active KGRA areas within the Western United States, such as the Geysers of Northern California and Dixie Valley, Nevada. Involvement in International Geothermal Exploration has also been undertaken on the Island of Kyushu in Japan. Client development functions include the education of the industry regarding magnetotellurics and how this exploration tool could be utilized in their exploration programs. These functions also include the marketing of magnetotelluric surveys. Included in his duties with Geotronics was a tenure as General Manager for Geotronics Corporations-Paraguayan operations in mid-1979 and early 1980, with the integrated interpretation of geophysical data for several prospects.

Diamond Shamrock Corporation - Denver, Colorado: GEOPHYSICIST - NORTHERN EXPLORATION DISTRICT. Responsible for oil and gas exploration efforts in the Continental United States from Michigan to California, the Rocky Mountain area, Canada, Offshore Western United States, Offshore and Onshore Alaska, and any foreign exploration. Primary involvement has been in the St. George Basin-Bristol Bay and Lower Cook Inlet areas of Alaska and in many

ROGER D. SMITH (Cont'd)

areas of the Rocky Mountain region, including the Williston Basin. The ostensible areas of responsibility within the aforementioned areas were in the interpretation of seismic records to construct time-structure and structure contour maps to determine structure as related to possible oil and gas entrapment. These interpretations were used to determine prospective blocks and bids for upcoming lease sales and for evaluation to determine involvement, either as an operator or as a partner, for prospective sites to drill for oil and gas.

Dames and Moore - Denver, Colorado: GEOPHYSICIST. Involved in all aspects of engineering geophysics. Included involvement in all phases of a project, from proposal to preparing the final report. Responsibility included preparing proposals which covered job specifications and cost breakdowns; field operations - set up, implementation and supervision, data reduction and interpretation, as well as final reporting. These projects were implemented world-wide but primary areas covered were in the Continental United States. Many of these projects involved PSAR and SAR reports for the Nuclear Power Industry. Duties also included the responsibility for providing engineering geophysical support on several geothermal projects and proposals around the world. Other responsibilities included the development, writing, and implementation of computer programs used in the processing of the geophysical data.

EDUCATION

New Mexico Institute of Mining and Technology - Socorro, New Mexico: Master Degree Geophysics, 1973: Feasibility of shallow hole temperature measurements and geothermal exploration in the Socorro Peak area (now KGRA).

State University of New York - Potsdam, New York. Bachelors Degree Applied and Theoretical, Minor Degree Geophysics, Physics, 1972: Gravity surveying and modeling of the Pope Mills area, New York

EMERALD EXPLORATION CONSULTANTS, INC.

ARNOLD S. ORANGE

POSITION Exploration Consultant

EXPERIENCE Mr. Orange's 21 years' experience covers an extremely broad range of applied geophysics. Working primarily on the acquisition and interpretation of field data, first for the U. S. Department of Defense and then for several geophysical contractors, he has been involved primarily in the application of novel technology to practical exploration problems. His more than 40 technical presentations and papers include, as co-author, a series of publications in the field of rock mechanics which are frequently cited today more than 15 years after publication. As an explorationist, he has worked primarily on the onshore and offshore frontier regions, and is a specialist in the application of geophysical techniques to nonseismic or poor seismic prospects.

His recent experience has emphasized exploration in the western United States for both hydrocarbon and geothermal resources. Clients have included both major companies and independent operators.

EDUCATION Massachusetts Institute of Technology - 1958
BS and MS in Electrical Engineering

EMERALD EXPLORATION CONSULTANTS, INC.

ERNEST BERKMAN

POSITION Exploration Consultant

EXPERIENCE Mr. Berkman acquired, during the first eight of his twenty years with Mobil Oil Corporation, in-depth technical experience in geophysical data acquisition, processing, and interpretation while assigned to various onshore and offshore seismic and gravity crews, district exploration offices, and the data processing and special problems center. He served one year as party chief of an onshore digital multifold seismic crew.

During the ensuing twelve years with Mobil, Mr. Berkman was involved with the acquisition and interpretation of all types of geophysical and geological data in all Pacific onshore and offshore basins, Michigan, the thrust portion of the North Slope of Alaska, the Rocky Mountain overthrust play extending through Montana, Idaho, Wyoming, Utah, Nevada, and Arizona, various Rocky Mountain foreland basins, and portions of North and West Texas. This work included the application of seismic stratigraphy and direct detection techniques in exploration plays and case histories.

Mr. Berkman was the manager of the Exploration Services Division of Geotronics Corporation, a small geophysical contracting firm, from 1978 until 1979. In this highly diversified technical management position, he supervised ten non-degreed and four degreed personnel in the processing and interpretation of magnetotelluric data. Areas of responsibility encompassed personnel, procurement, scheduling, quality control, budget, and management.

EDUCATION City College of New York, 1954-1955
Colorado School of Mines, 1955-1958, Geophysical Engineer
California State College at Fullerton, 1965-1969, Business Administration

EMERALD EXPLORATION CONSULTANTS, INC.

ANDREW G. ALPHA

POSITION

Geological Consultant

AREA OF
EXPERTISE

Western States - Emphasis on Basin and Range Province, and thrust belts. Canada and Alaska - In the fields of stratiform ore deposits, geothermal, oil, gas and ground water.

PROFESSIONAL
HISTORY

Twenty-two years - Mobil Oil Corporation

Geology of oil and gas, geothermal and stratiform ore deposits in states west of the Mississippi and Alaska

Thirteen years - Signal Oil and Gas Company

Geology of oil and gas and geothermal in states west of the Mississippi, Canada, Alaska, Eastern Seaboard, and the North Sea.

Eight years - after M. S. from the University of North Dakota worked in western states on geology of ground water and as a Soil Technologist for government agencies.

PROFESSIONAL
EXPERIENCE

May 1, 1977 to present

Consulting Geologist - stratiform ore deposits, geothermal, and oil and gas.

Two six month contracts with Mobil Oil Corporation on stratabound uranium - involving the concept of occurrence and field checks - Basin and Range Province.

Seven month contract with Resources Associates of Alaska. Performed field work and designated areas of probable uranium occurrences in the western United States.

June 1969 to May 1, 1977 (Retired from Mobil 5/1/77)

Mobil Oil Corporation - Regional Geological Advisor - western states and Alaska on oil and gas and geothermal-Los Angeles 1969-1972; Denver, Colorado 1972-1977

ANDREW G. ALPHA (Cont'd)

Geothermal - answering directly to the New York headquarters on all matters geothermal, with respect to geology, land acquisition and economics. As the Mobil staff technical expert on geothermal exploration and production, Mr. Alpha was concerned with the geochemistry of geothermal fluids both in relation to exploration and to reservoir analysis. He was responsible for the geochemical efforts undertaken by Mobil in the course of the company's geothermal activities.

Uranium - 1975-1980 - In addition to geothermal, his responsibility was to conceptualize the probable occurrence of uranium and other stratabound ore deposits based on field and literature studies, primarily in the Basin and Range Province.

May 1964 to June 1969

Mobil Oil Corporation - Regional Geological Advisor - West Coast Region;

Area of responsibility: West Coast States including Alaska, regional staff functions on matters of geology, management and employment.

August 1953 to May 1964

Signal Oil and Gas Company - Assistant Chief Geologist - August 1958 to May 1964, Los Angeles, California; Exploration Manager - August 1953 to August 1958, Denver, Colorado

Assistant Chief Geologist - area of responsibility: United States, Canada and foreign assignments. Three years of management and supervision. Two years research and special assignments relating to new areas foreign and domestic and special problems (tar sands, marine geology, etc.)

Exploration Manager - residing in Denver, Colorado for the Rocky Mountains, Williston Basin and Canada

June 1953 to August 1953

Consultant - Billings, Montana Consulting geologist, primarily Montana geology

ANDREW G. ALPHA (Cont'd)

April 1952 to June 1953

U. S. Smelting, Refining and Mining Company, Billings,
Montana; Regional Geologist, Rocky Mountains, Williston
Basin and Canada;

Supervised surface mapping, subsurface studies, and geophysical operations.

July 1943 to April 1952

General Petroleum Corporation (a Socony-Mobil Company)
Regional Geologist, January 1950 to April 1952 -
Casper, Wyoming
District Geologist, July 1943 to January 1950 -
Great Falls, Montana;

Regional Geologist with supervisory responsibility for Rocky Mountain states and Williston Basin. Coordinated exploration effort between Magnolia Petroleum Corporation, Socony Vacuum of Canada and General Petroleum in Williston Basin.

As District Geologist, had the responsibility for the exploration effort in Montana and the Williston Basin.

March 1941 to July 1943

Grazing Service - Department of Interior, Rawlins,
Wyoming;

Did ground water geology in eleven western states, located wells, supervised drilling and spring development.

November 1935 to March 1941

Soil Conservation Service - Department of Agriculture
Mobil party - North Dakota to Texas - 6 months
Lander, Wyoming - 4 years
Casper, Wyoming - 1 year
Ground water geologist and soil technologist

Summer employment 1933, 1934 and 1935

North Dakota Geological Survey - ground water geology

PUBLICATIONS Papers in: AAPG - Future Oil Provinces
Montana Guide Books (2)
World Oil
Montana Oil and Gas Fields Volume

R A D I A N C O R P O R A T I O N

MARSHALL F. CONOVER

POSITION

Program Manager, Engineering and Research Operations

SPECIAL EXPERTISE

Geothermal Energy Resources

SUMMARY OF EXPERIENCE

As Alternate Energy Program Manager at Radian Corporation, Mr. Conover has overall responsibility for the satisfactory performance of Radian's Geothermal energy programs. Mr. Conover has participated in numerous state, national, and international geothermal projects. He has also performed RD&D program planning. Programs and activities which demonstrate his technical and management experience and which qualify him to assist in this study are highlighted below:

- Currently Program Manager on an engineering program to produce a Geothermal Materials Selection Handbook. This handbook will guide future materials selection in geothermal electric power plants and direct utilization systems.
- Currently Program Manager for the direct utilization geothermal space and water heating system at Navarro College, Corsicana, Texas.
- Member of the special ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers) Geothermal Task Force. Mr. Conover is involved in the development of the necessary geothermal direct utilization data for inclusion in future ASHRAE handbooks.
- Mr. Conover has visited with geothermal energy officials and industry representatives in Japan, Italy, Mexico, New Zealand, and El Salvador to acquire information on geothermal projects and technological developments relevant to geothermal RD&D in the U. S.
- Prior to joining Radian, Mr. Conover performed consulting engineering to the U. S. Energy Research and Development Administration Office for Fossil Energy Development. In various senior project positions, Mr. Conover conferred with ERDA/FE to establish their annual plans for research and development as well as synthesizing and translating their RD&D requirements into procurements. In addition, Mr. Conover played a central role in formulating ERDA's plans for developing natural gas resources from the western tight gas sands and eastern gas shales.

EDUCATION

B. A., Physics, San Diego State University, 1963
Graduate Studies, University of California, San Diego,
California

R A D I A N C O R P O R A T I O N

KENNETH A. STROM

EDUCATION

Ph.D. - Inorganic Chemistry - University of California at Berkeley
Berkeley, California - 1972

B. A. - Chemistry - Central Washington State - 1967

EMPLOYMENT HISTORY

1981 - Present - Program Manager, Radian Corporation - Austin, Texas
1977 - 1981 - Manager, Environmental Sciences Department - LFE
Corporation, Environmental Analysis Laboratories
1973 - 1977 - Bechtel Corporation
1967 - 1972 - Research Assistant - Lawrence Berkeley Laboratory

EXPERIENCE

As a program manager on Radian's Operations Staff, Dr. Strom is responsible for managing and coordinating technical efforts with members of Radian's senior technical management staff; he oversees budget and scheduling, and provides technical guidance to the staff responsible for completing work efforts.

To assist the EPA in better delineating the potential of air pollution resulting from geothermal development, Dr. Strom managed a two-year study to determine the extent and variability of pollutant emissions from six geothermal resource areas in the Western United States, including East Mesa, Niland, and Raft River. During this effort, the relative amount and composition of the noncondensable gases in these areas were determined using a mobile laboratory and a portable separator/condenser system. Emissions of hydrogen sulfide, mercury, arsenic, and other possible pollutants were expressed relative to the expected thermal and electrical energy from the six reservoirs. The impact of these emissions on air quality and human health were evaluated. Emission control options were studied, and the results summarized in a separate report.

Dr. Strom also conducted a program for the Research Corporation of the University of Hawaii to continuously monitor hydrogen sulfide emissions from the Puna, Hawaii, wellhead generator feasibility project. This DOE-funded project is the first electrical generating plant using a hydrothermal/geothermal resource. Dr. Strom's involvement required procuring, installing, and operating the process monitoring and ambient air monitoring instruments and the data logging system. Weekly water and air samples were collected and analyzed on-site and in the laboratory for mercury, sulfur dioxide, carbon dioxide, trace elements, and radionuclides.

KENNETH A. STROM (Cont'd)

As a senior engineer at Bechtel Corporation, Dr. Strom specialized in the quantitative determination of the components of process streams and effluents of pollution control equipment and fossil fuel conversion processes. Experience included the design and specification of laboratory equipment and facilities and chemical analysis procedures for a flue gas scrubbing demonstration project in Louisville, Kentucky, for EPA, and a waste-to-oil conversion plant in Albany, Oregon, for ERDA. Dr. Strom also participated in a study to evaluate a pilot- and demonstration- scale SO₂ and particulate scrubber system for a utility company. He evaluated the performance of the system, predicted operating parameters, and determined emission rates and their acceptability with regard to local environmental regulations.

Dr. Strom developed methods and procedures for environmental monitoring, chemical analysis, and record keeping for an electric utility. He was project engineer for an SO₂ and boiler ash emission control pilot plant project. In this capacity, he supervised eight engineers, designed the test program, estimated costs, and procured equipment. Dr. Strom evaluated and selected process control instrumentation for monitoring pressure, temperature, and pH, and supervised the installation of the instruments.

PROFESSIONAL
ACTIVITIES

Engineer-in-Training, State of California
Member, Committee E-45, Geothermal Resources and Energy,
American Society for Testing and Materials

R A D I A N C O R P O R A T I O N

THOMAS W. GRIMSHAW

POSITION

Manager, Environmental Analysis Department

SPECIAL EXPERTISE

Environmental Analyses

PROFESSIONAL EXPERIENCE

Dr. Grimshaw has extensive experience in managing and contributing to environmental and permit acquisition programs. He is presently Project Coordinator for two programs for defining the regulatory and permit requirements for large coal conversion plants. These projects include site location efforts, environmental "fatal flaw" analyses, preparation of Regulatory Compliance Plans, and definition of field and laboratory programs for permit acquisition for the plants.

Dr. Grimshaw is Project Director for a large program for the Environmental Protection Agency to define existing EPA regulatory actions and permit granting procedures for major non-nuclear energy facilities and recently directed an audit of environmental health, and safety programs for an in situ oil shale retorting operation near Vernal, Utah.

Dr. Grimshaw also directed two programs in which Radian prepared input for environmental impact statements (EIS's) for municipal waste water management systems. In work done for the cities of San Antonio, Texas, and Greensboro, North Carolina, Dr. Grimshaw prepared a geologic characterization of the area in terms of physical properties significant to the 201 facilities; provided a soil map and interpreted soil units for their environmental significance to the facilities; and prepared a detailed description of potentially affected aquifers, their recharge zones, and their importance. He also participated in site-specific studies for alternatives considered in the EIS's and participated in public hearings for the proposed 201 facilities.

For a comprehensive environmental assessment of a proposed large lignite mine in Texas, Dr. Grimshaw prepared and conducted an aquifer test program. These efforts included design of the pump, wells and piezometers, layout of the well configuration in the field, oversight of well drilling operations, conduct of the two pump tests, and interpretation of the results in terms of the basic aquifer parameters. In another program related to this mine, Dr. Grimshaw was responsible for evaluating the potential effects on ground-water resulting from disposal of ash and FGD solids from a power plant by emplacement of the wastes in the mine.

THOMAS W. GRIMSHAW (Cont'd)

EDUCATION

Ph.D., Geology, University of Texas at Austin, 1976

M. A., Geology, University of Texas at Austin, 1970

B. S., Geology Engineering, South Dakota School of Mines and
Technology, 1967

AIPG

CERTIFICATION Professional Geologist 34425

Rogers

8.2

Geothermal Experience

Iceland - Krafla
Brawley
Hawaii
Philippines - Tiwi and Los Banos
The Geysers - Units 5 and 6
The Geysers - Units 7 and 8
Costa Rica - Miravalles
Iran
Turkey - Kizildere
Roosevelt Hot Springs
MagmaMax Power Plant

Rogers

PROJECT

Krafla Geothermal Project
Krafla Executive Committee
Appointed by the Iceland Government
Ministry of Industries
Akureyri, Iceland

Description

The Krafla Geothermal Electric Power Plant Project is the first commercial electric power plant in Iceland using geothermal fluids for the steam supply. A joint venture was formed between Rogers Engineering Co., Inc. and an Icelandic consulting engineering firm to provide the design, equipment and contractor procurement, construction management, and start-up services.

The process characteristics of the power plant are:

- Two 30 MW turbine generator units
- Double flash of geothermal fluid
- Two inlet steam pressures to turbine

Rogers' background of having already designed operating geothermal plants in the United States was helpful to the successful completion of the Krafla power plant. Rogers responsibilities for this project included development of the major power plant equipment specifications, bid evaluations and recommendations, process design, mechanical equipment layout and piping, instrumentation, electrical substation, station service and control supplies, assistance during construction for design interpretation, on site start-up engineers, and preparation of operations manuals.

The project was built on a very short schedule in spite of two national strikes, a volcanic eruption, and Icelandic winters. The project started in November 1974, and commercial power from the first unit came on line in February 1978.

The National Energy Authority (NEA) of Iceland undertook the drilling, steam procurement, and design and construction of the gathering system to the power plant building. The State Electric Power Works (RARIK) planned for, designed and built the power transmission lines to the substation.

**Construction
Cost**

\$30,000,000

Rogers

PROJECT:

BRAWLEY 10 MW GEOTHERMAL POWER PLANT
Imperial Valley, California
Southern California Edison Company
Rosemead, California

Description:

This geothermal power plant is a prototype 10 MW geothermal power plant designed to generate electric power on a commercial basis from the highly saline geothermal reservoir in the Imperial Valley in southern California. The steam supply to the plant is produced by Union Oil Company of California by flashing the hydrothermal resource in a proprietary process to provide steam of a quality acceptable for use in a conventional geothermal steam turbine. The electric power generated by the plant is marketed by the plant owner, Southern California Edison Company.

The power plant is a single nominal 10 MW turbine generator condensing unit having a single steam inlet and top exhaust to a grade level surface type condenser. Noncondensable gases contained in the steam are extracted from the main condenser by a first stage steam ejector condenser system followed by a second stage vacuum pump system discharging to atmosphere through vent silencers. All condensate generated by the plant is returned to the steam supplier. Cooling water make-up for main steam condenser and other auxiliary cooling requirements is supplied by the Imperial Irrigation District from selected locations in its irrigating canal system. Steam quality monitoring stations and revenue metering stations are provided to ensure steam supply contract compliance. Electric power generated by the plant is connected into the Imperial Irrigation Districts transmission system at the plant switchyard.

Services provided by Rogers Engineering for this plant included: critical path scheduling of all design and procurement activities; preparation of preliminary and final design, construction drawings and specifications for the complete power plant; and development of process plant layout and site preparation; buildings and structures for turbine-generator, control room, offices, laboratory and maintenance shop, tool room and spare parts storage; cooling tower; cooling water make up pipe lines and all on-site steam, condensate, cooling water, fire protection, drainage and utility piping; and electric switchyard. In addition, Rogers prepared the specifications for purchase of major equipment and all other Owner-furnished materials and equipment, and performed the complete procurement services including purchase order preparation, associated expediting, cost control scheduling and disbursement of funds to all contractors and suppliers.

Rogers

BRAWLEY 10 MW GEOTHERMAL POWER PLANT (Cont'd)

Rogers also initiated an operator training program and performed the start-up of the unit for turnover to the Client for commercial operation.

This project was designed, constructed and put in operation in a period of 23 months from date of authorization to proceed and is the first commercial electric power generation obtained from the extensive geothermal reservoir in the Imperial Valley.

Construction Cost: \$8,000,000 (rounded)

Rogers

PROJECT:

HGP-A Wellhead Generator Proof of Feasibility
The Research Corporation of the University of Hawaii

Description

The HGP-A Wellhead Generator Proof of Feasibility Project was established to demonstrate that a geothermal hydrothermal resource in Hawaii can be utilized to generate reliable electric power. The project utilizes an existing geothermal well in the Puna District on the Island of Hawaii.

The well has a nominal flow sufficient to supply a 3 MW plant which is the basis for the plant design. The plant includes a unique H₂S abatement system for control of the H₂S emissions content in the noncondensable gases. The turbine-generator unit features a single pressure, single flow condensing turbine. Construction has now been completed and start up tests are now underway.

Rogers' responsibilities for this project include preliminary design; preparation of major power plant equipment specifications, bid evaluations and recommended manufacturer; process design; mechanical equipment layout and piping; all electrical systems design for substation, station service and control supplies; preparation of construction contract documents, bid solicitation and recommendations for contract award; construction surveillance services; on site start-up engineering services, preparation of operations manuals; and a training program for operating personnel. The consulting engineering services for the site development and civil/structural design were provided by a local Hawaiian firm under subcontract to Rogers.

Construction Cost: \$7,500,000

Rogers

Project

Preliminary Design of Philippines Geothermal Power Plants
Tiwi and Los Banos, Philippines
National Power Corporation
Manila, Republic of Philippines

Description

Rogers Engineering completed the preliminary design, construction cost estimate, and economic analysis for two 100 MWe electric power plants in the Philippines, one at Tiwi and the other at Los Banos. Each 100 MWe plant consisted of two 50 MWe units, powered by geothermal steam obtained from hot water wells. A double-flash system design was used with dual entry turbines. Final design and construction were completed by Mitsubishi Heavy Industries.

**Construction
Cost**

U. S. \$66,000,000

Rogers

PROJECT

The Geysers Geothermal Project - Units 5 and 6
The Geysers, Sonoma County, California
Pacific Gas and Electric Company
San Francisco, California

Description

Rogers Engineering Co., Inc. was retained to provide the architectural, civil, structural, design and construction drawings for the geothermal power plant known as "Units 5 and 6." In addition, we provided for this project the mechanical and electrical design drawings relating to the power plant building facilities.

The work performed by Rogers Engineering was basically a support service to the Engineering Department of Pacific Gas and Electric Company, and was originated in view of the large design load of the power company and the short time requirements for producing the construction and bid documents for this project.

The project involved development of complete construction drawings, survey data reduction, project control, design of structural elements, as well as architectural requirements for the building. The site grading for this project was of major importance due to the location of this plant on what had been a mountainous ridge which had to be graded level so that there was sufficient room, not only for the power plant and its cooling tower basin, but also an access road.

This plant, at the time of its design, was the largest geothermal plant to be designed and built, in the world, and was the predecessor for Units 7 and 8, and 9 and 10, which have been subsequently designed and built.

Construction Cost \$12,000,000

Rogers

PROJECT

The Geysers Geothermal Project - Units 7 and 8
The Geysers, Sonoma County, California
Pacific Gas and Electric Company
San Francisco, California

Description

Units 7 and 8 generate a gross electric power of 110 megawatts. This plant is one of the largest geothermal generating plants in the world.

Rogers Engineering Company, Inc. was retained to provide the complete design for the construction and installation of the two 55 MW units (Units 7 and 8). Some of the specific elements performed by Rogers Engineering included: site studies and final siting of the powerhouse, cooling tower, step-up transformer substation and other site related equipment based on economic earthwork analysis, optimum access approach analyses and topography data obtained from the site; preparation of design and construction drawings and specifications for: all foundations, structures, powerhouse building, cooling tower basin and equipment foundations and supports; piping systems for steam, cooling water, lubrication, fire protection, etc., including thermal and seismic piping stress analysis and location and design of required system anchors and restraints; complete interior and exterior electrical power distribution, supervisory control and lighting systems, building mechanical systems; and general plant instrumentation and control systems including interfacing with vendor supplied control packages.

After construction contracts were awarded, Rogers provided consulting services in interpretation of plans and preparation of field sketches required to accommodate to field conditions, reviewed and evaluated Contractor- and Owner-generated construction change orders to provide the client with construction cost control.

Construction Cost \$12,000,000

Rogers

PROJECT

Miravalles Geothermal Project
Guanacaste Province, Costa Rica, Central America
Instituto Costarricense de Electricidad (ICE)
San Jose, Costa Rica

Description

The Miravalles Project consisted of the first three phases of geothermal development directed at installing the first geothermal electric power plant in Costa Rica. The project included an evaluation of all scientific data on geothermal resources collected by ICE in the Pailas-Hornillas Zone of the Cordillera Volcanica de Guanacaste, which is in the Northwestern part of Costa Rica, not far from the border of Nicaragua. This zone has active surface manifestations which indicate a prime geothermal resource. Following the data evaluation, geologic and geophysical surveys were conducted by ICE with Rogers' assistance, with the objective of locating the sites for exploratory wells to be drilled in the next phase of work. The second phase of the project was the drilling and testing of three production sized exploratory wells, and the reservoir assessment. The third phase was a feasibility study for the installation of a geothermal electric power plant.

As managers of this project, Rogers engaged specialists to assist in implementing the first-phase exploration effort in geology, geophysics, geohydrology and geochemistry. All work was accomplished by combining the efforts of Rogers, the geotechnical consultants and ICE's own scientists. A prefeasibility report that designated the optimum test well sites concluded this phase.

During the second or test well drilling phase, Rogers provided detailed consultation on design of drill sites, drilling specifications, solicitation and award of drilling contract, purchase of materials, and during actual drilling, furnished a resident drilling supervisor. Three successful hydrothermal wells were drilled out of three sites tested. Rogers designed and purchased a custom steam separator well test system, then provided a resident well test engineer to supervise testing of the wells. A reservoir assessment of available steam reserves concluded the second phase.

The feasibility study (third phase) included: (1) analysis of the chemical and thermodynamic characteristics of the geothermal resource; (2) preliminary design and cost estimate of the power generation equipment, power plant building geothermal well field, steam gathering system, waste fluid reinjection system and power distribution system; (3) projection of Costa Rica's power demand growth; and (4) economic analysis of the optimum rate of integration of geothermal power development with future hydro power development potential.

Rogers

Project	Iranian Geothermal Study Northwestern Iran - Sabalan, Sahand, Damavand, Khoy, Maku Ministry of Energy Imperial Government of Iran
Description	Rogers Engineering and GeothermEx Company conducted a resource exploration program including geological, geohydrological and geochemical studies. The project was intended to proceed through drilling and testing exploratory wells, reservoir assessment, feasibility studies, and design and construction of a power plant. Project operations were suspended as of May, 1979 due to internal problems in the country.
Construction Cost	Not Available

Rogers

PROJECT

**Kizildere Geothermal Power Plant Feasibility
Menderes River Valley, Western Anatolia, Turkey
United Nations Development Programme (Special Fund)**

Description

The United Nations Development Programme (Special Fund) has agreed to assist the Turkish government, in a survey of the geothermal energy potential in West Anatolia. Jointly with the staff of Maden Tetkik ve Arama Enstitüsü they have developed the Kizildere Field in the Menderes River valley, which has proved to be a significant geothermal area. Currently, the wells installed and tested are capable of flash flowing sufficient hot water to generate about 30 MW of electric power

Rogers' project scope included a feasibility study on generation of electricity, technical field assistance with well testing programs, and evaluation of test results.

Analysis and evaluation of well tests and geothermal hot water chemical composition brought about normal geothermal technical considerations which were developed: calcite deposition, well plugging, hot water flashing and hot water disposal.

Two geothermal alternatives were studied: a flashed steam system and a closed geothermal cycle (binary cycle generation). Consideration was given to the environment and the geothermal characteristics in the recommendation of a binary cycle for this project.

Rogers prepared complete plot plans, process flow diagrams, electrical single line diagrams, and architectural rendering of the completed plan. Preparation of capital costs, operating and maintenance cost was made to evaluate alternatives. An economic analysis was provided which from capital and operating costs showed its benefit/cost ratios in relation to generation costs from conventional power generating facilities.

The feasibility study report depicted the technical facets of the consideration as well as a summary and recommendation.

Construction Cost - Subject to approval of client

Rogers

Project	50 MWe Geothermal Power Plant Roosevelt Hot Springs Milford, Utah Utah Power and Light Company
Description	Rogers Engineering conducted power plant optimization studies based upon known resource characteristics to develop a preliminary design of the power plant. Cost comparisons were made with other types of electric generation plants.
Construction Cost	Not Available

Rogers

PROJECT

Magmamax Power Plant Feasibility Study
Magma Energy, Inc.
Los Angeles, California

Description

This project involved a comprehensive engineering study and the development of a preliminary design, complete with a construction cost estimate and economic analysis for a nominal 10 MW prototype electric generating plant, utilizing a geothermal energy source through a binary heat exchange cycle. The initial design concept was performed by J. Hilbert Anderson for Magma Energy, Inc., and essentially considers a dual heat cycle employing isobutane as the working fluid, utilizing heat from pumped hot geothermal well water through a heat exchange system.

Services provided included materials selection based on field test data, heat balance calculations, complete preliminary plant design, development of equipment purchase specifications, and economic evaluation for feasibility analysis.

Construction Cost - Subject to approval of client