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ERDA-76/53/1

Geothermal Project Summaries

Geothermal Energy Research, Development and Demonstration Program

Energy Research & Development Administration
Division of Geothermal Enermal Energy
Washington, D.C. 20545

Replaces ERDA 76-53 in its entirety

SEPT 1976

DISCLAIMER

ERDA-76/53/1

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PREFACE

The Division of Geothermal Energy "Geothermal Project Summaries" provides pertinent information on each active ERDA Geothermal project, includes a listing of all contractors and a compilation of completed projects. New project summaries and necessary revisions to current project data will be prepared on a semiannual basis. A revised report will be issued annually.

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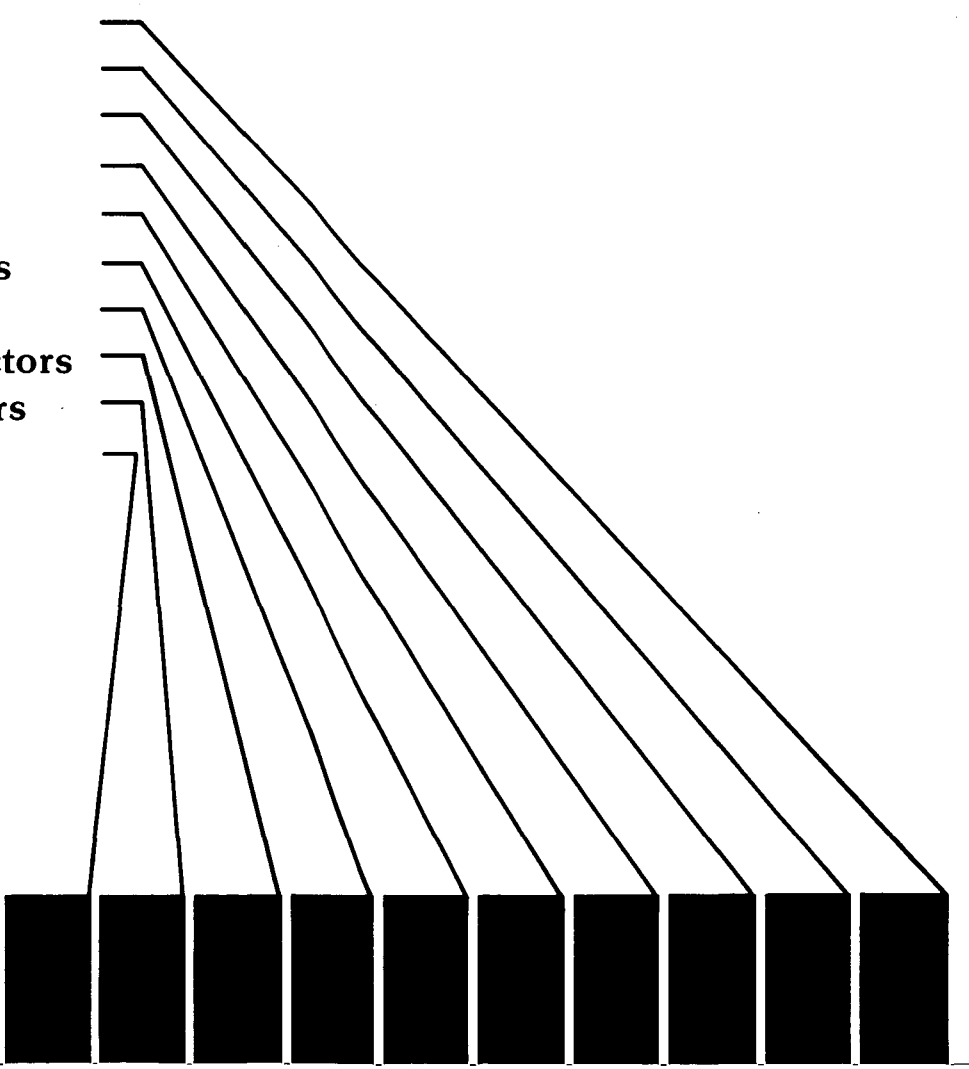


INTRODUCTION

This report, ERDA-76/53/1, replaces ERDA 76-53 in its entirety. As the report number indicates, this is the first 1976 revision to ERDA 76-53, the Division of Geothermal Energy (DGE) "Geothermal Project Summaries" issued in April 1976. The date of original issue or latest revision is identified on each page.

"Geothermal Project Summaries" makes available a compilation of all DGE supported projects for which contracts have been executed. Subcontracts and support contracts are generally included in the summary for the primary contract. All funding data are presented in the fiscal year(s) during in which the funds were obligated. Each summary includes pertinent statistical data for that project and an abstract, prepared by the appropriate Program Manager, summarizing the project plans and accomplishments.

It should be noted that each ERDA laboratory operates under a unique contract number. Thus all projects performed by that laboratory will carry the same contract number. These are identified in Appendix B.1. In addition, since the ERDA laboratories are funded each fiscal year, the Contract Terms indicated in the Project Summaries for the ERDA laboratories do not extend beyond FY 1977.

The projects summarized in this report fall into six categories: engineering research and development, resource exploration and assessment, hydrothermal technology applications, advanced technology applications, utilization experiments, and environmental control and institutional studies. All active contracts in a given category are listed at the beginning of that chapter. Completed projects are compiled in Appendix A. The listing of contractors presented in Appendix B identifies all projects pursued by each organization while Appendix C identifies those projects in which each principal investigator is engaged. Projects are listed by state in Appendix D.

Engineering Research and Development

1.0 ENGINEERING RESEARCH AND DEVELOPMENT

The objective of the Engineering Research and Development subprogram is to bring the technologies required for geothermal development to the point of readiness for practical application, thereby establishing the technical foundation for growth and development of the geothermal industry. Research and development projects will be carried out at ERDA laboratories, universities, and industrial facilities. Drilling technology development, to improve the efficiency and reduce the cost of drilling for geothermal resources, will stress high temperature drill bits, downhole replaceable drill-bit cutting surfaces and other novel drilling techniques such as explosive and spark drilling. In addition, jet drilling techniques will be refined for application to deep holes. Utilization technology projects will address development of: materials to perform in high temperature, corrosive environments; scaling and corrosion control techniques; direct-contact and other types of heat exchangers; total-flow power conversion systems; energy extraction technology; and reservoir stimulation techniques.

1.0 ENGINEERING RESEARCH AND DEVELOPMENT

Active Contracts

Project Title: Replaceable Cutting Surface Drill Bits

Contract No: E(29-1)-0789

Contractor: Sandia Laboratories
Albuquerque, New Mexico

Principal Investigators: E. W. Reece
(505) 264-4911
FTS 475-4911

C. W. Young
(505) 264-7783
FTS 475-7783

Program Manager: Clifton Carwile
(202) 376-4912
FTS 376-4912

Project Objective: To investigate the feasibility of a type of long-life drill bit.

Funding: FY 75 - $300K
FY 76/TQ - $458K

Contract Term: 7/1/74-9/30/77

Reports Issued: Melvin M. Newsom, "Drilling Research at Sandia Laboratories," SAND-76-5194 (March 1976)

Project Title: Replaceable Cutting Surface Drill Bits

Contract No: E(29-1)-0789

SUMMARY

This program investigates the feasibility of drill bits, usable on existing deep-well rotary drilling platforms, which would increase downhole life by providing an increase in the rock-cutting surface available. The drill bits would use a continuous belt of cutting surface, rotated into the bottom of the hole as necessary to maintain an effective cutting surface, and a more conventional roller cone bit that can be replaced downhole. The existing rotary turntable would rotate the drill stem and drill, while the drilling fluid would rotate the chain or sequence the cone replacement mechanism, thus eliminating the need for special drill-stem or additional downhole power.

Two types of drill bits will be designed: a continuous chain, diamond drag bit 4.75 inches in diameter for drilling hard rock formations; and a downhole changeable roller cone bit 8.0 inches in diameter for drilling softer formations. The driving mechanisms, load-bearing technique (supporting drilling loads on sprocket hubs) and fluid passages will be similar for both bits.

The length of the continuous-belt drills is variable up to 60 feet or more. Assuming a 30-foot length, the diamond drag bit could have approximately 1000 square inches of cutting surface, as compared to 20 square inches for conventional diamond bits. A roller cone bit of the same length could contain 3200 square inches of cutting surface, compared to 100 square inches in an existing roller bit of comparable diameter.

A working mechanical model of each bit will be developed to demonstrate this drilling technique in the laboratory, and working prototypes will be built to demonstrate the system potential with an existing rotary rig in the field.

Four low-cost prototypes of this continuous chain drill bit were fabricated and tested for drilling ability. These tests demonstrated significant improvement in instantaneous penetration rate in hard rock.

A prototype downhole changeable bit was tested in a drilling simulator. Due to the severe space limitations imposed by the design the journal bearings and cones were approximately one-half the diameter of comparable size tricone bits. The journals suffered structural failure at 40,000 pound total load. A bit redesign incorporating Compax elements is being considered.

Project Title: Drilling Research and Development on the Electrical Detonation and Subsequent Cavitation in a Liquid (Spark Drilling) Technique

Contract No: E(29-1)-0789

Contractor: Sandia Laboratories
Albuquerque, New Mexico

Principal Investigator: Melvin M. Newsom
(505) 264-8920
FTS 475-8920

Program Manager: Clifton Carwile
(202) 376-4912
FTS 376-4912

Project Objective: To develop and demonstrate a long life, high penetration rate drilling system based on spark drilling.

Funding: FY 75 - $157K
FY 76/TQ - $610K

Contract Term: 7/1/74-9/30/77

Reports Issued: R. J. Lawrence and E. G. Young, "Numerical Analysis of Spark Drill Phenomenology," Sandia Laboratories report SAND-75-0501 (October 1975)

Melvin M. Newsom, "Drilling Research at Sandia Laboratories," SAND-76-5194

Project Title: Drilling Research and Development on the Electrical Detonation and Subsequent Cavitation in a Liquid (Spark Drilling) Technique

Contract No: E(29-1)-0789

SUMMARY

The primary objective of the spark drilling program is to develop and demonstrate a long life, high penetration rate drilling system that is compatible with existing drilling rigs and which can be adapted to highly mobile special purpose rigs.

The proposed research will determine the feasibility of using an electrical discharge in a fluid for drilling. Specifically, spark drilling for exploration and development of geothermal reserves will be investigated, although the information developed in this investigation will have application to all types of drilling.

In determining the applicability of spark drilling, several fundamental questions must be answered. The first relates to the rock fracture mechanism. The two prime mechanisms believed responsible for fracture are the initial shock wave generated soon after the electrical breakdown and the cavitational collapse of the bubble generated by the spark. An electrical discharge in a liquid creates a pressure pulse with a shock front. This pressure pulse will be measured and characterized to evaluate its potential for failing rock using recently developed techniques. These experiments will also characterize the pressure wave at high hydrostatic pressures. The pressure pulse is formed by an expanding plasma channel which grows into a low pressure vapor bubble that collapses, causing a high pressure jet to be formed. This cavitating action gives an additional mechanism for comminution, but the destructive potential of this process under high pressures is unknown. The prime rock failure mode must also be identified so that optimization to maximize the effect can be accomplished.

Shock wave pressure magnitudes have been experimentally determined by photographic streak records and direct near field pressure measurements using a newly developed lithium-niobate transducer. This represents the first reported near field pressure measurement near an arc in water. One and two-dimensional hydrodynamic analyses have been completed based on these measurements.

Laboratory spark drilling experiments have been conducted on limestone, sandstone, granite, and diorite. Bit lifetime was on the order of minutes and additional work is required in this area.

Project Title:	Drilling Research on the Terra-Drill Technique
Contract No:	E(29-1)-0789
Contractor:	Sandia Laboratories Albuquerque, New Mexico
Principal Investigators:	E. W. Reece (505) 264-4911 FTS 475-4911
	C. W. Young (505) 264-7783 FTS 475-7783
Program Manager:	Clifton Carwile (202) 376-4912 FTS 376-4912
Project Objective:	To demonstrate the feasibility of and establish the economic tradeoffs of a Terra-Rock Drill system.
Funding:	FY 75 - $ 25K FY 76/TQ - $310K
Contract Term:	7/1/74-9/30/77
Reports Issued:	Melvin M. Newsom, "Drilling Research at Sandia Laboratories," SAND-76-5194 (March 1976)

Project Title: Drilling Research on the Terra-Drill Technique

Contract No: E(29-1)-0789

SUMMARY

The Terra-Drill combines the technology of terradynamics with that of the rotary rock bit. The goal of this project is to demonstrate the feasibility of and establish the economic tradeoffs of a Terra-Rock Drill System. This requires an understanding of small projectile penetration of rocks, projectile material selection for penetration and disintegration, high temperature projectile launcher propellant, and autolaunch and reload system development. Initial effort will be directed at air drilling, since use of this drilling fluid presents the least number of problems in launcher design.

As a projectile penetrates a rock it creates many fractures which in turn weaken, if not comminute, the rock. The Terra-Drill is based on the supposition that highly fractured rock can be drilled more easily than unfractured, homogeneous hard rock. Therefore, the Terra-Drill projectile penetrates and weakens the rock ahead of the bit and the rock bit cuts the hole to gauge with a higher penetration rate and longer bit life.

The Terra-Drill requires an automated projectile launcher system consisting of from one to three launchers with a magazine for projectile storage. Preliminary predictions indicate that approximately 500 lbs (240 kg) of projectiles would be required to penetrate 5,000 ft of hard rock. Bit weight is not a problem, since large static loads are required for a rock bit to drill satisfactorily.

In order to test the basic concept, an in-situ drilling test in a Madera limestone formation was designed and conducted. A three barrel gun assembly was lowered into a drill hole and the projectiles fired. The assembly was then removed from the hole and a rotary bit and stem put in. Drilling then proceeded for a distance of six inches. The drilling rate was improved by a factor of two over straight rotary drilling.

Project Title: Investigation for Innovative Diamond Compax Material in Geothermal Drill Bit Development

Contract No: E(49-18)-2360

Contractor: General Electric Company
Schenectady, New York

Principal Investigator: L. E. Hibbs, Jr.
(518) 385-8330

Program Manager: Clifton Carwile
(202) 376-4912
FTS 376-4912

Project Objective: Development of new type of drill bit designs that will permit increased penetration rates and longer bit life, utilizing high pressure sintered polycrystalline diamond compacts for the cutting edges.

Funding: FY 75 - --
FY 76/TQ - $272K

Contract Term: 6/30/76-6/30/77

Reports Issued: None

Project Title: Investigation for Innovative Diamond Compax Material in Geothermal Drill Bit Development

Contract No: E(49-18)-2360

SUMMARY

Under this project the General Electric Company will investigate the utilization of its diamond Compax material in a new and improved rock drill bit design. The bit design will be compatible with existing rotary drilling methods. It is expected that the new bits will have longer life and higher penetration rates compared to conventional types of bits in a wide range of rock formations under geothermal conditions.

The program includes laboratory testing of diamond compacts for cutter wear rates, failure mode analysis, shear and ultimate strength and impact at elevated temperature; design and fabrication of a Compax drill bit for instrumental laboratory testing; field testing; and an economic analysis of the improved bit utilization.

Project Title:	Geothermal Down-well Instrumentation (Pumping)
Contract No:	E(11-1)-2750
Contractor:	Sperry Research Center Sudbury, Massachusetts
Principal Investigator:	Warren D. McBee (617) 369-4000
Program Manager:	Clifton Carwile (202) 376-4912 FTS 376-4912
Project Objective:	To develop and demonstrate a downhole data transmission system for use during pumping operations.
Funding:	FY 75 - $ 67K FY 76/TQ - $182K
Contract Term:	6/20/75-9/30/76
Reports Issued:	None

Project Title: Geothermal Down-well Instrumentation (Pumping)

Contract No: E(11-1)-2750

SUMMARY

The objective of this project is to develop and demonstrate a wireless system for transmitting data to the surface from downhole in a geothermal well during pumping. The primary approach is to use acoustic transmission up piping strings and to generate signaling power from energy sources normally present downhole. The proposed plan includes field measurement of the acoustic noise spectra present in the field situation; analysis of existing energy sources and acoustic channels; and development, lab testing and field feasibility demonstrations of the necessary signal generation, data transmission, and signal processing systems. The field demonstrations will be performed in conjunction with field tests of the geothermal down-well pump being developed by Sperry under contract number E(11-1)-2838 and reported in Section 1.2.5. Several types of electromagnetic transmission systems will also be investigated as a back-up method.

For geothermal pumping, the end result will be data on the pump inlet and outlet pressures, pump speed, and brine temperature, all transmitted from pump to surface during operation. The system will use a pump-driven alternator for signal power, a downhole high-temperature electronics package, and acoustic (or, as back-up, electromagnetic) data transmission to the surface on pump piping. In addition to being a feasibility demonstration of pumping instrumentation, this effort will develop new and needed information on high-temperature electronics, transducers and acoustic (or electromagnetic) downhole-to-surface signal channels.

Project Title: Acoustical Drill Monitor

Contract No: E(11-1)-2817

Contractor: Sperry Research Center
Sudbury, Massachusetts

Principal Investigator: Warren D. McBee
(617) 369-4000

Program Manager: Clifton Carwile
(202) 376-4912
FTS 376-4912

Project Objective: To develop and demonstrate a downhole data transmission system for use during drilling operations.

Funding: FY 75 - --
FY 76/TQ - $323K

Contract Term: 12/1/75-11/30/76

Reports Issued: None

Project Title: Acoustical Drill Monitor

Contract No: E(11-1)-2817

SUMMARY

This project complements and extends development of the acoustic downhole data transmission system for pumping operations (by Sperry under contract number E(11-1)-2750 and reported in Section 1.1) to the severe environments experienced during drilling.

Activities on the project encompass the following tasks:

1. Measurement of the background noise on the drill string at the surface under a variety of drilling conditions.
2. Measurement of transmission losses on the drill string from the bit to the surface during a variety of operations.
3. Use of the data from 1. and 2. to specify the signaling method, signal design and signal processing requirements.
4. Study of approaches to signal power generation downhole during drilling.
5. Trade-off study and design recommendations for a drilling telemetry system.

Follow-up work will include detailed design, fabrication and feasibility demonstration of the drilling telemetry system.

Project Title: To Design and Experimentally Test an Improved Geothermal Drill Bit

Contract No: E(10-1)-1546

Contractor: Terra Tek, Inc.
Salt Lake City, Utah

Principal Investigator: Sidney J. Green
(801) 582-2220

Program Manager: Clifton Carwile
(202) 376-4912
FTS 376-4912

Project Objective: To design and experimentally test an improved geothermal rotary drill bit capable of operating in hard, abrasive rock at high temperatures.

Funding: FY 75 - $358K
FY 76/TQ - $359K

Contract Term: 5/16/75-5/26/77

Reports Issued: L. M. Barker, S. J. Green, and W. C. Maurer, "Semi-Annual Report on the Project to Design and Experimentally Test an Improved Geothermal Drill Bit," Terra Tek report TR 76-3 (January 1976)

William C. Maurer, "Topical Report - Patent Search and Review on Roller-Bit Bearings, Seals, and Lubrication Systems," Terra Tek report TR 75-55 (October 14, 1975)

H. R. Pratt and E. R. Simonson, "Geotechnical Studies of Geothermal Reservoirs," Terra Tek report TR 76-2 (January 1976)

William J. McDonald, "Topical Report - Steady-State and Transient Wellbore Temperatures During Drilling," Terra Tek report TR 76-11 (May 20, 1976)

L. M. Barker, et al, "Annual Report on the Project to Design and Experimentally Test an Improved Geothermal Drill Bit," Terra Tek Report TR 76-32 (June 1976)

Project Title: To Design and Experimentally Test an Improved Geothermal Drill Bit

Contract No: E(10-1)-1546

SUMMARY

In this program an improved geothermal rotary drill bit will be designed and experimentally tested.

This program presents a three phase approach. Phase I includes analysis and laboratory tests to determine drill-bit conditions during drilling, current modes and causes of failure, and improved bearing life at high temperatures. In phase II improved cutting structures will be designed and tested including full-scale, fully simulated laboratory tests to adequately qualify the improved bit. Phase III includes full-scale field tests, with the added objective of providing industry the technical background to pick up the bulk of the program at this stage.

Currently geothermal wells are drilled with oil and gas rotary bits which are not suited to drilling geothermal wells because of (a) the hard, abrasive and fractured rock encountered, and (b) the high temperatures encountered. Friction bearing seals will not stand up to temperatures above 300-400°F, and hence unlubricated roller bits are generally used; however, the current bit steels anneal substantially at even 400-600°F and therefore, give low bearing fatigue life. The cutting structure and bit core, which carry the high impact load during drillings, correspondingly anneal and degrade at elevated temperatures also.

Examination and testing of worn drill bits has shown that a major part of the problem can be attributed to the decrease in hardness of bearing surfaces as a result of annealing in the high temperature environment (the Geysers).

Project Title: To Develop Improved Downhole Drilling Motors for Deep Well Drilling at High Temperatures

Contract No: E(10-1)-1581

Contractor: Terra Tek, Inc.
Salt Lake City, Utah

Principal Investigator: Sidney J. Green
(801) 582-2220

Program Manager: Clifton Carwile
(202) 376-4912
FTS 376-4912

Project Objective: To improve downhole drilling motors for operation above 450°F in deep well drilling.

Funding: FY 75 - --
FY 76/TQ - $504K

Contract Term: 3/1/76-3/31/77

Reports Issued: None

Project Title: To Develop Improved Downhole Drilling Motors for Deep Well Drilling at High Temperatures

Contract No: E(10-1)-1581

SUMMARY

The specific objective of this project is to solve the high temperature seal, bearing and lubrication problems of current downhole drilling motors. Innovative drilling motor concepts will also be considered.

Project Title:	Waterjet Coring for Geothermal Exploration
Contract No:	E(45-1)-2325
Contractor:	Flow Research, Inc. Kent, Washington
Principal Investigator:	John B. Cheung (206) 854-1370
Program Manager:	Clifton Carwile (202) 376-4912 FTS 376-4912
Project Objective:	To study the feasibility of high pressure (30,000 to 60,000 psi) waterjet coring for geothermal exploration.
Funding:	FY 75 - -- FY 76/TQ - $163K
Contract Term:	2/2/76-5/2/77
Reports Issued:	None

Project Title: Waterjet Coring for Geothermal Exploration

Contract No: E(45-1)-2325

SUMMARY

The objective of this project is to study the feasibility of high pressure (30,000 to 60,000 psi) waterjet coring for geothermal exploration. The program includes the design, fabrication, and testing of a waterjet coring device applicable to coring in deep, hot granitic and basaltic rocks. Limited waterjet cutting experiments on rocks at elevated temperatures and under confining pressures will be conducted to provide currently unavailable data for the design of a waterjet coring device.

During the initial phase of the contract Flow Research conducted a technical feasibility study of the required system components and the suitability of available swivels, drilling stems, etc., for the high hydraulic pressures required. The results of this initial study of a field system will provide input to the design of the waterjet coring device and the testing program.

1.1 Drilling Technology

Project Title: Electromagnetic Lithospheric Information System for Geothermal Drilling

Contract No: E(11-1)-2816

Contractor: Raytheon Company
Sudbury, Massachusetts

Principal Investigator: Myer Kolker
(617) 443-9521

Program Manager: Clifton Carwile
(202) 376-4912
FTS 376-4912

Project Objective: To determine the feasibility and cost effectiveness for an electromagnetic system to telemeter data to the surface from a drill bit operating in a hot (up to 75°C) geothermal borehole.

Funding: FY 75 - --
FY 76/TQ - $136K

Contract Term: 6/1/76-6/30/77

Reports Issued: None

Project Title: Electromagnetic Lithospheric Information System for Geothermal Drilling

Contract No: E(11-1)-2816

SUMMARY

The system will operate at ELF (about 30Hz) and will utilize repeaters at 3,000 foot intervals along the drill string. Typical multiplexed data include pressure, temperature, bit weight, torque, mud resistivity, inclination, bit bearing conditions, accelerations and "red flag" alarm code for potential blow outs. The program will define the design, manufacturing and operating costs, and trade the cost impact against the savings in drilling time and expense.

Project Title:	Research and Development of Cavitation Descaling Techniques for Heat Exchanger Tubes Used in Geothermal Energy Plants
Contract No:	E(49-18)-2289
Contractor:	Daedalean Associates, Inc. Woodbine, Maryland
Principal Investigators:	A. A. Hochrein, Jr. (301) 442-2620
	A. P. Thiruvengadam (301) 442-2620
Program Manager:	Clifton Carwile (202) 376-4912 FTS 376-4912
Project Objective:	The overall objective of this research program is to develop an improved descaling technique using cavitating hydrojets.
Funding:	FY 75 - -- FY 76/TQ - $ 98K
Contract Term:	2/27/76-2/26/77
Reports Issued:	None

Project Title: Research and Development of Cavitation Descaling Techniques for Heat Exchanger Tubes Used in Geothermal Energy Plants

Contract No: E(49-18)-2289

SUMMARY

Under this contract Daedalean Associates will design, procure, and assemble a test apparatus for conducting the experimental studies. This will incorporate a piston pump capable of developing 10,000 psi output pressure. Using the experimental apparatus, the cleaning rate on various scale filled pipes will be determined as a function of a range of nozzle and jet parameters.

Using the experimental results a design specification for a cavitating hydrojet descaling system for heat exchanger tube cleaning will be developed.

Project Title: The Design of a Water Jet Drill for Development of Geothermal Resources

Contract No: E(11-1)-2677

Contractor: University of Missouri
Rolla, Missouri

Principal Investigator: David A. Summers
(314) 341-4365

Program Manager: Clifton Carwile
(202) 376-4912
FTS 376-4912

Project Objective: To determine the effects of jet pressure, fluid additives and cavitation bubbles on water jet performance, and to demonstrate the applicability of a design concept.

Funding: FY 75 - $152K
FY 76/TQ - $155K

Contract Term: 6/1/75-5/31/77

Reports Issued: "Proceedings of the Workshop on the Application of High Pressure Water Jet Cutting Technology," University of Missouri, Rolla Missouri, November 10-11, 1975, David A. Summers and Dwight J. Bushnell, editors, prepared under NSF grant number APR-76 00738

David A. Summers and Dwight J. Bushnell, "The Design of a Water Jet Drill for Development of Geothermal Resources - Progress Report for Period June 1, 1975 - June 1, 1976," Report No. COO-2677-2 (June 1976)

Project Title: The Design of a Water Jet Drill for Development of Geothermal Resources

Contract No: E(11-1)-2677

SUMMARY

The use of water jets to cut material has been investigated with increasing interest over the past ten years. The advantages of the water jet as a cutting tool are as follows: (a) a high level of energy can be transmitted through the jet to the cutting surface, with little disturbance of the rock outside the area of impact; (b) no resharpening is required; (c) the liquid used is already in use in boreholes as a means of rock removal; (d) the cutting head requires less thrust to keep it effectively cutting than is required with conventional equipment; and (e) the drilling stem does not need to be removed from the hole to replace the drilling head as frequently, thus saving both time and money.

A new water jet drilling device has been designed to carry out experiments to determine the optimum design characteristics and to obtain a measure of the potential performance in drilling rock.

The program is divided into five phases:

1. The effect of increasing jet pressure on drilling rate, under varying rock and borehole fluid pressure.

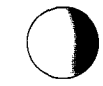
2. The effect of additives on jet cutting performance.

3. The effect of the introduction of cavitation bubbles into the jet stream on drilling rate.

4. An evaluation of the potential performance of a new design of nozzle drilling bit.

5. A field demonstration of the applicability of the design.

Tests have been performed to ascertain an optimum nozzle design. Using this optimum design, drilling rates in sandstone using water at 25,000 psi have approached 280 in/min. Initial tests using cavitation to attack quartz crystals have shown that the collapsing bubble does produce micropits and fracture cavities.



Project Title:	Computer Modeling of Geothermal Energy Extraction Systems
Contract No:	W-7405-ENG-36
Contractor:	Los Alamos Scientific Laboratory Los Alamos, New Mexico
Principal Investigator:	R. C. Feber (505) 667-4181 FTS 843-4181
Program Manager:	Robert R. Reeber (202) 376-4912 FTS 376-4912
Project Objective:	To develop a semi-empirical computer code for predicting the specific solids, and their mass transfer and precipitation characteristics, in geothermal utilization systems.
Funding:	FY 75 - -- FY 76/TQ - $22K
Contract Term:	6/1/76-9/30/77
Reports Issued:	None

Project Title: Computer Modeling of Geothermal Energy Extraction Systems

Contract No: W-7405-ENG-36

SUMMARY

Two first generation computer codes will be written to predict the amounts and identities of solids which can precipitate in geothermal energy extraction systems. These, an engineering model of a heat exchanger loop and a complex chemical equilibrium code, will be combined, elaborated and modified as required by a continuing coordination and comparison of code predictions with available data from differently scaled experimental geothermal systems in the ERDA program. The results will be initially directed at modeling synthetic brine analogs of natural brine systems. They will serve as input to GEOCOST (an economic analysis model developed by Battelle Pacific Northwest Laboratory and reported in section 6.2), and other economic analyses of natural brine geothermal systems. As these problems reach utilization, emphasis is expected to shift to modeling other geothermal systems.

1.2.1 Material Development and Corrosion Studies

Project Title: Alternate Materials of Construction for Geothermal Applications

Contract No: E(30-1)-0016

Contractor: Brookhaven National Laboratory
Upton, New York

Principal Investigators: M. Steinberg
(516) 345-2123, Ext. 3036
FTS 664-3036

L. E. Kukacka
(516) 345-2123, Ext. 3065
FTS 664-3065

Program Manager: Robert R. Reeber
(202) 376-4912
FTS 376-4912

Project Objective: To test several energy-related applications of concrete polymer materials as potential solution of corrosion problems.

Funding: FY 75 - $ 99K
FY 76/TQ - $190K

Contract Term: 7/1/74-9/30/77

Reports Issued: M. Steinberg, "Concrete-Polymer Composite Materials Development." Proc. of Third Inter-Amer. Conf. on Materials Tech., Rio de Janeiro, Aug. 1972, H. H. Frye and C. J. McHargue, Editors, pp. 555-9.

Project Title: Alternate Materials of Construction for Geothermal Applications

Contract No: E(30-1)-0016

SUMMARY

The concrete-polymer composite materials developed at BNL and funded by the Office of Saline Water also appear to offer an economical approach to the problem of handling hot geothermal brines.

Laboratory formulation studies, long term durability tests, and limited field tests have been made over several years for materials to withstand brine at temperatures up to 175°C (350°F).

The program tasks are listed below:

Task 1 -- Selection of Lining Materials: A survey will be performed to develop polymer-aggregate systems that can withstand temperatures up to 300°C. Initial work will be with highly crosslinked styrene and acrylate systems.

Task 2 -- Process Technology for PC Linings: Based upon the results obtained in Task 1, PC formulations will be developed and techniques for placing protective linings on steel pipe and plate tested.

Task 3 -- Physical and Chemical Property Testing: The suitability of materials and linings formulated in Tasks 1 and 2 will be evaluated for physical and chemical stability under geothermal use conditions.

Tests of materials formulated in Task 1 are underway at four geothermal sites. Preliminary results are very good with samples retaining high strength after 6 months exposure to geothermal brines and steam at temperatures up to 238°C (460°F). Under Task 2 many types of pipe lining have been fabricated and are under test. Work on Task 3 is progressing in the laboratory.

Project Title:	Cementing of Geothermal Wells
Contract No:	E(30-1)-0016
Contractor:	Brookhaven National Laboratory Upton, New York
Principal Investigators:	M. Steinberg (516) 345-2123, Ext. 3036 FTS 664-3036
	L. E. Kukacka (516) 345-2123, Ext. 3065 FTS 664-3065
Program Manager:	Robert R. Reeber (202) 376-4912 FTS 376-4912
Project Objective:	Evaluate potential of various polymer cements for geothermal wells and coordinate a well cementing research program definition study.
Funding:	FY 75 - -- FY 76/TQ - $ 60K
Contract Term:	2/1/76-9/30/77
Reports Issued:	None

Project Title: Cementing of Geothermal Wells

Contract No: E(30-1)-0016

SUMMARY

This project is being conducted to evaluate current status of geothermal well cementing capability and to coordinate a test program to develop adequate geothermal well cementing capability for insuring a maximum predicted well life.

A variety of polymer cement compositions developed at Brookhaven will be tested. Preliminary shallow well cementing indicates this type of material can be placed and cured under water.

Project Title: Brine Chemistry and Corrosion/Erosion Studies for Support of Total Flow Turbine Development

Contract No: W-7405-ENG-48

Contractor: Lawrence Livermore Laboratory
Livermore, California

Principal Investigator: A. L. Austin
(415) 447-1100, Ext. 3946
FTS 457-3946

Program Manager: Robert R. Reeber
(202) 376-4912
FTS 376-4912

Project Objective: To develop and evaluate brine chemistry, corrosion, and erosion problems associated with the development of total flow turbines utilizing the hot brines of the Salton Trough in California.

Funding: FY 75 - $600K
FY 76/TQ - $375K

Contract Term: 7/1/74-9/30/77

Reports Issued: A. Austin, G. Higgins, J. Howard, "The Total Flow Concept for Recovery of Energy from Geothermal Hot Brine Deposit," Lawrence Livermore Laboratory report UCRL-51366 (April 1973)

J. H. Hill, C. J. Morris, "Sampling a Two-Phase Geothermal Brine Flow for Chemical Analysis," Lawrence Livermore Laboratory report UCRL-77544 (December 1975)

J. Z. Grens, "The Effect of Salinity on Geothermal Well Performance," Lawrence Livermore Laboratory report UCID-16791 (May 1975)

Project Title: Brine Chemistry and Corrosion/Erosion Studies for Support of Total Flow Turbine Development

Contract No: W-7405-ENG-48

SUMMARY

The purpose of the project is to study brine chemistry and corrosion and erosion characteristics in total flow turbines utilizing the hot brines of the Salton Trough in California. The total flow turbine is being developed under contract number W-7405-ENG-48 as reported in Section 1.2.4.

Fluid-handling and materials studies involve investigations of the flow and chemistry of the geothermal fluids in the reservoir through the production wells, through the energy conversion apparatus and on to disposal. Understanding the behavior of structural materials in the brine environment is included in this category. Special problems of the hot brines of the Salton Trough are scaling and corrosion. Brine chemistry studies will emphasize development of methods for field analysis of flowing brines. The details of scale formation and corrosion will be investigated. Possible mineral recovery will be considered.

Studies of scale control and corrosion are being carried out at a field laboratory in the Imperial Valley. The efforts of brine chemistry modifications on corrosion/erosion phenomena are being evaluated. Wear plates are being subjected to chemistry modified brine erosion corrosion field testing.

Project Title:	Corrosivity of Geothermal Brines
Contract No:	W-7405-ENG-26
Contractor:	Oak Ridge National Laboratory Oak Ridge, Tennessee
Principal Investigator:	John Griess (615) 483-8611, Ext. 1546 FTS 850-1546
Program Manager:	Robert R. Reeber (202) 376-4912 FTS 376-4912
Project Objective:	To develop the means to estimate the corrosivity of brines from a knowledge of their composition and temperature.
Funding:	FY 75 - $ 54K FY 76/TQ - $212K
Contract Term:	7/1/74-9/30/77
Reports Issued:	None

Project Title: Corrosivity of Geothermal Brines

Contract No: W-7405-ENG-26

SUMMARY

The project will seek to gain an understanding of how the individual constituents affect corrosion and determine synergistic effects, if any. To accomplish this, a data base will be established, by electrochemical methods, on the influence of major and minor constituents of geothermal brines on the corrosion of candidate metallic materials of construction. The influence of scale growth on corrosion processes will be investigated. A quantitative evaluation will be made of the effect of solution flow on corrosion kinetics of promising metals at high temperatures and pressures. Field testing of the most promising materials will be carried out.

Laboratory equipment is being assembled for continuous operation and automated data recording. Preliminary runs using batch operation show good capability of controlling chemical and physical parameters in the test loop.

1.2.1 Material Development and Corrosion Studies

Project Title: Investigate Geothermal Corrosion--Study of Factors Limiting Use of Iron Base Alloys vs Alternate Materials in Mildly Acidic Geothermal Waters and Steam

Contract No: E(45-1)-1830

Contractor: Battelle Pacific Northwest Laboratory
Richland, Washington

Principal Investigator: D. W. Shannon
(509) 942-3139
FTS 444-3139

Program Manager: Robert R. Reeber
(202) 376-4912
FTS 376-4912

Project Objective: To clarify corrosion factors which influence materials selection for geothermal power plants.

Funding: FY 75 - $ 60K
FY 76/TQ - $313K

Contract Term: 7/1/74-9/30/77

Reports Issued: D. W. Shannon, "Economic Impact of Corrosion and Scaling Problems in Geothermal Energy Systems," Battelle Pacific Northwest Laboratory report BNWL-1866 (January 1975)

Project Title: Investigate Geothermal Corrosion--Study of Factors Limiting Use of Iron Base Alloys vs Alternate Materials in Mildly Acidic Geothermal Waters and Steam

Contract No: E(45-1)-1830

SUMMARY

The major effort in FY 1976 will be directed to a systematic study of factors affecting carbon steels in mildly acidic solutions up to 250°C (480°F), completion of the first corrosion fatigue test, fabrication of the field corrosion test unit and preparing a suitable field site.

Initial efforts, which will establish corrosion limits to the use of iron base alloys in geothermal water, will utilize laboratory scale stirred autoclaves (1 to 6 liter) to investigate the high temperature, high pressure corrosion behavior of iron base alloys in weakly acidic fluids and compare performance with alternate materials such as aluminum, titanium, and nickel 16 Cr - 16 Mo alloys.

To investigate corrosion fatigue in geothermal steam, a stirred autoclave will be set up to produce cyclic stress in specimens of 12% Cr steel which is in general use as a thermal turbine blade material. By varying the partial pressures of H_2, H_2S, and H_2O and traces of O_2 the chemical activity of the steam will be varied. Time to failure will be monitored by electrical connections to the specimens.

Finally, a field corrosion test will measure corrosion in geothermal water typical of waters proposed for binary cycle plants. Ideally a mildly acidic water with a pH around 5.5 to 6 would be chosen. After base line data are obtained on corrosion in the normal well water, changes in pH, temperature, and velocity will be made in the water flowing through the test stand. The change in corrosion performance will be compared with initial data to establish the validity of the conclusions obtained with the laboratory scale autoclaves.

Work began in April 1975. Detailed planning began and supplies for the R&D program were ordered. Existing ERDA autoclave equipment at PNL was relocated and several scouting tests of carbon steel in carbonic acid/bicarbonate solutions were run at temperatures up to 250°C. Work began on setting up and calibrating analytical chemistry procedures. Planning began on the experimental design for the corrosion fatigue test. Survey work began to locate a suitable site for the field test.

Work on this project has been delayed due to a labor dispute.

Project Title:	Develop Standard Methods and Manual for Sampling and Analysis for Geothermal Fluids and Gases
Contract No:	E(45-1)-1830
Contractor:	Battelle Pacific Northwest Laboratory Richland, Washington
Principal Investigator:	D. W. Shannon (509) 942-3139 FTS 444-3139
Program Manager:	Robert R. Reeber (202) 376-4912 FTS 376-4912
Project Objective:	Develop standard methods and publish a manual for sampling and analysis of geothermal fluids and gases in order to assure accuracy, reliability, and intercomparability of reported results.
Funding:	FY 75 - -- FY 76/TQ - $110K
Contract Term:	7/1/75-9/30/77
Reports Issued:	None

Project Title: Develop Standard Methods and Manual for Sampling and Analysis for Geothermal Fluids and Gases

Contract No: E(45-1)-1830

SUMMARY

Development of standard methods and publication of a manual for sampling and analysis of geothermal fluids will assist the developing geothermal industry to meet its analytical needs by reducing the analytical methods research required by each organization.

Work in FY 1976 will consist of assembling the state-of-the-art laboratory and field methods and planning a systematic test and evaluation program. The existing methods for sampling and analysis now used by various investigators will be assembled and critiqued by an analytical standards group of three user institutions. In order to accelerate standardization as soon as possible this "collection" of methods will be published for comment and interim use on a voluntary basis. The selection of material for this first report will reflect the standard group's best judgment on candidate methods.

Work on this project was begun in February 1976 and is still in the formative stages.

1.2.1 Material Development and Corrosion Studies

Project Title: The Development and Evaluation of Elastomeric Materials for Geothermal Applications

Contract No: E(49-27)-1011

Contractor: NASA
Pasadena, California

Work Performed by: Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Principal Investigator: William A. Mueller
(213) 354-3073
FTS 792-3073

Program Manager: Robert R. Reeber
(202) 376-4912
FTS 376-4912

Project Objective: Modify elastomeric compounds to extend their capabilities to include service in geothermal environments.

Funding: FY 75 - --
FY 76/TQ - $104K

Contract Term: 6/21/76-6/30/77

Reports Issued: None

Project Title: The Development and Evaluation of Elastomeric Materials for Geothermal Applications

Contract No: E(49-27)-1011

SUMMARY

In this project, techniques will be developed to modify elastomeric compounds to extend their capabilities to include service in geothermal environments. Specifically, one material will be developed for O-ring seals for 24-hour service at 260°C in a geothermal environment. One goal will be the development in 1977 of at least one elastomer for use as an O-ring seal at 300°C under high pressure in a geothermal environment.

A state-of-the-art survey of elastomeric materials for O-rings, seals, packing, etc., suitable for high temperature (260°C) operation in geothermal environments, has been initiated.

Project Title:	Materials Evaluation and Development for Sour Environments
Contract No:	E(11-1)-2602
Contractor:	Case Western Reserve University Cleveland, Ohio
Principal Investigator:	A. R. Troiano (216) 368-4234
Program Manager:	Robert R. Reeber (202) 376-4912 FTS 376-4912
Project Objective:	To adapt existing materials to new uses in sour environments.
Funding:	FY 75 - $325K FY 76/TQ - $ 12K
Contract Term:	12/15/74-5/31/77
Reports Issued:	None

Project Title: Materials Evaluation and Development for Sour Environments

Contract No: E(11-1)-2602

SUMMARY

Samples of two classes of commercially available alloys are being subjected to a range of environments chosen to produce stress corrosion cracking. Those alloys found to be resistant will be processed by thermal and mechanical treatments to further improve their susceptibility to stress corrosion cracking.

Screening tests for both commercial constructional and high strength corrosion resistant alloys are in progress at both ambient and higher temperatures to 290°C (550°F).

Work on improving heats of commercially suitable alloys is being coordinated with Armco Steel Company.

Project Title: Scale Formation and Control Support for Total Flow Turbine Development

Contract No: W-7405-ENG-48

Contractor: Lawrence Livermore Laboratory
Livermore, California

Principal Investigator: A. L. Austin
(415) 447-1100, Ext. 3946
FTS 457-3946

Program Manager: Robert R. Reeber
(202) 376-4912
FTS 376-4912

Project Objective: To develop control methods for scaling in total flow turbines, caused by geothermal hot brines brines such as those of the Salton Trough in California.

Funding: FY 75 - $600K
FY 76/TQ - $1125K

Contract Term: 7/1/74-9/30/77

Reports Issued: A. Austin, G. Higgins, J. Howard, "The Total Flow Concept for Recovery of Energy from Geothermal Hot Brine Deposit," Lawrence Livermore Laboratory report UCRL-51366 (April 1973)

D. D. Jackson, J. H. Hill, "Possibilities for Controlling Heavy Metal Sulfides in Scale from Geothermal Brines," Lawrence Livermore Laboratory report UCRL-51977 (January 1976)

R. N. Schock, A. Duba, "The Effect of Electrical Potential on Scale Formation in Saline Sea Brine," Lawrence Livermore Laboratory report UCRL-51944 (November 1975)

L. B. Owen, "Precipitation of Amorphous Silica from High-Temperature Hypersaline Geothermal Brines," Lawrence Livermore Laboratory report UCRL-51866, to be presented at the 1976 Spring Annual Meeting and Journal of Volcanology, Geochemistry, and Petrology.

Project Title: Scale Formation and Control Support for Total Flow Turbine Development

Contract No: W-7405-ENG-48

SUMMARY

The purpose of the project is to study total flow turbine scale formation control for brines, particularly the hot brines such as those of the Salton Trough in California. The total flow turbine is being developed under contract number W-7405-ENG-48 as reported in Section 1.2.4.

Fluid handling and materials studies involve investigations of the flow and chemistry of the geothermal fluids in the reservoir through the production well, through the energy conversion apparatus and on to disposal. Understanding the behavior of structural materials in the brine environment is included in this category. Special problems of the hot brines of the Salton Trough are scaling and corrosion. The details of scale formation and corrosion will be investigated.

A field testing laboratory was built and moved to the Imperial Valley. The test facility is being used to collect data on chemical modifications of brine to control scaling in total flow turbines.

Project Title:	Precipitation and Scaling in Dynamic Geothermal Systems
Contract No:	W-7405-ENG-26
Contractor:	Oak Ridge National Laboratory Oak Ridge, Tennessee
Principal Investigator:	E. G. Bohlman (615) 483-8611, Ext. 31371 FTS 850-1371
Program Manager:	Robert R. Reeber (202) 376-4912 FTS 376-4912
Project Objective:	Experimentation with synthetic brines under various conditions.
Funding:	FY 75 - $ 85K FY 76/TQ - $324K
Contract Term:	7/1/74-9/30/77
Reports Issued:	None

Project Title: Precipitation and Scaling in Dynamic Geothermal Systems

Contract No: W-7405-ENG-26

SUMMARY

Conditions for precipitation and scaling in dynamic geothermal systems will be determined by modifying an existing 100 gpm titanium loop.

Solids formed under varying flow conditions, temperature (to 300°C), and brine compositions will be quantitatively characterized by chemical analysis, metallography, crystallography and electron microscopy. This loop demonstrated excellent serviceability over a period of years in saline water corrosion studies with and without pollutant additives such as H_2S, NH_3, and SO_2 and should be equally satisfactory in this application.

Preliminary experiments, varying temperature and pH in a precursor once-through system, have produced scale that consists of conglomerates of particles cemented to the system wall. The scale has been characterized and is similar to that formed in geothermal brines.

Project Title: Development of Probes for Down Hole and In-Line Chemical Analysis of High Pressure, High Temperature Geothermal Fluids

Contract No: E(45-1)-1830

Contractor: Battelle Pacific Northwest Laboratory
Richland, Washington

Principal Investigator: D. W. Shannon
(509) 942-3139
FTS 444-3139

Program Manager: Robert R. Reeber
(202) 376-4912
FTS 376-4912

Project Objective: Develop probes to monitor high temperature, down hole, geothermal fluid chemistry.

Funding: FY 75 - --
FY 76/TQ - $130K

Contract Term: 7/1/75-9/30/77

Reports Issued: None

Project Title: Development of Probes for Down Hole and In-Line Chemical Analysis of High Pressure, High Temperature Geothermal Fluids

Contract No: E(45-1)-1830

SUMMARY

This project will initiate high temperature electrochemical studies of geothermal fluids in support of probe development and probe data interpretation and will develop a basis for control of geothermal fluid chemistry to minimize deposition in plant and during reinjection into the reservoir.

Measurement of pH, oxidation potential, solution conductivity and corrosion in situ will provide a satisfactory basis of understanding of working fluid chemistry. Present methods of monitoring geothermal fluid chemistry after cooling and depressurization do not give an adequate picture of local chemistry in the reservoir or in the plant. Successful development of even simple probes for use down hole or in the plant will improve understanding of what is happening internally during operation and provide a basis for correction of the problem.

Current activities are directed toward establishing the feasibility of high temperature, high pressure chemical measurements. The bulk of the effort will be focused on development of suitable high temperature electrodes to measure E_h, pH, and conductivity in a high pressure geothermal environment.

This project started late in FY 1976. Accomplishments include the design of candidate measurement systems and coordination with other workers in the field.

Project Title: Silica Precipitation and Brine Management

Contract No: W-7405-ENG-48

Contractor: Lawrence Berkeley Laboratory
Berkeley, California

Principal Investigators: John A. Apps
(415) 843-2740 ext. 5193
FTS 451-5193

Oleh Weres
(415) 843-2740 ext. 5625
FTS 451-5193

Program Manager: Robert R. Reeber
(202) 376-4912
FTS 376-4912

Project Objective: To characterize the chemical compositions of geothermal brines and to develop a geothermal brine management plan.

Funding: FY 75 - --
FY 76/TQ - $152K

Contract Term: 4/1/76-9/30/77

Reports Issued: None

Project Title: Silica Precipitation and Brine Management

Contract No: W-7405-ENG-48

SUMMARY

The objectives of this project are to characterize the chemical compositions of geothermal brines, to assist in the development of a geothermal brine management plan, and to develop a model for use in computer simulations of geothermal plant performance degradation.

The development of a brine management program plan has been initiated, as has acquisition and cataloging of available chemical data for brines likely to be exploited during the next 10 years.

Project Title: Study of Silica Scaling from Geothermal Brines

Contract No: E(11-1)-2607

Contractor: EIC Incorporated
Newton, Massachusetts

Principal Investigator: W. W. Harvey
(617) 965-2710

Program Manager: Robert R. Reeber
(202) 376-4912
FTS 376-4912

Project Objective: To establish kinetics and mechanisms of initial stages of silica scale formation in synthetic brines and indicate ways to control scale formation in geothermal power plants.

Funding: FY 75 - $289K
FY 76/TQ - --

Contract Term: 11/15/74-4/30/77

Reports Issued: None

Project Title: Study of Silica Scaling from Geothermal Brines

Contract No: E(11-1)-2607

SUMMARY

Homogeneous nucleation and growth of silica from brines supersaturated in silicic acid have been studied over a range of pH(4.5-6.7), temperature (75-105°C), salinity, and silicic acid concentrations (700 to 1200 ppm as SiO_2).

The isothermal rate of SiO_2 condensation is a strong function of supersaturation (C/C_{eq}), pH, and salinity. Overall kinetics follow the general theory of phase transitions and are adequately described by the Volmer expressions for condensation from solution. At supersaturations less than about 3 an induction period is observed; it amounts to several hundred minutes at supersaturations of 2. The "critical" supersaturation is estimated to be near 1.7.

Primary nuclei have radii of the order of a few Angstroms. Particles with radii of several hundred Angstroms are obtained at equilibrium. Nuclei growth is activation controlled, at least initially. Growth kinetics near equilibrium appear to be diffusion controlled.

The substantial effect of brine salinity on condensation rate can be quantitatively accounted for by decreased equilibrium solubility of H_4SiO_4 with increasing salt content.

An increase of one pH unit in the range from 4.5 to 6.7 decreases the induction period by a factor of about 10. The pH dependence of the growth rate is consistent with the hypothesis that $H_3SiO_4^-$ is one of the reacting species. Changes of temperature (75 to 105°C) have little effect either on nucleation or growth rate at a fixed initial H_4SiO_4 concentration, suggesting that at the higher temperatures the rate increase is compensated by lower supersaturation.

Future work will include:

(A) Evaluation of effects of increased temperature (105 to 225°C) and of cations (Fe, Al, and other metal ions) on nucleation and growth

(B) Investigation of heterogeneous nucleation on various surfaces (stainless steel, Ti, non-metallics)

(C) Correlation of scale composition to solution composition

A scale management conference was held at the University of California, San Diego, August 2-4, 1976.

Project Title:	A Study of Scale Formation and Suppression in Heat Exchange Systems for Geothermal Brines
Contract No:	E(11-1)-2833
Contractor:	Dow Chemical, USA Freeport, Texas
Principal Investigator:	John S. Wilson (713) 238-4153
Program Manager:	Robert R. Reeber (202) 376-4912 FTS 376-4912
Project Objective:	To investigate techniques for controlling scale formation from geothermal brine.
Funding:	FY 75 - -- FY 76/TQ - $112K
Contract Term:	1/12/76-4/5/77
Reports Issued:	None

Project Title: A Study of Scale Formation and Suppression in Heat Exchange Systems for Geothermal Brines

Contract No: E(11-1)-2833

SUMMARY

Experiments will be conducted to produce controlled scaling in heat exchangers from simulated geothermal brine. Four techniques will be studied to control scale formation; maintain high pressure of carbon dioxide, add surface active polymers, remove calcium by the addition of sulfate and electromagnetic protection. Work has commenced on installation of small heat exchangers for electromagnetic protection experiments. The work is being done at the Dow Chemical water materials test center in Freeport, Texas, and uses existing equipment of the Office of Saline Water.

Project Title: Transport and Conversion of Heat at Moderate Temperatures

Contract No: W-7405-ENG-26

Contractor: Oak Ridge National Laboratory
Oak Ridge, Tennessee

Principal Investigators: S. Combs
(615) 483-8611, Ext. 37754
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R. Murphy
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Program Manager: Cliff McFarland
(202) 376-4910
FTS 376-4910

Project Objective: To develop technology for efficient transport, transfer, and use of heat at temperatures below the temperature at which steam is the optimum medium for transport and conversion.

Funding: FY 75 - $234K
FY 76/TQ - $302K

Contract Term: 7/1/74-9/30/77

Reports Issued: S. L. Milora and J. W. Tester, "Thermodynamics and Economics of Geothermal Power Production Cycles," to be published Spring 1976, MIT Press.

R. N. Lyon, "An Approach to Optimizing the Operating Conditions of Low Temperature Heat Engine Systems Using 'Virtual Temperature Drops,'" ORNL-TM-4864.

S. L. Milora, "STATEQ: A Nonlinear Least Squares Code for Obtaining Martin Thermodynamic Representations of Fluids in the Gaseous and Dense Gaseous Regions," ORNL-TM-5115.

Project Title: Transport and Conversion of Heat at Moderate Temperatures

Contract No: W-7405-ENG-26

SUMMARY

This project will study "cold vapors," working and transport fluids with atmospheric boiling points below that of water. The maximum applicable peak temperature will depend on the nature of heat source. Although the refrigeration industry has extensive experience with many of these fluids at temperatures up to 50°C, knowledge of physical and chemical properties at higher temperatures is generally unreliable. Engineering practice and construction costs for using these fluids for higher temperatures must be refined to choose the best fluid or design efficient fluted-surface condensers or heat exchangers for heating supercritical nonaqueous fluids.

The program will monitor current efforts in scaling control and will investigate one or more attractive new concepts for design of heat exchangers. Specific objectives are: (1) collection, correlation, and presentation of information on the properties of cold vapor-fluids; (2) development and testing of components for cold vapor systems; (3) completion of cycle and cost studies, including comparison with flashing aqueous systems; and (4) subsystem development and demonstrations. Analytical work will continue on fluid properties, and a summary will be issued of the known properties for ammonia, isobutane, and at least one other working fluid--possibly Freon 115. General methods for choosing among candidate working fluids will be examined.

Experimental studies of condensation on fluted surfaces will begin. Preliminary experimental studies of supercritical heat transfer to nonaqueous fluids and a preliminary investigation of a multiflash type of closed heat exchanger will be made.

The investigators will initiate a theoretical analysis aimed at prediction of heat transfer and flow in heated supercritical fluids.

An extensive thermodynamic/economic analysis of binary cycles using conventional heat exchanger technology has been completed and reported in draft form. Analytical equations of state for 14 candidate binary cycle working fluids have been developed. Empirical data for condensing film coefficients on fluted vertical tubes have been obtained for R-21 and R-114.

Project Title:	Second Generation Heat Exchanger Development
Contract No:	E(10-1)-1375
Contractor:	Idaho National Engineering Laboratory Idaho Falls, Idaho
Principal Investigators:	B. C. Musgrave (208) 526-0111, Ext. 3269 FTS 583-3269
Program Manager:	Cliff McFarland (202) 376-4910 FTS 376-4910
Project Objective:	To develop the technology required to design efficient, non-fouling heat exchangers for transferring heat from mineralized geothermal fluids.
Funding:	FY 75 - $189K FY 76/TQ - $440K
Contract Term:	7/1/74-9/30/77
Reports Issued:	Dart, R. H., D. T. Neill, J. F. Whitbeck, "Conceptual Design and Cost Evaluation of Organic Rankine Cycle Electric Generating Plant Powered by Medium Temperature Geothermal Water," ANCR-1226 Madsen, W. W., I. J. Ingvarsson, "Analysis of the Binary Cycle for Geothermal Power Generation," ANCR -1245, December 1975.

Project Title: Second Generation Heat Exchanger Development

Contract No: E(10-1)-1375

SUMMARY

Various conditions of temperature, brine concentration and chemical compositions are being investigated in the laboratory and field. The fluidized bed is the heat exchanger concept being experimentally investigated. Theoretical studies of binary cycles are also in progress.

The program has the following principal goals:

1. Design and test on actual geothermal fluids a pilot model of a fluidized-bed heat exchanger having multiple stages to determine its efficiency and performance under varying conditions.

2. Examine present heat exchanger techniques now in operation and determine their efficiencies and characteristics.

3. Compare these heat exchangers giving their limitations, operating ranges, efficiencies with time, and other appropriate information.

Numerous other non-electric applications of these heat exchangers potentially exist utilizing geothermal energy in addition to heat exchange between geothermal and plant working fluids for electrical applications. Space heating and chemical process heating are examples.

Fluidized bed data have been obtained in bench and field testing programs. High film coefficients and no fouling were noted in the tests.

Project Title: Geothermal Energy Utilization - Heat Exchanger Coordination, Binary Fluid Experiment, Cycle Modeling

Contract No: W-7405-ENG-48

Contractor: Lawrence Berkeley Laboratory
Berkeley, California

Principal Investigators: K. F. Mirk
(415) 843-2740, Ext. 6105
FTS 451-6105

R. F. Fulton
(415) 843-2740, Ext. 6105
FTS 451-6105

Program Manager: Cliff McFarland
(202) 376-4910
FTS 376-4910

Project Objective: To coordinate DGE heat exchanger programs, to conduct experiments to evaluate the influence of contaminants on binary cycle condenser performance, and to perform thermodynamic cycle analysis.

Funding: FY 75 - --
FY 76/TQ - $285K

Contract Term: 5/26/76-9/30/77

Reports Issued: None

Project Title: Geothermal Energy Utilization - Heat Exchanger Coordination, Binary Fluid Experiment, and Cycle Modeling

Contract No: W-7405-ENG-48

SUMMARY

This project consists of three tasks: coordinating DGE heat exchanger contracts, conducting a binary fluid experiment, and continuing development and use of the computer code GEOTHM.

The subtasks involved in heat exchanger coordination are: (1) to formulate an ERDA DGE program in heat exchanger technology; (2) review this program with ERDA Headquarters and modify the program as required; (3) prepare RFP's for the subprograms identified; (4) review proposals and recommend contractors, ERDA laboratories and other government agencies to perform the subprograms; (5) review the progress of subprograms; and (6) review and modify the DGE program as new information is obtained both from within and outside the DGE program.

The Binary Fluid Experiment (BFE) has two subtasks. The first is to provide more precise data on secondary-fluid heat transfer coefficients that can be incorporated into the design of initial binary-cycle demonstration plants. The second subtask is to study the effects of contaminants on the secondary-fluid heat transfer coefficients. Knowledge of the effect of water contamination on the secondary-fluid condensing coefficients, for example, is crucial to the design of direct-contact heat exchangers.

The computer code GEOTHM, through a "building block" approach, permits the modeling of energy conversion cycles of potential application to geothermal energy.



Project Title: APEX: An Advanced Geothermal Primary Heat Exchanger

Contract No: E(04-3)-1125

Contractor: Aerojet Liquid Rocket Company
Sacramento, California

Principal Investigator: B. Breindel
(916) 355-3631

Program Manager: Cliff McFarland
(202) 376-4910
FTS 376-4910

Project Objective: To obtain sufficient analytical and experimental data to permit the design and development of an Advanced Primary Heat Exchanger (APEX) for geothermal power generation which does not foul when dissolved salts and minerals are precipitated during the heat transfer process.

Funding: FY 75 - $175K
FY 76/TQ - $228K

Contract Term: 6/75-6/76

Reports Issued: None

Project Title: APEX: An Advanced Geothermal Primary Heat Exchanger

Contract No: E(04-3)-1125

SUMMARY

In the APEX concept, a bed material is fluidized with the pressurized geothermal well water to provide precipitation sites for materials coming out of solution as the temperature of the geothermal water drops. This bed material also provides a scouring action on the heat transfer surfaces. As material precipitates, it builds up on the bed material where it is removed in a continuous process. Heat is transferred from the primary (geothermal) fluid to the secondary (power conversion) fluid, passing counterflow, by forced convection and by the bed material.

The APEX concept provides several unique features, not considered in other geothermal fluidized bed investigations, which will allow the construction of a single stage counterflow heat exchanger operating at much higher flow velocities. This combination of counterflow and high velocities in a single stage heat exchanger is expected to yield significant cost advantages over conventional multi-stage fluidized bed heat exchangers.

The research effort combines theoretical analyses and laboratory scale experimentation to characterize the APEX concept with sufficient confidence to proceed with the design and construction of a 10 MW proof-of-concept heat exchanger for test at a geothermal site to be selected. Laboratory tests are currently in progress to study injection, suspension characteristics and removal of sand particles in the brine side flow.

Bed material injection and extraction techniques have been evaluated and demonstrated. Tests on a prototype model loop involving simulated brine are presently in progress to evaluate scale suppression.

Project Title: Research on Direct Contact Binary Process for Geothermal Hot Water

Contract No: E(04-3)-1116

Contractor: The Ben Holt Company
Pasadena, California

Principal Investigator: Anker Sims
(213) 684-2541

Program Manager: Cliff McFarland
(202) 376-4910
FTS 376-4910

Project Objective: To expedite the commercialization of direct contact binary cycle process for geothermal power generation from liquid-dominated reservoirs.

Funding: FY 75 - $128K
FY 76/TQ - --

Contract Term: 6/23/76-5/12/76

Reports Issued: Sims, A. V., "Geothermal Direct Contact Heat Exchange," (June 1976)

Project Title: Research on Direct Contact Binary Process for Geothermal Hot Water

Contract No: E(04-3)-1116

SUMMARY

This project addresses the question of feasibility of direct contact heat exchange for binary cycle geothermal power plants. Included are experiments to study the physics of direct contact heat transfer including determination of solubility of hydrocarbons in brine and hydrocarbon stripping. Economic analysis of direct contact binary cycles and conceptual designs of direct contact heat exchangers have been performed.

A number of experiments studying the effect of column internals on heat exchanger performance for a hexane-water system at atmospheric pressure have been conducted. A computer code has been written which provides a capability for performing parametric studies of the economics of direct contact binary cycles.

Project Title:	Study and Testing of Direct Contact Heat Exchangers for Geothermal Brines
Contract No:	E(40-1)-4893
Contractor:	DSS Engineers Fort Lauderdale, Florida
Principal Investigator:	Bill Suratt (305) 792-6660
Program Manager:	Cliff McFarland (202) 376-4910 FTS 376-4910
Project Objective:	To assess the technical and economic feasibility of utilizing direct contact heat exchangers for geothermal applications.
Funding:	FY 75 - $130K FY 76/TQ - $219K
Contract Term:	4/1/75-6/30/76
Reports Issued:	None

Project Title: Study and Testing of Direct Contact Heat Exchangers for Geothermal Brines

Contract No: E(40-1)-4893

SUMMARY

The following eight tasks are to be addressed: (1) working fluid selection; (2) definition of preliminary design procedures; (3) test design and test procedures; (4) heat exchanger design and scale model fabrication; (5) conduct of experiments; (6) development of final design procedures; (7) technical and economic feasibility assessment; and (8) preparation of a recommended R&D program.

A test apparatus was designed to flow 10 gpm of isobutane and 5 gpm of brine. Two heat exchanger vessels are in the system, a liquid-liquid preheater and a liquid-vapor boiler. Tests have been made with clean water-isobutane and water saturated with NaCl. High volumetric heat transfer coefficients have been observed.

Project Title: A Study of Direct Contact Heat Exchange for Extraction of Energy from Geothermal Brines

Contract No: E(04-3)-1076

Contractor: Occidental Research Corporation
La Verne, California

Principal Investigator: Ed Wahl
(714) 593-7421

Program Manager: Cliff McFarland
(202) 376-4910
FTS 376-4910

Project Objective: To assess the technical and economic feasibility of direct heat exchange for geothermal applications.

Funding: FY 75 - $ 93K
FY 76/TQ - $ 27K

Contract Term: 6/26/75-12/31/77

Reports Issued: None

Project Title: A Study of Direct Contact Heat Exchange for Extraction of Energy from Geothermal Brines

Contract No: E(04-3)-1076

SUMMARY

Part of the current program, assessing the feasibility of applying direct contact heat exchange to geothermal processes, is an experimental study of a supercritical isobutane cycle operating at maximum conditions of about 150°C and 650 psia with brine through-put of 5 gpm. Tests are to be performed in the lab and field. Included will be a conceptual design study, construction of a scale model exchanger, development of design procedures, identification of engineering problems, assessment of feasibility and preparation of a program for follow-on research and development.

Design of the laboratory test system is complete and equipment fabrication is in progress.

Project Title:	Feasibility Study of the Application of Direct Contact Heat Exchangers to Power Cycles Utilizing Geothermal Brines
Contract No:	E(10-1)-1549
Contractor:	University of Utah Salt Lake City, Utah
Principal Investigators:	Harold R. Jacobs (801) 581-7104
	Robert F. Boehm (801) 581-7106
Program Manager:	Cliff McFarland (202) 376-4910 FTS 376-4910
Project Objective:	Evaluate feasibility of applying direct contact heat exchangers.
Funding:	FY 75 - $167K FY 76/TQ - --
Contract Term:	1/15/75-6/30/77
Reports Issued:	(see list after "Summary")

Project Title: Feasibility Study of the Application of Direct Contact Heat Exchangers to Power Cycles Utilizing Geothermal Brines

Contract No: E(10-1)-1549

SUMMARY

Items covered in the scope of the project involve heat transfer studies, solubility information and overall systems considerations. In the heat transfer studies, work is being directed primarily toward direct contact processes between immiscible fluids as one of the fluids undergoes phase change. A test of a scale model heat exchanger is one of the final goals of this work. Solubility information is being determined for hydrocarbon liquids and vapors in heavily-laden brines. Systems studies will be concerned primarily with the thermodynamic aspects of the direct contact-type power cycle. Although some previous work on binary power cycles will be of value here, additional parameters enter in the direct contact cycle.

Direct contact heat exchanger tests have been performed both in the laboratory and in the field at the Raft River site. Volumetric heat transfer coefficient for both liquid-liquid and boiler exchangers have exceeded expectations for brine-isobutane usage. Solubility and carry-over data have been acquired in the course of testing.

Project Title: Feasibility Study of the Application of Direct Contact Heat Exchangers to Power Cycles Utilizing Geothermal Brines

Contract No: E(10-1)-1549

Reports Issued:

R. F. Boehm and H. R. Jacobs, "Raft River Direct Contact Heat Exchanger Project Quarterly Report, July 1 to September 30, 1975," University of Utah, UTEC ME 75-156 (October 9, 1975).

H. R. Jacobs, R. S. Deeds and R. F. Boehm, "Heat Transfer Characteristics of a Surface-Type Direct Contact Boiler," Abstract submitted for consideration for presentation at the 1976 National Heat Transfer Conference (November 26, 1975).

C. K. Blair, R. F. Boehm and H. R. Jacobs, "Heat Transfer Characteristics of a Direct Contact Volume Type Boiler," Abstract submitted for consideration for presentation at the 1976 National Heat Transfer Conference (November 26, 1975).

H. R. Jacobs, R. W. Johnson and R. F. Boehm, "Heat Transfer and Temperature Distributions in Liquid-Liquid Direct Contact Parallel Flow of Immiscible Fluids," Abstract submitted for consideration for presentation at the 1976 National Heat Transfer Conference (November 26, 1975).

R. W. Johnson, "Direct Contact Heat Transfer Between Two Immiscible Liquids in Laminar Flow between Parallel Plates," Master of Science Thesis, University of Utah, (December 1975).

R. F. Boehm and H. R. Jacobs, "Direct Contact Heat Exchanger Project Work - Short Summary," ERDA Geothermal Progam Review Meeting, Washington, D.C. (December 10, 1975).

R. F. Boehm, H. R. Jacobs, C. K. Blair, R. S. Deeds, R. W. Johnson and D. Kelly, "Direct Contact Heat Exchangers for Geothermal Power Generation - Part 1 - Heat Transfer Considerations," Abstract submitted for consideration for presentation at the 1976 Intersociety Energy Conversion Engineering Conference (December 26, 1975).

R. F. Boehm, H. R. Jacobs, D. Riemer, R. Bliss, and G. Hellstrom, "Direct Contact Heat Exchangers for Geothermal Power Generation - Part 2 - Thermodynamic and Solubility Considerations," Abstract submitted for consideration for presentation at the 1976 Intersociety Energy Conversion Engineering Conference (December 26, 1975).

Project Title:	Small Geothermal Electric Generator
Contract No:	E(29-1)-0789
Contractor:	Sandia Laboratories Albuquerque, New Mexico
Principal Investigator:	J. D. Cyrus (505) 264-7338 FTS 475-7338
Program Manager:	John V. Walker (202) 376-4912 FTS 376-4912
Project Objective:	To develop a small wellhead geothermal electric generator.
Funding:	FY 75 - $ 22K FY 76/TQ - $184K
Contract Term:	7/1/74-9/30/76
Reports Issued:	None

Project Title: Small Geothermal Electric Generator

Contract No: E(29-1)-0789

SUMMARY

The objective of the Sandia Laboratories program "Small Geothermal Electric Generator" is to develop a self contained Freon system to use the heat from a natural hot spring or geothermal well to generate small amounts of electricity.

In 1975, the following efforts were initiated:

1. Design analysis of the energy conversion system.
2. Definition of the characteristics of the hot spring resource.
3. Selection of hardware that can be modified and assembled in a laboratory working model.

Follow-on work includes laboratory and field demonstrations.

A small test loop, installed at Sandia, produced 3KW in preliminary runs. The turbine and generator functioned well. However, the test was terminated as a result of the heat exchanger leaking.

Investigation of potential operating sites revealed that no suitable site can be found in Alaska to use the equipment. Thus the work will be terminated at the end of September 1976.

A larger, 40 to 90 KW turbine generator is being fabricated for testing in FY 77 at a site to be determined.

Project Title: Geothermal Total Flow Concept

Contract No: W-7405-ENG-48

Contractor: Lawrence Livermore Laboratory
Livermore, California

Principal Investigator: A. L. Austin
(415) 447-1100, Ext. 3946
FTS 457-3946

Program Manager: Cliff McFarland
(202) 376-4910
FTS 376-4910

Project Objective: To develop and evaluate methods for commercial production of electric power from the energy of geothermal deposits, particularly the hot brines such as those of the Salton Trough in California and the geopressured regions of the Texas and Louisiana Gulf Coasts.

Funding: FY 75 - $1,206K
FY 76/TQ - $2,155K

Contract Term: 7/1/74-9/30/77

Reports Issued: A. Austin, G. Higgins, J. Howard, "The Total Flow Concept for Recovery of Energy from Geothermal Hot Brine Deposit," Lawrence Livermore Laboratory report UCRL-51366 (April 1973)

A. A. Austin, "Prospects for Advances in Energy Conversion Technologies for Geothermal Energy Development," Lawrence Livermore Laboratory report UCRL-76532 (May 1975)

T. W. Alger, "The Performance of Two Phase Nozzles for Total Flow Geothermal Impulse Turbines," Lawrence Livermore Laboratory report UCRL-76417 (May 1975)

Project Title: Geothermal Total Flow Concept

Contract No: W-7405-ENG-48

SUMMARY

The purpose of the project is to develop and evaluate methods for commercial production of electric power from the energy of geothermal deposits, particularly hot brines such as those of the Salton Trough in California and the geopressured regions of the Texas and Louisiana Gulf Coasts. Some of the results should be applicable to other types of geothermal resources.

The project includes two broad areas of work, resource utilization and technology development. Resource utilization activities, basically directed toward a specific resource type, can be divided into five categories: geologic studies, fluid handling studies, energy conversion studies, field activities, and economic and environmental effects. Technology development, applicable to various types of geothermal resources, includes criteria for optimum utilization, extension of total flow concept, development of alternate energy conversion concepts, extraction technology and related topics, and reservoir analysis.

The "Total Flow" concept described in report no. UCRL-51366 is the main thrust of the effort in hot brines, but other concepts, such as heat exchangers, are also under investigation. The investigators will assess the production capacity for the reservoir and select a site for a Field Experimental Facility.

The project will advance general technology development through joint projects with and subcontracts to private industry both for specific services such as geophysical investigations and for fabrication of prototype turbine components and complete turbines different from the Lawrence Livermore Laboratory design. Other subcontracts will include drilling of production wells and reservoir analysis.

Brine characteristics and scaling control associated with total flow turbine development are being studied under contract number W-7405-ENG-48 as reported in Sections 1.2.1 and 1.2.2 respectively.

Analytical evaluation of various conversion concepts have been completed and documented. Nozzle tests have been conducted on clean low quality steam in preparation for laboratory tests of a single stage impulse turbine starting in the Fall of 1976. Laboratory evaluations of several prime movers have been completed and computational tools for designing optimum total flow nozzles are being developed.

Project Title:	Experimental Investigation of a Helical Rotary Screw Expander Power System Using Geothermal Brine
Contract No:	E(49-27)-1000
Contractor:	NASA Pasadena, California
Work Performed by:	Jet Propulsion Laboratory California Institute of Technology Pasadena, California
Principal Investigator:	Richard A. McKay (213) 354-3107 FTS 792-3107
Program Manager:	Cliff McFarland (202) 376-4910 FTS 376-4910
Project Objective:	Provide advanced technology for development of the helical rotary screw expander driven electrical power generation system for use with geothermal brines.
Funding:	FY 75 - $713K FY 76/TQ - --
Contract Term:	4/29/75-7/31/76
Reports Issued:	None

Project Title: Experimental Investigation of a Helical Rotary Screw Expander Power System Using Geothermal Brine

Contract No: E(49-27)-1000

SUMMARY

The objective of this project is to evaluate, by field measurements, a single-stage, full-scale experimental expander system. Measurements will include thermodynamics of the expansion process, performance characteristics, and determination of component reliability and life expectancy during use with geothermal brines. Support for this near-term objective is warranted by the advanced technology inherent in this innovative energy conversion concept, by the potential engineering advances to be derived from new experimental evidence in field operation, and by ERDA's responsibility as lead agency in the national geothermal energy research program.

Site selection studies have been initiated to determine a suitable location for field testing of a 1 MW prototype well head generator-expander system. Fabrication of the test unit has begun.

Project Title: Study of Practical Cycles for Geothermal Power Plants

Contract No: E(11-1)-2619

Contractor: General Electric Company
Schenectady, New York

Principal Investigator: J. H. Eskesen
(518) 346-8771

Program Manager: Cliff McFarland
(202) 376-4910
FTS 376-4910

Project Objective: Define procedures for selection of the power cycle and equipment.

Funding: FY 75 - $ 45K
FY 76/TQ - $141K

Contract Term: 6/15/75-3/15/77

Reports Issued: J. H. Eskesen, "Study of Practical Cycles for Geothermal Power Plants," Interim Report June 15, 1975 to March 31, 1976, General Electric Company report SRD-76-040 (April 1976)

Project Title: Study of Practical Cycles for Geothermal Power Plants

Contract No: E(11-1)-2619

SUMMARY

This study will define procedures for selection of the power cycle and equipment for a given geothermal resource type and specific site. For each of three specific geothermal fluid conditions, the procedures will be applied to select and evaluate the most promising cycle and equipment for near-term (3 to 5 years) implementation for large-scale power production. For cycles with the most attractive long-term promise, the technical barrier problems will be defined and research directions that will lead most effectively to solution of these problems will be indicated. For selected cycle with long-term promise, a practical research program will be defined, including specification of the team skills required to carry out the research through the first-phase efforts.

Parametric calculations of a variety of working fluids and binary cycles have been completed. Technical and economic studies of candidate prime movers for optimum cycles are in progress.

Project Title:	Demonstration of a Geothermal Rotary Separator-Turbine
Contract No:	E(04-3)-1228
Contractor:	Biphase Engines, Inc. La Canada, California
Principal Investigator:	L. Hays (213) 450-3892
Program Manager:	Cliff McFarland (202) 376-4910 FTS 376-4910
Project Objective:	To demonstrate (on geothermal fluids) separation of two phase flows following isentropic nozzle expansion.
Funding:	FY 75 - $ -- FY 76/TQ - $185K
Contract Term:	4/1/76-12/31/76
Reports Issued:	None

Project Title: Demonstration of a Geothermal Rotary Separator-Turbine

Contract No: E(04-3)-1228

SUMMARY

In this project, a geothermal rotary separator will be fabricated and field tested. The device, in principle, can approximate isentropic flashing as opposed to conventional isenthalpic processes with attendant loss in thermodynamic availability. Fabrication of the unit is in progress with laboratory testing scheduled for August 1976 and field testing shortly thereafter.

Project Title: An Analytical Study of Concepts Related to the Utilization of Geothermal Energy

Contract No: N/A (Purchase Order 76-24)

Contractor: Weidlinger Associates
New York, New York

Principal Investigator: Ivan S. Sandler
(212) 838-2830

Program Manager: Cliff McFarland
(202) 376-4910
FTS 376-4910

Project Objective: To perform selected analytical and numerical evaluations of advanced energy conversion concepts.

Funding: FY 75 - --
FY 76/TQ - $10K

Contract Term: 4/19/76-4/18/77

Reports Issued: None

Project Title: An Analytical Study of Concepts Related to the Utilization of Geothermal Energy

Contract No: N/A (Purchase Order 76-24)

SUMMARY

Analysis of conversion concepts in which bounds on performance can be made from first principles are in progress. Similitude considerations in the analysis and planning of conversion experimental programs, particularly involving heat transfer, are being evaluated.

Project Title:	Resource Utilization Efficiency Improvement of Geothermal Brine Cycles -- Phase I
Contract No:	E(40-1)-4944
Contractor:	University of Oklahoma Norman, Oklahoma
Principal Investigator:	Kenneth E. Starling (405) 325-0311
Program Manager:	Cliff McFarland (202) 376-4910 FTS 376-4910
Project Objective:	To examine advantages and disadvantages of the use of mixtures as working fluids in geothermal power cycles including development of a computer code capable of mixture and pure fluid cycle simulation.
Funding:	FY 75 - $ 40K FY 76/TQ - $ 53K
Contract Term:	6/15/75-6/14/76
Reports Issued:	Kenneth E. Starling, Larry W. Fish, Khan Zafar Iqbal, Dennis Yieh, "Resource Utilization Efficiency Improvement of Geothermal Brine Cycles - Phase I - Semiannual Progress Report - June 15, 1975 to December 15, 1975" report number ORO-4944-3

Project Title: Resource Utilization Efficiency Improvement of Geothermal Brine Cycles -- Phase I

Contract No: E(40-1)-4944

SUMMARY

The major thrust of this research is to investigate the use of mixtures, rather than pure compounds, as working fluids in geothermal binary cycles. The advantage offered by the use of a mixture centers on the possibility of increasing the cycle area on a thermodynamic T-s diagram, i.e., increasing the net work of the cycle. There often is a trade-off, however, between thermodynamic cycle efficiency and other factors including resource energy extraction efficiency, resource utilization efficiency, plant capital costs, and plant operating costs.

Major objectives of this Phase I effort are development of design criteria for maximizing geothermal utilization efficiency and evaluation of the advantages and disadvantages of alternative cycles including the use of mixtures as working fluids. The evaluation of alternative cycles will be made by comparing design results at different operating conditions for mixtures and selected candidate baseline pure fluids. Pure fluids to be considered include hydrocarbons and refrigerants which have been previously studied and proposed for geothermal binary cycle power plants. This work will necessitate a large number of computations, and consequently a digital computer cycle simulator will be required. Because existing pure fluid cycle simulations cannot be applied easily for mixtures, a digital computer simulation which can be used both for mixtures and pure fluids will be developed. Accurate thermodynamic and physical properties for candidate working fluids are required for alternate cycle evaluation. Therefore the thermodynamic and physical properties package for predicting properties for both mixtures and pure fluids which is under development for use in ocean thermal energy conversion cycle simulation will be incorporated in the binary cycle simulation. Results of the study will be presented in matrix form for a range of fluids (including different composition mixtures as well as pure fluids) and ranges of constraints (including geothermal resource and cooling water temperatures) sufficient to evaluate the alternate cycles.

Mixture equation of state for several candidate fluids have been developed and employed in binary cycle calculations.

Project Title: Analysis of Thermal/Mechanical Energy Conversion Concepts

Contract No: E(11-1)-4051

Contractor: Brown University
Providence, Rhode Island

Principal Investigator: Joseph Kestin
(401) 863-2685

Program Manager: Cliff McFarland
(202) 376-4910
FTS 376-4910

Project Objective: To evaluate and analyze geothermal energy conversion concepts and cooperate in coordinating and disseminating research results to the user community.

Funding: FY 75 - --
FY 76/TQ - $164K

Contract Term: 8/1/76-7/31/77

Reports Issued: None

Project Title: Analysis of Thermal/Mechanical Energy Conversion Concepts

Contract No: E(11-1)-4051

SUMMARY

The ultimate objective of this project is to assist industry in accelerating the market penetration of the geothermal energy option. A Geothermal Energy Conversion Handbook will be produced as part of the effort.

The plan is to conduct a closely coordinated study of a broad spectrum of conversion concepts including a preliminary thermodynamic analysis for each system. The study will:

1. Identify the most important difficulties and gaps in knowledge pertaining to each system.

2. Identify, by the further infusion of sound engineering judgment, the obvious non-starters.

3. Arrange promising systems according to possible economic merit.

4. Arrange promising systems in a matrix that relates them to different geothermal resource types.

The preliminary analysis will be followed by a period of data collecting and of filling gaps in knowledge. Subsequently, an iterative analysis will be undertaken in order to optimize thermodynamic performance in a manner consistent with economics. Particular attention will be paid to distinguish between system components which presently exist, those which could be designed in the near-term, components which require a period of research and development, and those which show promise but require further research prior to undertaking development. Close liaison with DGE will be maintained throughout the program.

Project Title:	Feasibility Demonstration of Geothermal Down-Well Pumping System
Contract No:	E(11-1)-2838
Contractor:	Sperry Research Center Sudbury, Massachusetts
Principal Investigator:	Warren D. McBee (617) 369-4000
Program Manager:	John V. Walker (202) 376-4912 FTS 376-4912
Project Objective:	To demonstrate the technical feasibility of the Sperry Matthews Pumping System by a field test.
Funding:	FY 75 - -- FY 76/TQ - $1,197K
Contract Term:	10/1/75-9/30/76
Reports Issued:	None

Project Title: Feasibility Demonstration of Geothermal Down-Well Pumping System

Contract No: E(11-1)-2838

SUMMARY

A 60 day down-hole test of the pump developed under an NSF grant will be performed. The pump is projected to produce 900 gpm with an added pressure of 200 psi at the surface.

The pump has been installed in a well at Heber, California. Preliminary runs are in progress. The boiler, condenser, and pump are functioning to design specifications.

Project Title: Two-Phase Flow in Geothermal Energy Systems

Contract No: E(11-1)-2729

Contractor: University of Denver Research Institute
Denver, Colorado

Principal Investigator: Laurence Ross
(303) 753-2271

Program Manager: Cliff McFarland
(202) 376-4910
FTS 376-4910

Project Objective: Provide guidelines and a manual for the design of geothermal production wells which operate the two-phase flow regime.

Funding: FY 75 - $378K
FY 76/TQ - $ 31K

Contract Term: 6/1/75-11/30/77

Reports Issued: Lawrence W. Ross, "Two-Phase Flow in Geothermal Energy Resources - Annual Report - June 1, 1975 to May 31, 1976."

A. E. Dukler, Aluf Orell "Two Phase Flow in Geothermal Energy Sources - Progress Report No. 1 - October 1, 1975 to May 30, 1976," prepared for Denver Research Institute by University of Houston (June 1976)

"Production of Goethermal Fluids by the Natural Flashing Process - Design and Analysis of Geothermal Wells in Two-Phase Flow - First Annual Report," Coury and Associates, Inc. (June 18, 1976)

Project Title: Two-Phase Flow in Geothermal Energy Systems

Contract No: E(11-1)-2729

SUMMARY

This project will provide a manual for the design of geothermal production wells which operate in the two-phase flow regime. The manual will permit optimum design of the hydrothermal system, including selection of the producing stratum, specification of the well diameter profile, and selection of wellhead pressure and temperature. The calculation procedures developed will also permit a firm analysis of the need for downhole pumping of the well and will provide a basis for deciding whether the costs of a pumped system can be justified in any particular case.

A project team highly experienced in industrial and laboratory applications of two-phase flow and in analysis of geothermal production systems has been organized for the study. Included are the University of Denver Research Institute, the University of Houston, and the firm of Coury and Associates, Inc., represented by co-investigators Drs. L. W. Ross, A. E. Duckler, and G. E. Coury, respectively.

The majority of the scientific effort during the first six months was devoted to preliminary operations, including: (1) obtaining cooperation of federal organizations who assist in field operations; (2) obtaining reported data on two-phase flow; (3) defining the measurement parameters required to achieve the goals of the program; and (4) establishing working relationships with the two project subcontractors, Coury and Associates and University of Houston.

Project Title: Stimulation Review

Contract No: W-7405-ENG-36

Contractor: Los Alamos Scientific Laboratory
Albuquerque, New Mexico

Principal Investigator: Thomas McGetchin
(505) 667-7209
FTS 843-7209

Program Manager: David B. Lombard
(202) 376-4902
FTS 376-4902

Project Objective: To develop a history of geothermal well failures.

Funding: FY 75 - --
FY 76/TQ - $ 30K

Contract Term: 7/1/75-9/30/76

Reports Issued: None

Project Title: Stimulation Review

Contract No: W-7405-ENG-36

SUMMARY

In exploring for (or drilling for production) geothermal wells, developers produce numerous "dry holes" that do not produce geofluids at economically attractive rates. The present study will assemble and analyze available data on such wells in the U.S. and abroad in an attempt to characterize the need for a stimulation technology for geothermal wells.

Resource Exploration and Assessment

2.0 RESOURCE EXPLORATION AND ASSESSMENT

The objectives of the Resource Exploration and Assessment subprogram are to improve existing exploration and assessment technology, to accelerate the identification of geothermal resources, to verify their utilization potential, and to apply the technology to the evaluation of candidate geothermal sites. Where a commercial interest is present, resource exploration and assessment activities will be performed by, or in cooperation with, industry.

Exploration technology will encompass development of geophysical sensing devices and techniques for borehole investigation and well log interpretation, as well as techniques for surface and aerial exploration. In developing resource assessment technology, geological and computer models of reservoir and candidate facilities will be constructed. Laboratory experiments will be performed to improve understanding of fluid flow, heat transfer, and chemical reactions in subsurface porous media. Techniques will be developed for performance estimation and risk assessment. Reservoir confirmation will be performed to determine the accuracy of current United States Geological Survey (USGS) estimates and to establish, as required, more reliable estimates of reserves. This will be accomplished by slim-hole drilling, refinement of geological models, and development of data and economic analysis techniques. Any activity involving drilling is considered to be categorized as reservoir confirmation.

2.0 RESOURCE EXPLORATION AND ASSESSMENT

Active Contracts

Project Title: Active Electronics Circuits for High Temperature Instrumentation

Contract No: W-7405-ENG-36

Contractor: Los Alamos Scientific Laboratory
Albuquerque, New Mexico

Principal Investigator: Byron McCormick
(505) 667-7145
FTS 843-7145

Program Manager: Larry Ball
(202) 376-4914
FTS 376-4914

Project Objective: To develop new integrated thermionic circuit (ITC) devices capable of withstanding ambient temperatures in excess of 400°C (750°F).

Funding: FY 75 - --
FY 76/TQ - $212K

Contract Term: 7/1/75-9/30/77

Reports Issued: None

Project Title: Active Electronics Circuits for High Temperature Instrumentation

Contract No: W-7405-ENG-36

SUMMARY

This project will develop a new device called an integrated thermionic circuit (ITC) device which consists of a thermionic photoresist cathode and titanium grid thin films on a sapphire substrate bonded to a heater. Emitted electrons follow a grid-potential controlled trajectory through a vacuum to the anode. The anode is a titanium thin film deposited on a sapphire substrate. The resulting triode amplifier size is about 50 x 50 x 100 mils and has characteristics similar to a vacuum tube triode.

Work commenced in January 1976. Initial efforts included project organization, laboratory set up, and initial tests of capacitor and resistor components of the device, fabricated using various fabrication methods. A cathode configuration was devised which provides nearly uniform emission over the cathode area. A cathode activation station has been designed and constructed. A technician training program has been instituted and is working well.

A subcontract was negotiated with the University of Arizona in Tucson. This program will evaluate and develop metalization and photolithographic techniques and cathode activation procedures. This work will proceed in advance of the new clean room facility being installed at LASL.

In June, the first ITC breadboard was operated in a vacuum chamber at room temperature with a cathode temperature of 720°C. The triode performed exactly as predicted, thus demonstrating the feasibility of the concepts and analytical predictions.

Project Title:	Geothermal Well Logging Development and Demonstration
Contract No:	E(29-1)-0789
Contractor:	Sandia Laboratories Albuquerque, New Mexico
Principal Investigator:	Melvin M. Newsom (505) 264-8920 FTS 875-8920
Program Manager:	Larry Ball (202) 376-4914 FTS 376-4914
Project Objective:	To develop and demonstrate an improved geothermal logging capability using high temperature instrumentation, sondes and cables.
Funding:	FY 75 - -- FY 76/TQ - $375K
Contract Term:	4/1/76-9/30/77
Reports Issued:	None

Project Title: Geothermal Well Logging Development and Demonstration

Contract No: E(29-1)-0789

SUMMARY

Sandia will work with industry to develop state-of-the-art geothermal logging equipment. The equipment will feature high temperature electronics developed at Sandia and improved sondes and logging equipment to be developed by industry under Sandia management. An interim skid-mounted logging unit will be assembled at Sandia using commercially available cable, draw works and instrumentation. The interim unit should be available for testing new and modified sondes during the first quarter of FY 77.

Project Title: Accelerated Testing of Borehole Geophysical Logging Instruments and Development of Log Interpretation in Representative Geothermal Environments

Contract No: E(49-27)-1012

Contractor: U.S. Department of the Interior
Geological Survey
Reston, Virginia

Principal Investigator: W. Scott Keys (Geological Survey, Denver, Colorado)
(303) 234-2617
FTS 234-2617

Program Manager: Larry Ball
(202) 376-4914
FTS 376-4914

Project Objective: Perform laboratory and borehole testing of geothermal logging tools which have been developed by the USGS; obtain analysis of representative core materials in holes logged; and install a digital recording system in the new logging vehicle.

Funding: FY 75 - --
FY 76/TQ - $79K

Contract Term: 6/14/76-11/30/76

Reports Issued: None

Project Title: Accelerated Testing of Borehole Geophysical Logging Instruments and Development of Log Interpretation in Representative Geothermal Environments

Contract No: E(49-27)-1012

SUMMARY

The digital recording system has been ordered. Several logging tools were reworked and improved. New logs were acquired in Long Valley, California, Marysville, Montana, Raft River, Idaho, Los Alamos (Valles Caldera), New Mexico. Some core samples have been acquired and a number of commercial logs for the areas visited are being analyzed. Electrical measurements, supporting this project, will be made by USGS under Contract No. E(49-27)-1013 as reported in section 2.1.2.

Project Title:	Experimental Evaluation of Well Logging Cables
Contract No:	E(04-3)-1208
Contractor:	Systems, Science and Software La Jolla, California
Principal Investigator:	Edward Day (714) 453-0060
Program Manager:	Larry Ball (202) 376-4914 FTS 376-4914
Project Objective:	To evaluate the characteristics of commercially available cables in a laboratory simulator.
Funding:	FY 75 - -- FY 76/TQ - $98K
Contract Term:	2/23/76-1/23/77
Reports Issued:	None

Project Title: Experimental Evaluation of Well Logging Cables

Contract No: E(04-3)-1208

SUMMARY

The first phase of the two phase program will examine the mechanical and electrical characteristics of available logging cables at temperatures up to 350°C at atmospheric pressure. Designs for a full environment chamber for both cables and sondes will be examined.

The second phase goal will be the construction and operation of a full environment chamber capable of mechanical and electrical tests in hot, pressurized and corrosive fluids.

Project Title: The Electrical Properties of Geological Materials as Functions of Temperature, Pressure, and Water Content in Geothermal Environments

Contract No: E(49-27)-1013

Contractor: U.S. Department of the Interior
Geological Survey
Reston, Virginia

Principal Investigator: Gary R. Olhoeft (Geological Survey, Denver, Colorado)
(303) 234-5390
FTS 234-5390

Program Manager: Larry Ball
(202) 376-4912
FTS 376-4912

Project Objective: To measure the electrical properties of geological materials as functions of temperature, pressure, and water content in geothermal environments.

Funding: FY 75 - --
FY 76/TQ - $138K

Contract Term: 7/1/76-12/31/77

Reports Issued: None

Project Title: The Electrical Properties of Geological Materials as Functions of Temperature, Pressure, and Water Content in Geothermal Environments

Contract No: E(49-27)-1013

SUMMARY

In measuring electrical properties of geological materials in geothermal environments, particular emphasis will be placed upon identifying and understanding the mechanisms behind the observed properties, and upon the development of models which describe the observed properties. The resultant models will aid the interpretation of geophysical field data and in the determination of optimum field experiments and techniques for geothermal exploration.

The investigations to be performed during this project are:

1. Measure the electrical properties of representative geothermal materials as functions of frequency, current density, temperature, pressure, and water content. Measurements as a function of frequency will cover at least 10^3 Hz to 10^6 Hz, thereby measuring in the ranges of such field techniques as IP (induced polarization), AMT (audiomagnetotellurics), VLF (airborne and ground very low frequency electromagnetics), and others. Particular emphasis will be placed upon using core samples from known geothermal areas, supporting the activities of USGS under contract number E(49-27)-1012 as reported in Section 2.1.1.

2. Characterize the sample materials as to their porosity, pore size distribution, permeability, specific surface area, and so on.

3. Using the results of previous work, develop a mathematical model to describe the observed electrical properties, and attempt to identify the mechanisms behind those properties.

This work comprises an 18 month program. During the first 6 months laboratory equipment will be acquired and set up. Preliminary measurements on available cores will be made. During the second 6-month period, the full range of parameters will be investigated in detail on one or more samples. Finally, during the last 6-month period, specific phenomena will be examined for particular down-hole environments on a number of samples.

At the present time, the experimental program has been finalized and the procurement procedures have been initiated for the major equipment items. Samples are being acquired and some characterization has begun.

Project Title:	Research on the Physical Properties of Geothermal Rocks
Contract No:	E(11-1)-2908
Contractor:	Colorado School of Mines Golden, Colorado
Principal Investigators:	George R. Pickett (303) 279-0300
	George V. Keller (303) 279-0300
Program Manager:	Larry Ball (202) 376-4914 FTS 376-4914
Project Objective:	To investigate the properties of moist, hot rocks taken from typical geothermal reservoirs.
Funding:	FY 75 - -- FY 76/TQ - $60K
Contract Term:	5/1/76-4/30/77
Reports Issued:	None

Project Title: Research on the Physical Properties of Geothermal Rocks

Contract No: E(11-1)-2908

SUMMARY

Geophysical well surveys have become an essential tool in evaluating the potential productivity of oil and gas wells. If a significant geothermal industry should develop, similar evaluations of many geothermal wells will be needed. The techniques which have proved so effective in the oil and gas industry are largely empirical in nature, and are based on extensive experience and laboratory research. However, the research has been done only for the rock types in which oil and gas are found, and not for many additional rock types in which geothermal fluids are likely to occur. Therefore, the present research will investigate the interrelationships of physical properties, primarily in volcanic rocks, to determine the necessary relationships for interpreting well logs in geothermal wells. Of primary interest in the studies will be rocks saturated with a combination of water and gaseous steam.

Project Title: Downhole Fission Track -- $^{40}K/^{40}Ar$ Age Determinations and the Measurement of Perturbations in the Geothermal Gradient

Contract No: E(45-1)-2229

Contractor: University of Alaska Geophysical Institute
Fairbanks, Alaska

Principal Investigator: Robert B. Forbes
(907) 479-7558

Program Manager: Clayton R. Nichols
(202) 376-4914
FTS 376-4914

Project Objective: To use radiogenic dating methods as an exploration tool to locate geothermal anomalies.

Funding: FY 75 - $242K
FY 76/TQ - --

Contract Term: 6/1/75-5/31/77

Reports Issued: "The Los Alamos Scientific Laboratory's Dry Hot Rock Experiment: Engineering and Scientific Studies," LA-UR-76-658 presented at the 1976 Spring Meeting of the American Geophysical Union, Washington, D.C. April 12-15, 1976

Project Title: Downhole Fission Track -- $^{40}K/^{40}Ar$ Age Determinations and the Measurement of Perturbations in the Geothermal Gradient

Contract No: E(45-1)-2229

SUMMARY

The purpose of this project is to refine and evaluate techniques of radiogenic dating of rocks as a viable geothermal prospecting method. The project will be carried out in the field in Alaska and in New Mexico, where cores from the Los Alamos hot dry rocks project will be used for analysis. United States Geological Survey (USGS) will contribute work in fission track analysis.

At the Eielson hole in central Alaska, K/Ar dates of 120 million years at the surface decrease to 65 million years at a depth of 2970 meters and a temperature of 94.7°C. Apatite fission track dates for the same site decrease from 100 million years at 315 meters to 12 million years at 2970 meters.

Samples from GT-2 at Fenton Hill, New Mexico show a consistent decrease of the biotite K/Ar ages below a depth of 2580 meters. From the surface to 2580 meters an age of 1.4 billion years is obtained but below that depth the apparent ages decrease to 1.26 billion years at 2900 meters where the present temperature is 197°C. Apatite fission track dates at the surface of 240 million years decrease to 69 million years at 790 meters depth and yield apparent ages of 0 years and 1880 meters and 135°C.

Project Title: Lineament Analysis as an Exploration Technique for Geothermal Energy

Contract No: E(26-1)-0671

Contractor: Nevada Bureau of Mines and Geology
University of Nevada at Reno
Reno, Nevada

Principal Investigator: Dennis T. Trexler
(702) 784-6691

Program Manager: Clayton R. Nichols
(202) 376-4914
FTS 376-4914

Project Objective: To conduct a study of the relationship between hot springs and structural lineaments in northern Nevada and to evaluate, in a general sense, the usefulness of lineament analysis as a reconnaissance technique for geothermal exploration.

Funding: FY 75 - --
FY 76/TQ - $27K

Contract Term: 6/15/76-6/14/77

Reports Issued: None

Project Title: Lineament Analysis as an Exploration Technique for Geothermal Energy

Contract No: E(26-1)-0671

SUMMARY

The Nevada Bureau of Mines and Geology will utilize existing aircraft and spacecraft photography to determine the relationship between geothermal activity as expressed by hot springs and structural trends in an extensively studied region of north central Nevada, the Battle Mountain area. The high altitude U2 low-sun-angle photography of the Battle Mountain area, flown by NASA at the request of Lawrence Berkeley Laboratory will be utilized for the initial lineament study together with the coverage by Landsat (ERTS) imagery. Specific lithologic and tectonic relationships to be investigated include relationships of late Cenozoic normal faulting, regional structures and lineaments, recent volcanic activity and zones of hydrothermal alteration to present and past hot spring activity.

Project Title: Radiogenic Heat Source Reservoir Assessment

Contract No: W-7405-ENG-36

Contractor: Los Alamos Scientific Laboratory
Los Alamos, New Mexico

Principal Investigator: M. C. Smith
(505) 667-4733
FTS 843-4733

Program Manager: Clayton R. Nichols
(202) 376-4914
FTS 376-4914

Project Objective: To examine and characterize the possible geothermal resources of the Eastern U.S., with special emphasis on radiogenic heat sources.

Funding: FY 75 - --
FY 76/TQ - $ 80K

Contract Term: 7/1/75-9/30/77

Reports Issued: None

Project Title: Radiogenic Heat Source Reservoir Assessment

Contract No: W-7405-ENG-36

SUMMARY

The focus of the former "Normal Gradient Program" has been redirected to the characterization of the possible geothermal resources of the U.S. East, with emphasis on radiogenic heat sources. The initial research is being conducted by several universities, and includes heat flow measurements, geologic mapping, and analyses of warm spring hydrology. The task of LASL is to assist Headquarters and the various contractors as technical consultant and coordinator.

Projects have been initiated through Universities and State Geological Surveys in New York, New Hampshire, Virginia and West Virginia. Coordination with other Federal agencies interested in radioisotope distribution has included the total gamma and temperature logging of the Conway granite hole by the Water Resources Division of the United States Geological Survey.

Project Title: Reservoir Analysis and Modeling

Contract No: W-7405-ENG-48

Contractor: Lawrence Livermore Laboratory
Livermore, California

Principal Investigator: J. S. Kahn
(415) 447-1100, Ext. 8793
FTS 457-8793

Program Manager: Clayton R. Nichols
(202) 376-4914
FTS 376-4914

Project Objective: To develop and evaluate methods for reservoir analysis and modeling for geothermal deposits, particularly the hot brines such as those of the Salton Trough in California.

Funding: FY 75 - $600K
FY 76/TQ - $585K

Contract Term: 7/1/74-9/30/77

Reports Issued: Donald Towse, "An Estimate of the Geothermal Energy Resource in the Salton Trough, California," Lawrence Livermore Laboratory (June 18, 1975)

T. D. Palmer, J. H. Howard, D. P. Lande, "Geothermal Development of the Salton Trough, California and Mexico," Lawrence Livermore Laboratory (April 1, 1975)

A. L. Austin et al., "The Lawrence Livermore Laboratory Geothermal Energy Development Program Status Report, January 1975 through August 1975," Lawrence Livermore Laboratory (September 1975)

Project Title: Reservoir Analysis and Modeling

Contract No: W-7405-ENG-48

SUMMARY

The purpose of the project is to develop and apply techniques for reservoir analysis and modeling of geothermal resources, particularly the hot brines such as those of the Salton Trough in California. Geologic, geophysical, and geochemical data will be collected from industry, governmental and academic sources and will be supplemented by additional studies as required. This data base on the geothermal resource in the Salton Trough will be utilized for the refinement of predictions of reservoir behavior and production characteristics. Improved reservoir analysis techniques will be developed and applied to the prediction of flow rates, fluid enthalpy and useful lifetime of the geothermal resources.

Available geologic data for the Salton Trough has been analyzed, and additional geologic structural information has been acquired through contracted refraction seismic surveys in the vicinity of the Niland sites. Electric log cross-sections have been prepared which indicate the general vertical and lateral distribution of the sand units which constitute the geothermal reservoirs. The location of the major fault zones has been more accurately determined.

Preparation of a "case study" for publication is now in progress. It will include articles of the development of the Salton Sea Geothermal Field, including brine chemistry, reservoir engineering economics and surface exploration.

Project Title: Reservoir Engineering Support

Contract No: E(10-1)-1375

Contractor: Idaho National Engineering Laboratory
Idaho Falls, Idaho

Principal Investigator: Roger Stoker
(202) 522-6640 ext 1781
FTS 583-1781

Program Manager: Clayton R. Nichols
(202) 376-4914
FTS 376-4914

Project Objective: To utilize geothermal wells at Raft River and Boise, Idaho, for the field testing of geothermal reservoir evaluation techniques.

Funding: FY 75 - --
FY 76/TQ - $150K

Contract Term: 7/1/76-9/30/77

Reports Issued: None

Project Title: Reservoir Engineering Support

Contract No: E(10-1)-1375

SUMMARY

The number of producing geothermal wells available for field testing of reservoir evaluation techniques in a research mode is limited. Three wells in the Raft River, Idaho area will be subjected to flow testing, brine injection tests and additional logging. Wells at Boise, Idaho, drilled in connection with the Boise Demonstration Space Heating Project (reported in section 3.2) will also be tested and evaluated. The results of these studies will aid technique refinement as well as provide an input to the location of additional holes.

Project Title:	Hydrothermal Moderate Temperature Conductive System (Low Salinity)
Contract No:	W-7405-ENG-48
Contractor:	Lawrence Berkeley Laboratory Berkeley, California
Principal Investigators:	Paul A. Witherspoon (415) 843-2740, Ext. 5082 FTS 451-5082
	Frank Morrison (415) 642-3804 (Univ. of California, Berkeley, Calif.) FTS 451-5635
Program Manager:	Larry Ball (202) 376-4914 FTS 376-4914
Project Objective:	To advance the development of geothermal resource assessment technology by the multiple application of geological, geochemical, and geophysical techniques to a moderate temperature, low salinity hydrothermal reservoir and by pursuit of a supporting research and development program involving both field and laboratory reservoir engineering technology.
Funding:	FY 75 - $ 839K FY 76/TQ - $1,206K
Contract Term:	7/1/74-9/30/77
Reports Issued:	H. A. Wollenberg, et. al., "Geothermal Energy Resource Assessment," Lawrence Berkeley Laboratory report UCID-3762 (July 1975)

Project Title: Hydrothermal Moderate Temperature Conductive System (Low Salinity)

Contract No: W-7405-ENG-48

SUMMARY

The field work in developing geothermal resource assessment technology will be performed in three valleys of northern Nevada, namely: Buffalo (Buffalo Hot Springs), Grass (Leach Hot Springs), and Buena Vista (Kyle Hot Springs). Laboratory work will be accomplished in the Lawrence Berkeley Laboratory and on the University of California campus. The primary goal in FY 75 is to select a site. Program objectives will be extending the field exploration of the three sites under study using a variety of geophysical and geochemical methods, and research and development programs to enhance the methodology for predrilling geologic understanding of geothermal reservoirs.

Field exploration utilizes both geophysical and geochemical methods and will serve the purposes of locating a reservoir confirmation site, furthering the development of equipment, and improving detection methodology and data analysis.

The initial phase of field work at the three northern Nevada sites is essentially complete with the exception of some supplemental heat flow work. An area in Grass Valley north of Kyle Hot Springs has been identified by various geophysical techniques as a probable geothermal reservoir. The geochemical thermometers indicate a moderate base level temperature (160-180°C) for the reservoir. The spatial distribution and probable depth of the reservoir has been modeled in terms of apparent resistivity, gravity, and seismic velocity data. In Buffalo Valley a diffuse, lower temperature hot water reservoir has been modeled on the basis of the geophysical and geochemical data. Microearthquake surveys have indicated a number of fault zones which are seismically active.

The Program Manager held an informal review of the program results as of December 1975. LBL has developed an impressive exploration capability which includes passive and active seismics, geochemistry, radioisotope analysis, d.c. resistivity, tellurics, magneto tellurics, self potential, and geology. Ongoing efforts will concentrate primarily on Grass Valley with some technique confirmation work in other areas such as the California areas of East Mesa, Long Valley, Roosevelt Hot Springs, and Coso.

Project Title: Cerro Prieto Data Compilation

Contract No: W-7405-ENG-48

Contractor: Lawrence Berkeley Laboratory
Berkeley, California

Principal Investigator: Paul Witherspoon
(415) 843-2740, Ext. 5082
FTS 451-5082

Program Manager: Clayton R. Nichols
(202) 376-4914
FTS 376-4914

Project Objective: To provide the geothermal industry with a complete data base for the Cerro Prieto geothermal field.

Funding: FY 75 - --
FY 76/TQ - $75K

Contract Term: 5/1/76-9/30/77

Reports Issued: None

Project Title: Cerro Prieto Data Compilation

Contract No: W-7405-ENG-48

SUMMARY

The Cerro Prieto geothermal field located in Baja California, Mexico, has the same geologic setting as the systems found in the neighboring Imperial Valley. Cerro Prieto has been producing 75 MW of electric power for more than 3 years, while the California fields are still in the exploration and development stages. This provides the rare opportunity to be able to predict the approximate future behavior of the presently undeveloped Imperial Valley geothermal fields by studying the past and future response of the Cerro Prieto reservoir to fluid production. Presently, Cerro Prieto has about 30 production wells, 15 of which are supplying the steam for the 75 MW power plant. In the near future, drilling of new production and stand-by wells will begin in order to provide steam to the new power plants. Before the end of 1977, a new 75 MW plant is expected to be on line and in mid 1982, the total power generated at Cerro Prieto will reach 400 MW.

Data collection has already begun. The information is being obtained from the records and unpublished internal reports kept at Mexicali, Baja California, by the Mexican Comision Federal de Electricidad which is in charge of the Cerro Prieto project. The collected data can be divided into five categories:

a) Geology: Geologic maps, lithologic columns; electric well logs; preliminary cross-sections.

b) Geophysics: Resistivity, aeromagnetic and gravimetry surveys.

c) Geochemistry: Chemical analysis of separated water, non-condensable gases and casing incrustations.

d) Hydrogeology: Regional maps of ground water levels and chemical composition of shallow ground water.

e) Reservoir engineering: Temperature and pressure profiles measured in wells under various flowing conditions; well head temperature and pressure history of several wells; cumulative fluid production data; construction characteristics of most wells; small number of core analyses.

The information presently being gathered will result in a better understanding of the geologic structure of the field with respect to the transfer of heat and fluids within the reservoir and across its boundaries.

Project Title: A Comprehensive Laboratory Study of Samples from Natural Hydrothermal Systems

Contract No: E(49-27)-1005

Contractor: U.S. Department of the Interior
Geological Survey
Reston, Virginia

Work Performed by: University of California, Riverside
Riverside, California

Principal Investigators: P. R. L. Browne
(714) 787-1012

W. A. Elders
(714) 787-1012

Program Manager: Clayton R. Nichols
(202) 376-4914
FTS 376-4914

Project Objective: Establish a laboratory facility capable of the rapid, detailed, mineralogical examination of hydrothermally altered rock samples from geothermal zones.

Funding: FY 75 - $ 82K
FY 76/TQ --

Contract Term: 6/25/75-12/25/76

Reports Issued: None

Project Title: A Comprehensive Laboratory Study of Samples from Natural Hydrothermal Systems

Contract No: E(49-27)-1005

SUMMARY

The project is a joint ERDA/DGE-USGS program for the development of a laboratory facility capable of comprehensive analysis of rock samples from natural hydrothermal systems. The project will adapt equipment originally utilized in the analysis of samples from the JOIDES deep sea drilling program to the analysis of hydrothermally altered samples.

The Pickering automated XRD unit has been calibrated and reprogrammed to the extent that automated analysis of most minerals routinely encountered in hydrothermally altered rock samples is possible. Programming to extend the capability to include specific zeolites and clay minerals is continuing. Cores and cuttings analyzed to date have been largely from hydrothermal systems in sedimentary environments, i.e., Imperial Valley.

Project Title: Coso and Other Site Assessment Studies

Contract No: E(49-27)-1009

Contractor: U.S. Department of the Interior
Geological Survey
Reston, Virginia

Principal Investigator: Richard Fiske
(703) 860-6584
FTS 928-6584

Program Manager: Clayton R. Nichols
(202) 376-4914
FTS 376-4914

Project Objective: To obtain resource data relevant to a number of ongoing, site specific reservoir studies sponsored by ERDA.

Funding: FY 75 - --
FY 76/TQ - $90K

Contract Term: 6/1/76-9/30/76

Reports Issued: None

Project Title: Coso and Other Site Assessment Studies

Contract No: E(49-27)-1009

SUMMARY

This research is directed towards topics and sites of mutual interest to ERDA and the USGS. The field sites are at locations where ERDA/DGE is sponsoring or plans to sponsor work. They include the Imperial Valley, Snake River Plain, Coso, Aeolian Buttes, Raft River, the Geysers and northern Nevada. The present funding level of these projects will probably not provide results soon enough to enhance the success of the ERDA sponsored work. The proposed funding is designed to support additional field work during the 1976 summer field season. This accelerated work schedule should provide more timely results.

The proposed studies will attempt to investigate conditions several kilometers beneath the earth's surface. Geoscience studies at the proposed sites have, in general, been directed at surface or near surface manifestations. Reservoirs in these areas, if they exist, will most likely be located at a greater depth.

Project Title:	Analysis of Geothermal Energy in Eastern United States
Contract No:	E(49-27)-1008
Contractor:	U.S. Department of the Navy Naval Sea Systems Command Arlington, Virginia
Work Performed by:	Applied Physics Laboratory Johns Hopkins University Laurel, Maryland
Principal Investigator:	A. M. Stone (301) 953-7100, ext. 3037
Program Manager:	J. W. Salisbury (202) 376-4914 FTS 376-4914
Project Objective:	To survey geothermal resources in the Eastern United States and study potential utilization scenarios.
Funding:	FY 75 - -- FY 76/TQ - $75K
Contract Term:	4/1/76-9/30/76
Reports Issued:	None

Project Title: Analysis of Geothermal Energy in Eastern United States

Contract No: E(49-27)-1008

SUMMARY

This project is designed to provide both a survey of geothermal resources in Region 5 (all of the states east of the Mississippi, excluding Texas and Louisiana), and a study of potential utilization scenarios. Thus, upon identification of a potential resource in Region 5, regional consultation and planning will identify potential customers. Efforts will be made to match resource quality, such as temperature and salinity, to customer requirements. Where good matches are not apparent, steps necessary to transform the resource (such as by raising its temperature with a heat pump) will be evaluated.

Project Title: Utilization of Seismic Exploration Technology for High Resolution Mapping of a Geothermal Reservoir

Contract No: E(04-3)-1249

Contractor: Systems, Science and Software
La Jolla, California

Principal Investigator: Pierre Goupillaud
(714) 453-0060

Program Manager: Clayton R. Nichols
(202) 376-4914
FTS 376-4914

Project Objective: To evaluate the capabilities of seismic reflection profiling utilizing P and S wave VIBROSEIS sources in determining the detailed geologic structure and fracture porosity of geothermal reservoirs in the Imperial Valley, California.

Funding: FY 75 - --
FY 76/TQ - $170K

Contract Term: 4/16/76-2/16/77

Reports Issued: None

Project Title: Utilization of Seismic Exploration Technology for High Resolution Mapping of a Geothermal Reservoir

Contract No: E(04-3)-1249

SUMMARY

Since geothermal projects involving major site construction efforts are planned or under study at a number of Imperial Valley sites (Niland, East Mesa, Heber and elsewhere), there is an urgent need for the development and application of pre-drilling techniques for the detailed determination of geologic structure and reservoir conditions. The study will apply a proven petroleum exploration technique, P wave reflection seismic profiling, to a carefully selected Imperial Valley site. Specific portions of the P wave lines will be chosen for the S wave experiment. By the estimation of Vp/Vs from the reflection data, an attempt will be made to detect variations in high pressure, fluid-filled porosity in the producing zones.

One month of contracted P wave reflection profiling will be timed to coincide with availability of Continental Oil Company's (CONOCO) S wave VIBROSEIS unit. Systems, Science and Software will be responsible for the overall coordination of the project including planning and supervision of the field work and synthetic interpretation of the data. In addition to the experimental reservoir aspects of the combined P and S wave study, the field investigation will produce detailed structural information which will be of immediate value to planned resource utilization efforts at the study sites.

Project Title:	Evaluation of Geothermal Energy Exploration and Resource Assessment
Contract No:	E(04-3)-1269
Contractor:	R&D Associates Marina del Rey, California
Principal Investigators:	John G. Lewis (213) 822-1715
	Ernest E. Martinelli (213) 822-1715
Program Manager:	J. W. Salisbury (202) 376-4914 FTS 376-4914
Project Objective:	To assess the present state of numerical modeling as applied to geothermal reservoirs and to identify critical research needs in supportive technologies relevant to reservoir measurements.
Funding:	FY 75 - -- FY 76/TQ - $97K
Contract Term:	5/3/76-12/3/76
Reports Issued:	None

Project Title: Evaluation of Geothermal Energy Exploration and Resource Assessment

Contract No: E(04-3)-1269

SUMMARY

The modeling of a potential geothermal reservoir represents an attempt to develop all available information concerning the site in question into a single coherent picture from which predictions can be made of the most effective utilization procedure, and the effects of utilization on the reservoir itself.

The utilization of a geothermal resource at the ground surface will, of necessity, entail a depletion of the resource at the reservoir level. Thus, utilization implies a disturbance of initial conditions existing at depth. As this disturbance may decrease the utility of the reservoir (as by compaction and reduced permeability), or pose an environmental hazard, it is highly important that reservoir models and modeling procedures be carefully evaluated.

This study will assess the present state of geothermal reservoir modeling techniques, identifying critical parameters where additional information is needed to reduce modeling uncertainties. The nature, availability and proper use of instrumentation appropriate for acquisition of critical parameters will be investigated.

Project Title: Terrestrial Heat Flow Studies in Arizona

Contract No: E(29-2)-3721

Contractor: New Mexico Bureau of Mines and Mineral Resources
New Mexico Institute of Mining and Technology
Socorro, New Mexico

Principal Investigator: Marshall Reiter
(505) 835-5306

Program Manager: Clayton R. Nichols
(202) 376-4914
FTS 376-4914

Project Objective: To conduct terrestrial heat flow studies in Arizona by which the surface heat flux pattern and regional geothermal trends may be better outlined and areas of regional geothermal potential defined.

Funding: FY 75 - --
FY 76/TQ - $32K

Contract Term: 5/1/76-4/30/77

Reports Issued: None

Project Title: Terrestrial Heat Flow Studies in Arizona

Contract No: E(29-2)-3721

SUMMARY

Several anomalously high heat flow areas in western New Mexico appear to extend into Arizona. Preliminary data also suggests low heat flow areas in the Colorado Plateau and the Basin and Range portions of Arizona. The scarcity of data at present, however, has prevented the accurate definition of heat flow provinces within Arizona. Heat flow studies will better define the surface heat flux pattern and will suggest regional geothermal trends and areas of regional geothermal potential.

Heat flow measurements will be made utilizing existing holes. The holes will be selected from among those holes owned by oil or gas companies for which permission can be obtained to log and publish the results of the thermal measurements. Approximately 25 to 50 heat flow measurements will be made during the course of the total program (30 months). It is anticipated that at least 15 of these would be reduced heat flow measurements.

Project Title:	Development of Criteria Useful in the Detection of Low Permeability Geothermal Systems
Contract No:	E(11-1)-2763
Contractor:	University of Arizona Tucson, Arizona
Principal Investigator:	Denis Norton (602) 884-1419
Program Manager:	David B. Lombard (202) 376-4902 FTS 376-4902
Project Objective:	To develop exploration criteria for the assessment and evaluation of low permeability geothermal resources.
Funding:	FY 75 - $133K FY 76/TQ - $ 11K
Contract Term:	6/20/75-6/19/77
Reports Issued:	None

Project Title: Development of Criteria Useful in the Detection of Low Permeability Geothermal Systems

Contract No: E(11-1)-2763

SUMMARY

Geologic evidence suggests the presence of young intrusive igneous bodies, some possibly at readily attainable depths, in the Basin and Range Province of Arizona, a region with no recognized geothermal resources. The investigator believes, on the basis of data on subsurface fluid circulation, hydrothermal mineral alteration, and heat transfer in the upper crust, that the intrusive thermal source must have associated hydrothermal systems which, though low in power production potential, would serve as clues to the location of the intrusive thermal source.

A mathematical model for the analysis of the relationships between the basaltic plutonic intrusives and associated hydrothermal convective systems will be developed, incorporating data on the temperature, depth, composition, and movement of hydrothermal fluids in the Province. Conclusions may then be drawn as to the location, depth, age and temperature of possible hot dry rock geothermal targets.

The investigator will first prepare generalized geologic cross-sections of typical Basin-and-Range plutonic intrusives from existing geologic and geophysical information. From the cross-sections, initial and boundary conditions for the model will be established.

The model will then be constructed on the basis of existing programs describing dispersion of thermal energy from igneous subterranean sources in two dimensions. The inclusion of rock permeability, adjustable as a function of position, will add considerable geologic "reality." Single phase fluid properties such as viscosity, density, heat content, and coefficient of thermal expansion, all as functions of temperature and pressure, will be incorporated in the model. Existing software will be adapted to predict the intrinsic electrical resistivity throughout the model domain.

Calculation of the rate of cooling of the intrusive bodies will establish the maximum age at which they would still represent viable geothermal resources for different sets of cooling conditions. Other calculations of such parameters as heat flux, temperature versus depth, electrical resistivity, and water composition, will provide useful guides for interpretation of field data gathered in the search for hot dry rock resources.

Project Title:	Feasibility Study of the Conway Granite as a Geothermal Energy Resource
Contract No:	E(11-1)-2686
Contractor:	University of Maine at Orono Orono, Maine
Principal Investigator:	Philip H. Osberg (207) 581-2718
Program Manager:	Clayton R. Nichols (202) 376-4914 FTS 376-4914
Project Objective:	To determine whether the strongly radioactive Conway granite constitutes a source of useful geothermal heat and to quantify this source.
Funding:	FY 75 - $ 51K FY 76/TQ - --
Contract Term:	6/1/75-5/31/77
Reports Issued:	None

Project Title: Feasibility Study of the Conway Granite as a Geothermal Energy Resource

Contract No: E(11-1)-2686

SUMMARY

The White Mountain batholith is targeted as a possible source of geothermal heat. Under this proposal: (1) the pertinent geological and geophysical information will be assembled and collated; (2) additional gravity measurements will be obtained and these along with existing gravity, aeromagnetic, and radioactivity data will be analyzed to obtain a model of the three dimensional shape of the batholith consistent with the geology; (3) the hypothesis that the biotite granite and the amphibole granite are products of a continuous crystallization process will be tested and the external conditions at which the radioactive elements were fixed in minerals will be investigated; (4) chemical determinations of uranium, thorium, and potassium will be made to expand the existing data on radioactivity and these data will be used to determine the distribution of radioactivity with position in the batholith; and (5) the geological and geophysical models will be used with existing heat flow data to estimate the temperature within the batholith.

Project Title:	Deep Heat-Flow and Fracturing Tests in Conway Granite, New Hampshire
Contract No:	E(11-1)-2720
Contractor:	University of New Hampshire Durham, New Hampshire
Principal Investigator:	Glenn W. Stewart (603) 862-1216
Program Managers:	Clayton R. Nichols (ERDA) (202) 376-4914 FTS 376-4914 Bill Laughlin (LASL) (505) 667-7077 FTS 843-7077
Project Objective:	To determine the natural heat flow in strongly radioactive portions of Conway granite at greater depths (circa 3000 feet) than those for which heat flow has been measured; to conduct limited hydraulic fracturing tests.
Funding:	FY 75 - $165K FY 76/TQ - --
Contract Term:	6/1/75-6/30/77
Reports Issued:	None

Project Title: Deep Heat-Flow and Fracturing Tests in Conway Granite, New Hampshire

Contract No: E(11-1)-2720

SUMMARY

New Hampshire has numerous areas where radiogenic heat in the Conway Granite, one of the most radioactive granite rocks known, could constitute a geothermal heat source. The proposed work seeks to determine the natural heat flow in strongly radioactive portions of Conway granite at greater depths (circa 3000 feet) than those for which heat flow has been measured.

In addition to assessing the geothermal gradient, the borehole will be used to:

1. Locate the jointing and shear zones by geophysical logging with an induced gamma gamma-neutron probe.

2. Determine the natural radiation of the borehole and the core with a gamma radiation probe.

The core will be available for: (1) chemical, spectrochemical, geophysical and other analyses; and (2) for preparing thin sections to study the petrographic characteristics of the Conway Granite.

A site was selected at the town of Conway within the abandoned Redstone Quarry for initial test drilling. A 2-7/8" hole with a total depth of 3003' was completed by a commercial contractor in early December 1975. A 98% recovery of 1-7/8" core was obtained and the core is being described by University of New Hampshire geologists. A number of hydrothermally altered zones were encountered.

Project Title: Investigation of Two Areas in New York State Which May Have Potential for Geothermal Energy

Contract No: E(11-1)-2694

Contractor: University of the State of New York
Albany, New York

Principal Investigator: Yngvar W. Isachsen
(518) 457-3300

Program Manager: Clayton R. Nichols
(202) 376-4914
FTS 376-4914

Project Objective: Two potential areas for dry hot rock geothermal energy in New York will be studied.

Funding: FY 75 - $ 60K
FY 76/TQ - --

Contract Term: 5/1/75-12/31/76

Reports Issued: None

Project Title: Investigation of Two Areas in New York State Which May Have Potential for Geothermal Energy

Contract No: E(11-1)-2694

SUMMARY

Two potential areas for dry hot rock geothermal energy in New York State will be studied as follows:

1. The Adirondack Mountains dome, which has been undergoing vertical uplift along its eastern flank, will be releveled across its axis by the National Geodetic Survey as part of this research project. The investigators will evaluate the results in terms of possible contemporary doming of the Adirondacks as a whole. At the center of the dome is Blue Mountain Lake, site of recurrent swarm-type earthquakes. The investigators will study the surface trace of the fault plane involved in detail by geological, magnetic and gravity mapping.

2. An anomalous circular drainage feature in the Catskill Mountains, which shows prominently on LANDSAT imagery, will be investigated in terms of bedding altitude, photolinears which approach but do not pass through the structure, gravity, magnetics, scintillometry, and seismic monitoring. If the structure is one of increased volume, such as a gentle dome, and is characterized by attenuated P and S waves, thermal expansion and a thermal source at depth will be suspected.

A first order leveling line across the Adirondack Mountains Dome has been resurveyed and preliminary results indicate a doming at a rate of 3.76 mm/year. The stratigraphy of adjacent areas is being examined in an attempt to date the doming. Chemical samples have been obtained from Blue Mountain Lake in the vicinity of recurrent, swarm-type earthquakes and are being analyzed in order to determine if gases or thermal brines are being released under water. East-West and North-South gravity profiles across the study area in the Catskill Mountains indicate a major gravity low.

Project Title: A Secondary Recovery Method for the Extraction of Geothermal Energy

Contract No: E(45-1)-2227

Contractor: Oregon State University
Corvallis, Oregon

Principal Investigator: Gunnar Bodvarsson
(503) 754-0123

Program Manager: Glayton R. Nichols
(202) 376-4914
FTS 376-4914

Project Objective: To investigate the possibility of using permeable basaltic dikes and other suitable structures as fluid conductors for extraction of low-to-medium temperature thermal energy in regions with above normal heat flow.

Funding: FY 75 - $ 50K
FY 76/TQ - --

Contract Term: 6/20/75-6/30/77

Reports Issued: Gunnar Bodvarsson, "A Secondary Recovery Method for the Extraction of Geothermal Energy--Annual Progress Report, for period July 1, 1975-June 1, 1976," Oregon State University report RLD-2227-T21-1 (July 1976)

Project Title: A Secondary Recovery Method for the Extraction of Geothermal Energy

Contract No: E(45-1)-2227

SUMMARY

This project addresses a special secondary method for extraction of geothermal energy from hot rock. In regions of above normal heat flow and where permeable basaltic dikes are present, it is proposed that the dike be used as a fluid conductor by drilling boreholes to intersect the dike at two different depth levels and circulating water down the deeper holes and up the shallower ones. Preliminary studies of a system of this type have been encouraging.

In many thermal areas dikes appear to be more important to vertical conduction of fluid than faults. Moreover, dikes are extensive structures that are readily located. The downward continuation of their position presents little difficulty. Using such dikes as fluid conductors in heat extraction projects would probably alleviate the problems of artificial fracturing and the siting of boreholes that are so critical to other hot rock projects. On the other hand, basaltic dikes of sufficient permeability have the disadvantage that their occurrence is generally restricted to volcanic areas such as the Tertiary sections of the flood basalts of Iceland, and other flood basalt areas such as the Columbia Plateau and other Cenozoic volcanic areas in the Pacific Northwest.

The present project has involved field observations, both in the United States and in Iceland, and theoretical investigations. The emphasis is on the theory, mainly on the thermoelastic, heat transfer, and fluid flow modeling of the heat extraction processes. The effort will also include planning of relevant field experiments, which would constitute the logical follow-up to the field determinations of permeability conditions and theoretical modeling of the present project.

A field investigation of the role of dikes in providing vertical permeability for hydrothermal fluid circulation has been completed in the Columbia Plateau province. All outcropping dikes which were visited in the region turned out to be heavily fragmented and altered. There was no possibility of obtaining useful data on the hydrologic properties of fractures within or along the dikes. The Eyjafjordur region of North-Central Iceland was visited during June 1976. There appears to be little doubt that all the hot springs in the region are controlled by mafid dikes. Computer modeling of fluid injection into nonuniform temperature fields and injection at nonuniform rates is nearing completion.

Project Title: U.S. Gulf Coast Geopressured Geothermal Aquifer Simulation

Contract No: E(40-1)-5040

Contractor: University of Texas at Austin
Austin, Texas

Principal Investigator: Roy M. Knapp
(512) 471-5393

Program Manager: Keith Westhusing
(202) 376-4902
FTS 376-4902

Project Objective: To develop a mathematical model to simulate the behavior under production conditions of Gulf Coast geopressured geothermal aquifers.

Funding: FY 75 - --
FY 76/TQ - $175K

Contract Term: 2/1/76-1/31/77

Reports Issued: None

Project Title: U.S. Gulf Coast Geopressured Geothermal Aquifer Simulation

Contract No: E(40-1)-5040

SUMMARY

The Gulf Coast of Texas is underlain by sandstone reservoirs containing low salinity hot water under great pressure. In addition, the water probably contains significant amounts of dissolved methane. This geothermal resource, if present in sufficient quantities for production, has great potential in one of the country's major energy-consuming areas. The proposed research will develop computer programs which simulate the behavior of Gulf Coast geopressured geothermal aquifers.

Two separate but related models will be developed. The first will be based on the momentum equations governing fluid flow in the geopressured aquifers. Such a model should be adequate for estimating the early depletion behavior of the aquifers. The second model will include the effects of thermal and kinetic energy transport in the geopressured aquifers. This additional complexity will be required to model the long-term behavior of the geopressured geothermal aquifers. Both types of models will include the effects of pore collapse due to fluid withdrawal on reservoir parameters and account for reservoir heterogeneity and anisotropy. The University of Texas at Austin will be supported in this research program by Systems, Science and Software, Inc., La Jolla, California, under subcontract.

The models developed during this project will be used with reservoir parameter estimates to perform studies to estimate the ultimate recovery of useful energy from geopressured aquifers under various operating strategies. Such studies will be necessary to plan performance tests for pilot plant operations and to refine estimates of the recovery from geopressured aquifers as additional data become available.

The investigations are to be cooperatively coordinated with all of the geopressured geothermal programs of the University of Texas at Austin and the Louisiana State University at Baton Rouge as reported in Section 4.1.



Project Title:	Reconnaissance Geothermal Resource Assessment of the Rio Grande Valley, Trans-Pecos, Texas
Contract No:	E(40-1)-5106
Contractor:	Bureau of Economic Geology University of Texas at Austin Austin, Texas
Principal Investigator:	Charles G. Groat (512) 471-1534
Program Manager:	Clayton R. Nichols (202) 376-4914 FTS 376-4914
Project Objective:	To conduct a reconnaissance level evaluation of the geothermal potential of the Rio Grande Valley between El Paso, Texas and Big Bend National Park, utilizing geologic mapping, geochemical thermometry and gravity surveys.
Funding:	FY 75 - -- FY 76/TQ - $54K
Contract Term:	6/1/76-5/30/77
Reports Issued:	None

Project Title: Reconnaissance Geothermal Resource Assessment of the Rio Grande Valley, Trans-Pecos, Texas

Contract No: E(40-1)-5106

SUMMARY

The presence of hot springs and hot wells along the Texas portion of the Rio Grande Valley indicate that the thermal anomaly associated with the "Rio Grande Rift" in New Mexico and Colorado extends southward into Texas. Numerous hot springs occur along the margins of this graben system in Texas and they appear to be related to the major graben-boundary faults. The first phase of the investigation will involve the synthesis of published reports, maps, unpublished thesis dissertations and open file reports available for the area. Particular attention will be given to apparent structural control of the hot springs and the igneous rocks of the area, and a gravity survey will be planned. A field phase will involve the sampling of hot springs and wells for chemical analysis, gravity work and detailed geologic mapping of the spring area. The data acquired during the investigation will be interpreted together with geophysical data available from the USGS Water Resources Division in its studies of west Texas ground-water basins. A report will be prepared for the investigation which will include recommendations for subsequent studies of specific areas which appear to have a potential for geothermal development.

Project Title: Evaluation and Targeting of Geothermal Energy Resources in the Southeastern United States

Contract No: E(40-1)-5103

Contractor: Virginia Polytechnic Institute and State University

Principal Investigators: John K. Costain
(703) 951-6310

L. Glover III
(703) 951-6310

A. K. Sinha
(703) 951-6310

Program Manager: Clayton R. Nichols
(202) 376-4914
FTS 376-4914

Project Objective: To develop and apply a methodology for targeting radiogenically-derived geothermal reservoirs in the Southeastern United States.

Funding: FY 75 - --
FY 76/TQ - $231K

Contract Term: 5/1/76-10/31/76

Reports Issued: None

Project Title: Evaluation and Targeting of Geothermal Energy Resources in the Southeastern United States

Contract No: E(40-1)-5103

SUMMARY

The optimum sites for geothermal development in the eastern United States will probably be associated with areas of relatively high heat flow derived from crustal igneous rocks containing relatively high concentrations of radiogenic heat-producing elements. Commercially exploitable reservoirs will occur where crustal radiogenic heat sources are overlain by poorly conductive sediments containing favorable reservoir conditions. In order to systematically locate these sites, a methodology employing geological, geochemical and geophysical techniques is being developed and applied.

The initial phase of the investigation has been aimed at developing a methodology for locating radiogenic heat sources buried beneath the insulating sedimentary rocks of the coastal plain of South Carolina, North Carolina, and Virginia. Preliminary results of the temperature gradient and thermal conductivity measurements in 20 existing holes in South Carolina indicate that coastal plain conditions are optimum for shallow, radiogenically related hot water production. The average observed gradient measured was approximately 30^{o}C/kilometer. Measured thermal conductivities are sufficiently low that even a buried radiogenic source with a low concentration of heat-producing elements will provide sufficient heat for an accessible low temperature reservoir. The radiogenic distribution within the igneous rocks of various ages and magma types will be determined by a correlation between radioelement composition and the rocks bulk chemistry.

Project Title:	A Reconnaissance Study of Mine-Water Temperatures in Hardrock Mining Districts of Montana
Contract No:	E(45-1)-2426*
Contractor:	Montana College of Mineral Science and Technology Butte, Montana
Principal Investigator:	John L. Sonderegger (406) 792-8321, ext. 241
Program Manager:	Clayton R. Nichols (202) 376-4914 FTS 376-4914
Project Objective:	To conduct a reconnaissance evaluation of anomolous temperatures in western Montana through investigations of mine-water temperature and water chemistry.
Funding:	FY 75 - -- FY 76/TQ - $20K
Contract Term:	5/15/76-5/14/77
Reports Issued:	None

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* This project encompasses Task Agreement No. 2 under the referenced contract.

Project Title: A Reconnaissance Study of Mine-Water Temperatures in Hardrock Mining Districts of Montana

Contract No: E(45-1)-2426

SUMMARY

Reconnaissance investigations of mine-water temperatures provide a cost effective means of locating thermal anomolies in advance of more costly and time consuming geophysical techniques. The study will consist of a systematic sampling for temperature and conductivity of mine-water in 199 hardrock mining districts in western Montana. Approximately 750 individual mines will be sampled and sampling will be repeated 3 times in areas accessable throughout the year in order to observe any seasonal variations. Flow of water at the sampling point will be estimated and waters having a temperature of 40°C or greater will be collected according to standard thermal water sampling techniques and analyzed in the Montana Bureau of Mines and Geology laboratory. An evaluation of the distribution of anomolous temperatures and water chemistry will be possible as a result of the broad geographic distribution of the mining districts.

Project Title: Coso Geothermal Project

Contract No: E(45-1)-1830

Contractor: Battelle Pacific Northwest Laboratory
Richland, Washington

Principal Investigator: Joseph W. Upton
(509) 946-2689
FTS 444-7411, Ext. 946-2689

Program Manager: Martin R. Scheve
(202) 376-4902
FTS 376-4902

Project Objective: Characterization of the Coso geothermal resource using heat flow studies and slim-hole drilling.

Funding: FY 75 - --
FY 76/TQ - $1310K*

Contract Term: 7/1/75-9/30/77

Reports Issued: None

* includes $135K to Naval Weapons Center for support activities.

Project Title: Coso Geothermal Project

Contract No: E(45-1)-1830

SUMMARY

Battelle Memorial Institute, Pacific Northwest Laboratory (PNL) is undertaking a research project in search of geothermal Hot Dry Rock resources at the Coso Geothermal anomaly using slim-hole (< 4-inch diameter) drilling as a primary exploration technique, together with the usual geophysical surface surveys to obtain information at depth (up to 5,000 feet) early in the exploration project.

Coso Hot Springs, near China Lake, California, offers a high probability of finding a hot dry rock source, and the Naval Weapons Center (NWC) and United States Geological Survey (USGS) have already done extensive geophysical and geological research of the area.

About 15 heat flow holes have been drilled by PNL to depths of about 300 feet, and a seismic monitoring network for both ground noise and microseismic activity has been established. Two to four slim holes to about 4,000 feet will provide the control and means to evaluate the anomoly.

Battelle will work with the University of Texas at Dallas on heat flow and seismic analysis and NWC on logistics, site preparation, environmental analysis. USGS will continue their work at the site and will support the project with core examination and water sample analysis. Liaison will be established with the California State Geothermal Offices. The project will be coordinated with the hot dry rock projects of the Los Alamos Scientific Laboratory.

Project Title:	Static and Dynamic Well Test of the Delcambre Well, Louisiana
Contract No:	E(40-1)-5140
Contractor:	Osborn-Hodges-Roberts-Wieland Engineering Bryan, Texas
Principal Investigator:	W. F. Osborn (713) 779-2732 or 779-2733
Program Manager:	Keith Westhusing (202) 376-4902 FTS 376-4902
Project Objective:	To measure the gas content, temperature, pressure, composition, and character of geopressure fluids and the character of geopressured formations to determine their productivity so that a more accurate economic analysis of the geothermal geopressured resource may be made.
Funding:	FY 75 - -- FY 76/TQ - $1,453K
Contract Term:	8/1/76-3/31/77
Reports Issued:	None

Project Title: Static and Dynamic Well Test of the Delcambre Well, Louisiana

Contract No: E(40-1)-5140

SUMMARY

This project's purpose is to obtain data on the geopressured resource by performing static and dynamic tests in an existing natural gas well: the 14,000-foot Delcambre #1 in El Tigre Lagoon, East Vermillion Parish, Louisiana. Two virgin geopressured formations will be sampled and flow tested between 12,500 and 12,900 feet. Fluid samples will be analyzed by McNeese University under contract number E(40-1)-4937 as reported in Section 2.3. Other laboratories will perform similar analyses for verification.

Osborn-Hodges-Roberts-Wieland will be responsible for necessary services and equipment to prepare the site, rework the well, perform on-site testing, and ensure the clean-up and necessary reporting. They will comply with all applicable local, state, and Federal laws, regulations, and requirements related to the operations on the geopressured well.

The report on the results of the work will include the measured quantity of gas entrained in processed geopressured fluids, the composition and character of the fluids, the character of the geopressured formation and the results of flow tests performed to determine reservoir productivity and possible problems associated with production. Recommendations for improved static and dynamic test methods will also be included.

Project Title: Analyses of Fluid Samples from Geopressured Formations of the Delcambre Well, Louisiana

Contract No: E(40-1)-4937

Contractor: McNeese State University
Lake Charles, Louisiana

Principal Investigator: O. Carrol Karkalits
(318) 478-8070

Program Manager: Keith Westhusing
(202) 376-4902
FTS 376-4902

Project Objective: To conduct physical and chemical analyses of fluid samples from the Delcambre Well taken from surface flow line locations under conditions approaching in-situ values.

Funding: FY 75 - $237K
FY 76/TQ - $240K

Contract Term: 6/1/75-3/31/77

Reports Issued: None

Project Title: Analyses of Fluid Samples from Geopressured Formations of the Delcambre Well, Louisiana

Contract No: E(40-1)-4937

SUMMARY

The purpose of this project is to conduct analyses of the fluid samples taken from the two geopressured sands of the Delcambre Well, Louisiana. Samples will be taken under conditions of temperature and pressure approaching in-situ values and from surface flow line locations. Tests will be performed on fluid samples to determine:

1. Viscosity, density, compressibility
2. Total dissolved solids (including silica)
3. Salinity
4. Dissolved gas content
5. Total undissolved solids

Gas released from the sample vessels will be measured for their total volume. Released gas will be analyzed for CO_2 and hydrocarbons and ammonia, etc., by gas liquid chromatography. Hydrocarbon content will be further analyzed for individual constituents (e.g., methane, ethane, etc.).

Sampling and analysis methodology and analysis results will be incorporated in the final report with data resulting from the static and dynamic well-test contract performed on the Delcambre well by Osborn-Hodges-Roberts-Wieland Engineering under contract number E(40-1)-5140 as reported in Section 2.3.

This contract was originally titled "Investigation and Definition of Parameters Associated with Testing Geopressured Water" and was performed with a subcontract to Osborn-Hodges Engineering. That contract resulted in the acquisition of a geopressured well, the Delcambre #1, and the development of a static and dynamic test plan for determining the nature of geopressured formations and their entrained fluids. Effective August 1, 1976, Osborn-Hodges-Roberts-Wieland will perform the well-tests and sample acquisitions. The McNeese University scope-of-work has been modified to consist of performing the analyses of the geothermal fluids from the well in accordance with the above summary.

Hydrothermal Technology Applications

3.0 HYDROTHERMAL TECHNOLOGY APPLICATIONS

The objective of the Hydrothermal Technology Applications subprogram is to establish the technical feasibility of using liquid-dominated geothermal resources for both electric power generation and nonelectric uses. Development effort will progress systematically from the testing of components through subsystems and processes in field test facilities, to scaled testing of integrated energy conversion or utilization systems in pilot plants. Establishment of the technical feasibility in such plants is designed to reduce the technical risk to a level that is reasonably acceptable and attractive to industry. (Subsequently, demonstration of economic feasibility will be the objective of the Utilization Experiment Subprogram.) The programs concerned with test facilities and pilot plants will obtain technical operating data under actual field test conditions in order to establish: ability of developed components and systems to meet performance and reliability criteria; sustained capacity of geothermal reservoirs and geologic formations to produce fluids and accept rejected brines; suitability of environmental control technology; effectiveness of developed techniques and methods, such as well stimulation and brine conditioning for reinjection; and other parameters essential to full-scale commercial demonstrations.

3.0 HYDROTHERMAL TECHNOLOGY APPLICATIONS

Active Contracts

Project Title:	LLL Industrial Support Program (ISP)
Contract No:	W-7405-ENG-48
Contractor:	Lawrence Livermore Laboratory Livermore, California
Principal Investigators:	F. Holzer (415) 447-1100, Ext. 8301 FTS 457-8301
	A. L. Austin (415) 447-1100, Ext. 3946 FTS 457-3946
Program Manager:	A. G. Follett (202) 376-4905 FTS 376-4905
Project Objective:	To provide technical support to joint ERDA/industry programs which involve scaling and corrosion problems associated with the high temperature, high salinity hydrothermal resource.
Funding:	FY 75 - -- FY 76/TQ - $625K
Contract Term:	7/1/75-9/30/77
Reports Issued:	None

Project Title: LLL Industrial Support Program (ISP)

Contract No: W-7405-ENG-48

SUMMARY

The primary objective of the LLL Industrial Support Program (ISP) is to carry out relevant research investigations in potential problem areas in order to broaden opportunities for solutions and provide alternate approaches where needed, and to provide ad hoc R&D assistance to help solve critical problems that may arise during the operations of joint ERDA/industry projects. The ISP will also provide a mechanism for effective transfer of geothermal expertise and technology developed at LLL.

The general thrust of the ISP is embodied in the following major technical areas and tasks to be addressed during FY 1977:

A. Brine Chemistry and Materials

1. Suspended Solids Composition and Handling Procedures
2. Brine Characterization
3. Scale Control
4. Corrosion Tests

B. Materials Evaluation and Development

C. Reinjection and Reservoir Modeling

D. Energy Conversion and Systems Engineering

Early laboratory success was achieved during FY 1976 in using gamma radiography for in-process surveillance of scale formation.

Project Title: Reservoir Engineering and Resource Utilization Support

Contract: W-7405-ENG-48

Contractor: Lawrence Berkeley Laboratory
Berkeley, California

Principal Investigators: R. J. Budnitz
(415) 843-2740, Ext. 5110
FTS 451-5110

K. Mirk
(415) 843-2740, Ext. 5275
FTS 451-5275

Program Manager: A. G. Follett
(202) 376-4905
FTS 376-4905

Project Objective: To provide reservoir engineering support and technical assistance in planning the design, construction, operation and management of the ERDA Geothermal Component Test Facility.

Funding: FY 75 - $400K
FY 76/TQ - $462K

Contract Term: 7/1/74-9/30/77

Reports Issued: "High Temperature, Low Salinity Geothermal Test Facility," Energy and Environment Division, Lawrence Berkeley Laboratory report UCID-3720 (April 1975)

Project Title: Reservoir Engineering and Resource Utilization Support

Contract: W-7405-ENG-48

SUMMARY

LBL has acted as the technical representative for ERDA in the interagency agreement with the U.S. Bureau of Reclamation (USBR), under contract number E(49-27)-1003 as reported in Section 3.1.1, for the design and construction of Phase IA of the ERDA Geothermal Component Test Facility located at the USBR East Mesa site in the Imperial Valley of southern California. Design and specifications for Phase IA have been completed. Construction began in the summer of 1976 and is scheduled for completion in November 1976.

In addition to providing technical assistance for design and construction of the facility, LBL is developing, and will implement, the facility management plan and test program.

During the design of Phase IB of the ERDA Geothermal Component Test Facility, LBL will continue to act as the technical representative for ERDA, providing technical assistance to TRW Systems Group. TRW is performing the Phase IB design under contract number E(04-3)-1140 as reported in Section 3.1.1.

Project Title:	ERDA Geothermal Component Test Facility
Contract No:	E(49-27)-1003
Contractor:	U.S. Department of the Interior Bureau of Reclamation Washington, D.C.
Principal Investigator:	Kenneth Fulcher (Bur. of Reclamation, Boulder City, Nev.) (702) 293-8434 FTS 598-7434
Program Manager:	A. G. Follett (202) 376-4905 FTS 376-4905
Project Objective:	To design and construct Phase IA of the ERDA Geothermal Component Test Facility.
Funding:	FY 75 - $1,040K FY 76/TQ - --
Contract Term:	6/20/75-12/31/76
Reports Issued:	"Project Development Plan for East Mesa Geothermal Test Center," Bureau of Reclamation (March 1975)

Project Title: ERDA Geothermal Component Test Facility

Contract No: E(49-27)-1003

SUMMARY

The ERDA Geothermal Component Test Facility, located at the U.S. Bureau of Reclamation (USBR) East Mesa site in the Imperial Valley of southern California, will be utilized for testing components and subsystems in a high temperature, low salinity environment. USBR is responsible for the design and construction of Phase IA of the facility. On completion, USBR will provide maintenance and support services. As reported in section 3.1.1, Lawrence Berkeley Laboratory functions as the technical representative for ERDA during design, construction and operation of the facility.

Design and specifications for Phase IA of the facility are completed. Construction of Phase IA started in the summer of 1976 and is scheduled for completion in November 1976.

Project Title: Electric Power Generation Using Geothermal Brine Resources

Contract No: E(04-3)-1124

Contractor: Bechtel Corporation
San Francisco, California

Principal Investigator: Lawrence O. Beaulaurier
(415) 764-5914

Program Manager: A. G. Follett
(202) 376-4905
FTS 376-4905

Project Objective: Development of conceptual designs, capital cost estimates and construction schedules for two commercial-scale (50 MWe) power plants utilizing two types of geothermal reservoirs: high temperature, high salinity and high temperature, moderate salinity.

Funding: FY 75 - $269K
FY 76/TQ - $152K

Contract Term: 6/30/75-7/16/76

Reports Issued: "Electric Power Generation Using Geothermal Brine Resources for a Proof-of-Concept Facility," Bechtel Corporation report NSF-RA-N-75-049 prepared under Phase 0 study for National Science Foundation (May 1975)

"Conceptual Design of Commercial 50 MWe (Net) Geothermal Power Plants at Heber and Niland, California," Bechtel Corporation report (July 1976)

Project Title: Electric Power Generation Using Geothermal Brine Resources

Contract No: E(04-3)-1124

SUMMARY

Work involves the development of the following information:

- o A conceptual design, capital cost estimate and construction schedule for a commercial-scale (50 MWe) power plant, based on the direct flash steam-process, Heber-type site data, and extrapolation from the 10 MWe design completed under the Phase 0 study.
- o Based on the high salinity, and the high corrosive and scaling character of the Niland-type brines, state-of-the-art candidate energy conversion processes will be identified as applicable to sites.
- o Technical and economic criteria will be developed for use in selecting candidate processes.
- o The conceptual design, capital cost estimate and construction schedule of a power plant for the Niland-type site utilizing the most favorable energy conversion process selected for the Niland site reservoir data.
- o The effects on the design and on the economics of geothermal (hydrothermal) power plants caused by a predicted timewise decline in available reservoir temperatures.
- o The relative merits of desuperheating an organic working-fluid in the binary cycle by use of regenerative heat exchange as opposed to desuperheating in the condenser.

Project Title:	Planning and Design of ERDA Geothermal Component Test Facility, Phase IB
Contract No:	E(04-3)-1140
Contractor:	TRW Systems Group, TRW, Inc. Redondo Beach, California
Principal Investigator:	R. O. Pearson (213) 536-3340
Program Manager:	A. G. Follett (202) 376-4905 FTS 376-4905
Project Objective:	To provide drawings, specifications and preliminary cost estimates for the ERDA Geothermal Component Test Facility.
Funding:	FY 75 - -- FY 76/TQ - $215K
Contract Term:	3/1/76-9/15/76
Reports Issued:	"Experimental Geothermal Research Facilities Study (Phase 0)," Volumes I and II, TRW Systems Group Final Report No. 26405-6001-RU-00 prepared for the National Science Foundation (December 31, 1974)

Project Title: Planning and Design of ERDA Geothermal Component Test Facility, Phase IB

Contract No: E(04-3)-1140

SUMMARY

TRW Systems Group, under sponsorship of the National Science Foundation, performed a Phase 0 study for an East Mesa geothermal test facility. The results of that study (reported in Appendix A.6) include a recommended implementation plan for a Phase I component and subsystem test facility at East Mesa. Subsequently, it has been decided to build the facility incrementally. The facility has been designated as the ERDA Geothermal Component Test Facility. The Phase IA portion is currently under construction. The subject of this study is the Phase IB portion of the facility.

As reported in section 3.1.1, Lawrence Berkeley Laboratory functions as the technical representative of ERDA for Phases IA and IB.

Phase IA of the ERDA Geothermal Component Test Facility is being constructed by the U.S. Bureau of Reclamation (USBR) under contract E(49-27)-1003 as reported in section 3.1.1.

The Phase IB study will include (i) assessment and updating of the component and subsystem test facility configuration requirements; (ii) development of detailed designs, specifications and preliminary cost estimates for the Phase IB additions to the ERDA Geothermal Component Test Facility; and (iii) identification of long lead items required for implementation of the Phase IB additions to the facility.

TRW will assess and update the facility configuration requirements to reflect coordinated consideration of the following:

- Expansion of the Phase IA facility,
- City of Burbank accelerated development plans for East Mesa leases 9, 10 and 11,
- Future industry/government experimenter needs for component and subsystem development and test.

Project Title: Thermal Loop Experimental Facility

Contract No: E(49-3)-1137

Contractor: San Diego Gas and Electric Company
San Diego, California

Principal Investigator: Gilbert Lombard
(714) 348-2700 (Niland, California)

Program Manager: A. G. Follett
(202) 376-4905
FTS 376-4905

Project Objective: To determine the technical and economic feasibility of using geothermal resources in a heat exchange train, and to gain information on the extent and characteristics of the geothermal reservoir.

Funding: FY 75 - --
FY 76/TQ - $3,300K

Contract Term: 7/1/75-6/30/78

Reports Issued: None

Project Title: Thermal Loop Experimental Facility

Contract No: E(49-3)-1137

SUMMARY

The Thermal Loop Experimental Facility has two objectives: one is to determine the technical and economic feasibility of using geothermal resources in a heat exchange train, and the other is to gain information on the extent and characteristics of the geothermal reservoir at the site. The heat exchange train will be used to transfer heat to a binary fluid which could then be used to drive a turbine expander for the generation of electric power. Only that equipment required to initiate the well flow and the heat exchange process will be installed initially. Equipment needed to generate electrical energy may be installed at a later date if required for test or demonstration purposes. In this event, the electrical output of the Test Facility would not exceed ten megawatts.

An essential aspect of operation of the Test Facility is the determination of characteristics of the geothermal reservoir. During the drilling and initial testing of the wells, certain geological characteristics were observed and information obtained in regard to the temperature and salinity of the reservoir. This information is not sufficient to provide knowledge of the longevity and productivity characteristics of the reservoir.

Through observations of pressures and temperatures that will be obtained during the operation of the Thermal Loop Experimental Facility, a determination can be made of the capability of the reservoir. Pressure changes within the wells over periods of time will provide answers to the questions of reservoir size and permeability. Determination of the permeability characteristics of the reservoir is necessary to optimize the design of the production-injection system.

Construction has been completed. Start up was accomplished in May. The initial shake-down run of 400 hours has been completed and minor modifications are in progress.

Project Title:	Raft River Geothermal Project
Contract No:	E(10-1)-1375
Contractor:	Idaho National Engineering Laboratory Idaho Falls, Idaho
Principal Investigator:	J. F. Kunze (208) 522-6640, Ext. 1781 FTS 583-1781
Program Manager:	Donald H. Clements (202) 376-4902 FTS 376-4902
Project Objective:	To improve energy extraction/conversion technology to the extent required for economic production of electricity from a moderate temperature hydrothermal resource.
Funding:	FY 75 - $2,744K FY 76/TQ - $3,300K*
Contract Term:	7/1/74-9/30/77
Reports Issued:	(see list after "Summary")

* includes $80K to Lawrence Berkeley Laboratory for support activity.

Project Title: Raft River Geothermal Project

Contract No: E(10-1)-1375

SUMMARY

The overall goals of the project are as follows:

1. To demonstrate the extraction of energy from a moderate temperature hydrothermal resource utilizing full reinjection of the waste fluid. The reinjected fluid will contribute to the fluid recharge of the hydrothermal field, with minimum degradation of the environment and the thermal heat source.

2. To demonstrate the design and operational characteristics of a geothermal power plant operating from a reservoir temperature well below the enthalpy limits now considered to be economically attractive for commercial development.

3. To determine the most efficient and effective utilization of the Raft River resource including the combined electric/non-electric applications.

To achieve these goals, test wells will be drilled to aid in resource evaluation and a thermal loop will be established to test potential for sustained electric power generation using moderate temperature (150°C) geothermal waters. Primary work associated with electric power production studies will consist of a conceptual design of a binary (isobutane) 10 MWe net power plant and associated component test systems specifically for the Raft River Geothermal Resource. Environmental studies in support of this project are being performed under contract number E(10-1)-1375, as reported in Section 6.1.

In FY 1974 shallow holes were drilled to the 1000 foot level to determine hydrology and water temperatures as a preliminary step in characterization of the geothermal resources existing in the Raft River Valley. A preliminary power plant design was initiated, and a number of power cycles were investigated.

Resource evaluation and work on the conceptual and engineering design for a geothermal electric power plant continued throughout FY 1975. The first and second boreholes were drilled tapping a geothermal reservoir at the 5000 ft and 6,000 levels. The design, procurement, and assembly of a portable field laboratory for component corrosion and scaling tests was started. The detailed environmental assessment required for the Raft River Geothermal project was also continued.

Project Title: Raft River Geothermal Project

Contract No: E(10-1)-1375

SUMMARY (continued)

In FY 1976 work has progressed in resource development, brine management, fluid flow test loop, and the conceptual design of the binary (isobutane) power plant. A third exploratory production well in the Raft River reservoir was also completed using multiple slant hole drilling at the depth of 4200 feet.

Studies of electric power conversion cycle options and variations have shown that the conventional binary cycle energy conversion system can be satisfactorily operated using 150°C geothermal brines and that the electric power cost can be significantly reduced by use of advanced design heat exchangers, condensers, and cooling systems to improve conversion efficiency. Development of a fluidized bed heat exchanger and an improved condenser concept is now underway.

The three deep wells at the Raft River site have all produced fluids of approximately 150°C temperatures. Artesian flow rates are as high as 900 gpm. The flow rate in the test loop pipeline has been increased to 1200 gpm by use of a downhole submersible pump. Efforts are currently directed toward operation of a continuous production-reinjection cycle from which flow rates and heat production can be accurately measured and estimates of reservoir extent and capacity made.

The production reinjection test loop and materials corrosion and scaling test programs, now in progress, coupled with advanced heat exchanger and cooling system development studies discussed in Section 1.2.3 will lead to field experiments to verify the technical and economic viability of an integrated energy extraction and conversion system for electric power generation.

3.1.2 Moderate Temperature Resources

Project Title: Raft River Geothermal Project

Contract No: E(10-1)-1375

Reports Issued:

IDAHO NATIONAL ENGINEERING LABORATORY REPORTS

J. F. Whitbeck, "Design Concept for Flashed Steam Systems for Use with Moderate Temperature Geothermal Water," ANCR-1210 (July 1975).

W. W. Madsen, I. J. Ingvarsson, "Preliminary Thermal Analyses of Binary Cycle for Geothermal Pilot Plant," ANCR-1191 (February 1975).

J. W. Neitzel, "Cooling Methods Study for the Proposed Raft River Geothermal Power Plant," ANCR-1203 (April 1975).

J. F. Whitbeck, et al., "Conceptual Design Report, Geothermal Demonstration Power Plant, 10 MW Experimental Binary System," CI-1274 (August 1975).

R. H. Dart, D. T. Neill, J. F. Whitbeck, "Conceptual Design and Cost Evaluation of Organic Rankine Cycle Electric Generating Plant Power by Medium Temperature Geothermal Water," ANCR-1226.

Project Title:	Hawaii Geothermal Project - Phase II
Contract No:	E(04-3)-1093*
Contractor:	University of Hawaii Honolulu, Hawaii
Principal Investigator:	John W. Shupe (808) 948-7727
Program Manager:	David L. Williams (202) 376-4914 FTS 376-4914
Project Objective:	Determine the geothermal energy potential of the Island of Hawaii and suitable engineering, environmental, and socio-economic approaches for its commercial development.
Funding:	FY 75 - $1,183K* FY 76/TQ - $ 605K
Contract Term:	5/1/75-10/29/76
Reports Issued:	"The Hawaii Geothermal Project - Summary Report for Phase I," University of Hawaii (May 1975) "The Hawaii Geothermal Project - Initial Phase II Progress Report," University of Hawaii (February 1976)

* includes work performed under contract number E(04-3)-1088

Project Title: Hawaii Geothermal Project - Phase II

Contract No: E(04-3)-1093

SUMMARY

This project includes exploratory surveys to define the most favorable areas for geothermal reservoirs, analytical models to assist in interpretation of geophysical results, studies on energy recovery from hot brine, legal and regulatory aspects of ownership and administration of geothermal resources, economic and planning studies on the impact of geothermal power, and a research drilling program.

Phase II comprises continuation of Phase I supporting studies and drilling an exploratory well on the Big Island to a target depth of 6000 feet.

The well has been drilled to a depth of 6,450 feet, the bottom hole temperature of which is 350°C (662°F). A 4-hour flow test demonstrated sufficient steam flow from this well to provide 4-5 MWe, assuming 20 percent efficiency in power conversion. Longer flow tests will follow, together with more detailed geophysical and reservoir engineering studies.

Project Title: Space Heating for Commercial Buildings in Boise, Idaho, and Other Non-Electric Applications of Geothermal Heat

Contract No: E(10-1)-1375

Contractor: Idaho National Engineering Laboratory
Idaho Falls, Idaho

Principal Investigator: R. J. Schultz
(208) 522-6640, Ext. 1781
FTS 583-1781

Program Manager: Donald H. Clements
(202) 376-4902
FTS 376-4902

Project Objective: To design a demonstration geothermal space heating system to serve State, Federal, and city buildings in Boise, Idaho, and evaluate the potential for other non-electric applications using the Raft River geothermal resource.

Funding: FY 75 - --
FY 76/TQ - $941K

Contract Term: 7/1/75-9/30/77

Reports Issued: (see list after "Summary")

Project Title: Space Heating for Commercial Buildings in Boise, Idaho, and Other Non-Electric Applications of Geothermal Heat

Contract No: E(10-1)-1375

SUMMARY

1. Basic Project: The primary objective of this project is to design a demonstration space heating system for public buildings in the City of Boise, Idaho. The R&D effort will: (1) determine if the local geothermal resource is adequate; (2) estimate costs and evaluate the practicality of retrofitting existing heating systems for utilization of low-temperature (less than 95°C (200°F)) geothermal water; and (3), design the distribution systems and the geothermal waste water discharge system.

2. Other Non-Electric Applications: The primary objective is to evaluate the potential for direct use of geothermal energy for industrial processing, agriculture, aquiculture and other non-electric applications at the Raft River site and examine technology transfer opportunities to adjoining regions with similar geothermal reservoirs.

A study to evaluate the feasibility of converting various building heating systems in Boise, Idaho so that geothermal water at 75°C (170°F) may be used as a heat source has been completed. Two distinct heating concepts have potential for use of geothermal energy: hot water circulated to convectors located in heated spaces and heated forced air blown to diffusers located in heated spaces. Existing hot water systems (12 buildings) would be modified by installing a geothermal hot water heated heat exchanger in series with the existing steam heated heat exchanger. Water to be used for heating would then be pumped through the new heat exchanger and back into the existing hot water piping. The heated forced air systems (2 buildings) would be modified by installing a new hot water coil in the existing ductwork. Air to be used for space heating would then be drawn or blown through the geothermal hot water heating coil and continue in through existing ductwork. Hydrologic and geophysical studies of the Boise reservoir are underway as part of the resource evaluation phase of the project. Exploratory drilling has shown 55°C (132°F) temperature water at a depth of 650 feet with the temperature gradient of 1.1°C (2°F) every 10 feet.

Project Title: Space Heating for Commercial Buildings in Boise, Idaho, and Other Non-Electric Applications of Geothermal Heat

Contract No: E(10-1)-1375

SUMMARY (Continued)

Preliminary analyses show that no major resource or engineering difficulties exist that would prevent successful completion of the project. Success in the project could lead to significant long term savings in both scarce fossil fuels and total heating costs to the State of Idaho. It is estimated that for a capital investment of approximately 3 million dollars by the State, the necessary production wells, distribution system and discharge system, and the conversion of building heating systems could be accomplished for ten state buildings with potential for expansion to the equivalent of 28 more public buildings by using fossil fuel peaking for the coldest days. The significance of this project in size and scope is that, if fully implemented to the equivalent 38 buildings, it will be similar to providing the heat for approximately 4,000 average homes, i.e., a city of 15,000 to 20,000 people.

A number of studies have been completed which address the potential for other non-electric applications of low-temperature (less than 150°C (300°F)) geothermal water of the Raft River reservoir. A number of potential users have shown interest in the use of geothermal heat for industrial processing. Land and water acquisition problems appear resolvable and no insurmountable system conversion problems have been identified. A study of large scale utilization of geothermal heat in an integrated industrial complex with multiplicity of participating industries has been completed. The study emphasizes the value of integrated, multiple-use concept of process heat applications for the maximum and most efficient use of available geothermal energy at the Raft River site. Additional studies related to non-electric applications have been supported under subcontract with Boise State University, Utah State University and others.

Project Title: Space Heating for Commercial Buildings in Boise, Idaho, and Other Non-Electric Applications of Geothermal Heat

Contract No: E(10-1)-1375

Reports Issued:

IDAHO NATIONAL ENGINEERING LABORATORY REPORTS

"Feasibility Review for Geothermal Conversion of Existing H&V Systems on the Boise Geothermal Space Heating Project," Idaho National Engineering Laboratory report ANCR-1256 (September 1975).

"Geothermal Space Heating of a Geothermal Drilling Rig," Idaho National Engineering Laboratory report ANCR-1241 (June 1975).

"Geological Aspects of an Assessment of the National Potential for Non-Electric Utilization of Geothermal Resources," Idaho National Engineering Laboratory report ANCR-1213 (June 1975).

"Use of Geothermal Water for Agriculture," Idaho National Engineering Laboratory report ANCR-1221 (June 1975).

"Fish Culture Utilization of Geothermal Energy," Idaho National Engineering Laboratory report ANCR-1220 (June 1975).

Project Title: Susanville Geothermal Energy Project

Contract No: E(04-3)-1077

Contractor: City of Susanville, California

Principal Investigator: Alfred B. Longyear
(916) 257-2174

Program Manager: David B. Lombard
(202) 376-4902
FTS 376-4902

Project Objective: To establish the feasibility of a small community building an economic base on the use of a geothermal resource for energy.

Funding: FY 75 - $300K
FY 76/TQ - $ 4K*

Contract Term: 6/1/75-8/31/76

Reports Issued: Susanville Geothermal Energy Project Quarterly Report, SAN 1077-1 (October 10, 1975)

Susanville Geothermal Energy Project Quarterly Report, SAN 1077-2 (January 8, 1976)

Susanville Geothermal Energy Project Quarterly Report, SAN 1077-3 (April 8, 1976)

Susanville Geothermal Energy Project Workshop Proceedings; Final Technical Report SAN 1077-4 (July 13, 1976)

* $4K to U.S. Geological Survey for support activity.

Project Title: Susanville Geothermal Energy Project

Contract No: E(04-3)-1077

SUMMARY

The primary goal of this study is to evaluate the use of geothermal energy as an economic base for a small community. Susanville, California, is typical of many small communities in that it suffers economic deprivation and high costs for energy. By using an available geothermal resource as a source of power or heating, the community hopes to improve its competitive position and develop an improved economic base. This research, therefore, will aim to generate data so that Susanville can serve as a model of a community which uses geothermal energy as a significant part of its economic base. The study seeks to answer such questions as:

(1) What is the extent of the geothermal resource?
(2) Which industries will benefit most from the development of the geothermal resource?
(3) What institutional actions are needed to develop the resource?
(4) How do geothermal and conventional energy intermix in the overall economic pattern?
(5) What are the environmental effects of developing the resource?

The project is essentially complete. A guideline for community geothermal development based on Susanville, but applicable to other communities, has been developed. Several other replicable communities participated in the project, and some of these are considering the development of their local geothermal resources, based on the results of the Susanville project.

U.S. Geological Survey supported this project performing geochemical analyses of samples from geothermal wells in the Susanville area.

Project Title:	Evaluation and Design of Downhole Heat Exchangers for Direct Application
Contract No:	E(45-1)-2429
Contractor:	Oregon Institute of Technology Klamath Falls, Oregon
Principal Investigators:	Gordon Culver (503) 882-6321
	Gordon Reistad (503) 754-2575
Program Manager:	Eric Peterson (202) 376-4905 FTS 376-4905
Project Objective:	To characterize the circumstances under which the use of downhole heat exchanger (DHE) would and would not be economically desirable; to develop the procedure and critical inputs for designing a DHE in situations where its use appears desirable.
Funding:	FY 75 - -- FY 76/TQ - $164K
Contract Term:	5/1/76-4/30/78
Reports Issued:	None

Project Title: Evaluation and Design of Downhole Heat Exchangers for Direct Application

Contract No: E(45-1)-2429

SUMMARY

In the development of heat exchangers for use in the direct application of geothermal energy, there is a need to establish the relationship of geological configuration and heat extraction techniques for low temperature, near surface aquifers. In this investigation, design criteria will be developed correlating the downhole heat exchanger (DHE) and the aquifer configuration. Temperature and flow (rate and direction) profiles will be measured for several bore holes to determine the influence of the casings and the DHE during both idle and operating modes. Using the measured temperature and flow data, an analytical model of the heat exchange process will be developed. With this model and DHE design parameters, the relative amounts of natural and forced convection can be evaluated for various heat exchanger designs. To verify the validity of the model, the most promising DHE designs will be tested and the test results compared with those obtained analytically.

Advanced Technology Applications

4.0 ADVANCED TECHNOLOGY APPLICATIONS

Longer-range expectations for extensive utilization of geothermal resources are embodied in the Advanced Technology Applications subprogram. Specifically, the major targets are the huge resources represented by hot dry rock systems expected to be found over large areas of the Western states, the geopressured systems along the U.S. Gulf Coast, and ultimately the widely distributed conductive heat of the earth's crust (normal gradient resources).

The Advanced Technology Applications subprogram has the objective of proving the technical feasibility of using geothermal resources which require technologies that are now less mature than those for hydrothermal convection systems. Development effort will progress systematically from characterization of the resources to the testing of components, subsystems and processes in field test facilties to scaled testing of systems in pilot plants. By this means, technical feasibility will be demonstrated and technical risks thereby reduced to a level that is reasonably acceptable and attractive to industry.

4.0 ADVANCED TECHNOLOGY APPLICATIONS

Active Contracts

Project Title:	Investigations on the Geopressure Energy Source of Southern Louisiana
Contract No:	E(40-1)-4889
Contractor:	Louisiana State University Baton Rouge, Louisiana
Principal Investigator:	Murray F. Hawkins (503) 388-5215
Program Manager:	Keith Westhusing (202) 376-4902 FTS 376-4902
Project Objective:	To investigate the value of well log analyses in assessing the character of geopressured geothermal resources and to delineate large volume geopressured sand areas.
Funding:	FY 75 - $158K FY 76/TQ - --
Contract Terms:	4/1/75-9/30/76
Reports Issued:	Progress report in "Proceedings of the Second Geopressured Geothermal Energy Conference," Center for Energy Studies, University of Texas at Austin, February 23-25, 1976 (5 volumes), Myron H. Dorfman and Richard W. Deller, editors

Project Title: Investigations on the Geopressure Energy Source of Southern Louisiana

Contract No: E(40-1)-4889

SUMMARY

The objective of the proposed research is to establish the value of geophysical and geological analysis based on well logs in determining the physical and geological characteristics of geopressured geothermal resources and to delineate large volume geopressured sand areas along the Louisiana Gulf Coast.

Geopressured geothermal resources have been found in sedimentary formations along the U.S. Gulf Coast and other locations by crews drilling for oil and gas. The undercompacted sandstone strata are known to contain highly pressurized hot water and believed to contain dissolved methane gas but have not been extensively investigated because of technical problems in drilling into high pressures. It may be possible to recover energy from the heat content of the water, the pressure, and separated natural gas. To determine whether this would be feasible, it is necessary to learn more about location, thickness, areal extent, depth, porosity, permeability, temperature, pressure, salt content and gas content of the resources.

Data gathered in the search for petroleum deposits could establish many of the key geopressured geothermal resource parameters. The University of Texas at Austin is applying this type of analysis in a broad band across the Texas coastal plain under contract number E(40-1)-4891 and reported in Section 4.1. This project continues the assessment into the contiguous portion of Louisiana. The limited information now available indicates that there is considerable variation.

This project is designed to establish whether the new method is applicable to a broad range of subsurface conditions. If so, it is expected to be a valuable tool for assessing other geopressured geothermal deposits offshore along the Gulf Coast as well as the Wyoming and California occurrences.

About 85% of the well logs have been analyzed and the results converted to a format suitable for electronic data processing. This format is compatible with that developed for the University of Texas project.

Project Title: Assessment of Geothermal (Geopressured) Resources in the Texas Gulf Coast Region

Contract No: E(40-1)-4891

Contractor: University of Texas at Austin
Austin, Texas

Principal Investigator: Charles G. Groat
(512) 471-1534

Program Manager: Keith Westhusing
(202) 376-4902
FTS 376-4902

Project Objective: To investigate the value of well log and seismic record analyses in assessing the character of geopressured geothermal resources and to delineate optimum Frio formation reservoirs along the Texas Gulf Coast.

Funding: FY 75 - $495K
FY 76/TQ - $272K

Contract Term: 5/31/75-10/31/77

Reports Issued: Progress report in "Proceedings of the Second Geopressured Geothermal Energy Conference," Center for Energy Studies, University of Texas at Austin, February 23-25, 1976 (5 volumes), Myron H. Dorfman and Richard W. Deller, editors

Project Title: Assessment of Geothermal (Geopressured) Resources in the Texas Gulf Coast Region

Contract No: E(40-1)-4891

SUMMARY

The objective of the proposed research is to establish the extent to which information from geophysical logs and seismic surveys can be used to determine the physical and geologic characteristics of geopressured geothermal resources.

Geopressured geothermal resources have been found in sedimentary formations along the U.S. Gulf Coast and other locations by crews drilling for oil and gas. The undercompacted sandstone strata are known to contain highly pressurized hot water and believed to contain dissolved methane gas but have not been extensively investigated because of technical problems in drilling into high pressures. It may be possible to recover energy from the heat content of the water, the pressure, and separated natural gas. To determine whether this would be feasible, it is necessary to learn more about location, thickness, areal extent, depth, porosity, permeability, temperature, pressure, salt content and gas content of the resources.

Much of this information can be obtained by analyzing existing geophysical data that have been accumulated in the search for petroleum deposits. This method appears to be capable of establishing some key geopressured resource parameters but has hitherto been tested only in a limited region of south Texas. The researchers will extend their analysis northeastward into a band across the Texas coastal plain, establishing whether this method applies to a broad range of subsurface conditions, as is thought to exist throughout this area. If it works it is expected to be a valuable tool for assessing other geopressured deposits on the Gulf Coast, and possibly in Wyoming and in California.

The basic analysis technique has been supplemented with salinity data, micropaleontological information, and porosity-permeability correlations supplied to the project by oil companies on a confidential basis. Additional seismic information will be acquired and used in confirming well-to-well correlations. Examination of the Frio formation in the south and middle Texas coast is complete and several potentially attractive geothermal fairways have been identified. Work in the Frio on the north coast is nearly complete and work on the Wilcox formation in south Texas has begun. Several high volume geopressured sand areas will be selected for which detailed analyses will be performed to determine the optimum reservoir area for drilling a geopressured well and producing geothermal fluids for at least 1 year.

Project Title: LASL Hot Dry Rock Geothermal Project

Contract No: W-7405-ENG-36

Contractor: Los Alamos Scientific Laboratory
Los Alamos, New Mexico

Principal Investigator: Allen G. Blair
(505) 667-6722
FTS 843-6722

Program Manager: Martin Scheve
(202) 376-4902
FTS 376-4902

Project Objective: Investigation and development of methods to extract energy economically from hot dry rock in the earth's crust.

Funding: FY 75 - $4,587K
FY 76/TQ - $5,386K

Contract Term: 7/1/74-9/30/77

Reports Issued: (see list after "Summary")

Project Title: LASL Hot Dry Rock Geothermal Project

Contract No: W-7405-ENG-36

SUMMARY

The initial goal of the Project will be to produce and demonstrate an energy extraction system of a type suitable for use in relatively impermeable rocks such as the granites of the Western and Northeastern United States. The project includes microseismic and water quality monitoring tasks.

The major objective of the project for fiscal year 1977 is the development of an interim heat extraction experiment between boreholes EE-1 and GT-2. This will be accomplished by directional drilling of EE-1 to intersect an hydraulic fracture created in the bottom of GT-2, enlarging this fracture or flow connection, casing the holes for water circulation through the fracture and a surface air cooled heat exchange, and extracting 10 to 20 MWt of heat from the rock reservoir.

The major goals for subsequent fiscal years are to extend EE-1 and drill a new borehole, EE-2, to a depth having a temperature of 250°C (480°F) and to connect the two boreholes for a 100 MWt extraction experiment.

Exploratory hole GT-2 at the LASL Fenton Hill site was completed on December 9, 1974, at a total depth of 9607 ft, and a rock temperature of 197°C. Drilling of GT-2 was interrupted at a depth of 6700 ft, where the rock temperature was 146°C, for a series of pressurization and fracture experiments. It was determined that at least below about 3600 ft the permeability of the granitic basement rock was extremely low, and it appeared competent to contain pressurized water with acceptably low leakoff rates. Hydraulic fractures were produced at pumping pressures of about 2500 psi and appeared to be nearly vertical, essentially planar, and oriented about 35° east of north. The largest fracture produced had a calculated radius of about 700 ft and, when vented after propping, it returned about 90% of the water previously injected to inflate it. Preliminary experiments in the bottom of the hole have indicated that hydraulic fracturing occurs at a pumping pressure of about 1750 psi and that, again at this depth, the permeability of the hot granite is extremely low.

Project Title: LASL Hot Dry Rock Geothermal Project

Contract No: W-7405-ENG-36

SUMMARY (continued)

During the fourth quarter of FY 1975, drilling was begun on EE-1, the first of two holes of an energy extraction system. Directional drilling of EE-1 was accomplished to 10,053 feet depth and a rock temperature of 206°C during FY 1976. GT-2 and EE-1 were connected through hydraulic fractures. This connection is presently a high impedance flow path which must be improved for significant heat extraction. Experiments continue in GT-2 and EE-1 to increase understanding of the hydraulic-fracturing and crack-extension behavior of hot granite, of its stress condition at depth and the interactions of pressurized pore fluids with this stress field, of methods of improving hydraulic fracture connections and of techniques for locating and mapping deeply buried water-filled fractures. Once the appropriate techniques for minimizing the flow path impedance have been determined, the system will be improved for the interim (10 to 20 MW_t) heat extraction experiment.

All present indications are that a successful pressurized-water energy extraction loop can be produced in the dry hot rock underlying the Fenton Hill experimental site.

Project Title: LASL Hot Dry Rock Geothermal Project

Contract No: W-7405-ENG-36

Reports Issued:

LOS ALAMOS SCIENTIFIC LABORATORY REPORTS

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R. L. Aamodt, "An Experimental Measurement of In Situ Stress in Granite by Hydraulic Fracturing," Los Alamos Scientific Laboratory report LA-5605-MS (April 1974).

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J. W. Tester, "Proceedings of the NATO-CCMS Information Meeting on Dry Hot Rock Geothermal Energy, September 17-19, 1974, Los Alamos, New Mexico," Los Alamos Scientific Laboratory report LA-5818-C, NATO-CCMS report No. 38 (December 1974).

R. A. Pettitt, "Planning, Drilling, and Logging of Geothermal Test Hole GT-2, Phase I," Los Alamos Scientific Laboratory report LA-5819-PR (January 1975).

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Project Title: LASL Hot Dry Rock Geothermal Project

Contract No: W-7405-ENG-36

Reports Issued (continued)

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M. C. Smith and R. D. McFarland, "Energy from Dry Geothermal Reservoirs," Los Alamos Scientific Laboratory report LA-UR-74-1201 (July 1975). [Submitted through ERDA Headquarters for publication in the Soviet Union.]

Georg Delisle, "Determination of Permeability of Granitic Rocks in GT-2 from Hydraulic Fracturing Data," Los Alamos Scientific Laboratory report LA-6169-MS (December 1975).

F. G. West, P. R. Kintzinger, and A. W. Laughlin, "Geophysical Logging in Los Alamos Scientific Laboratory Geothermal Test Hole No. 2," Los Alamos Scientific Laboratory report LA-6112-MS (November 1975).

"The Los Alamos Scientific Laboratory's Dry Hot Rock Experiment: Engineering and Scientific Studies," LA-UR-76-658 presented at the 1976 Spring Meeting of the American Geophysical Union, Washington, D.C., April 12-15, 1976.

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P. R. Kintzinger, "Seismic Signal Location Program for the Los Alamos Scientific Laboratory's Dry Hot Rock Geothermal Project," Los Alamos Scientific Laboratory report LA-6274-MS (in press).

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D. W. Brown, M. C. Smith, and R. M. Potter, "A New Method for Extracting Energy from 'Dry' Geothermal Reservoirs," Proc. Twentieth Annual Southwestern Petroleum Short Course, Texas Tech University, Lubbock, Texas, 1973, pp. 249-255. [Preprinted as Los Alamos Scientific Laboratory report LA-DC-72-1157, Revised September 1972.]

Project Title: LASL Hot Dry Rock Geothermal Project

Contract No: W-7405-ENG-36

Reports Issued (continued)

Robert M. Potter, Eugene S. Robinson, and Morton C. Smith, "Method of Extracting Heat from Dry Geothermal Reservoirs," U.S. Patent No. 3,786,858 (January 22, 1974).

M. C. Smith, "The Los Alamos Dry Geothermal Source Demonstration Project," Proceedings of the Geothermal Power Development Conference, Lawrence Berkeley Laboratory report LBL-3099 (August 1974), pp. 29-34.

H. D. Murphy, "Hydraulic-Fracture Geothermal Reservoir Engineering," Proc. Workshop on Geothermal Reservoir Engineering and Well Stimulation, Stanford University, Stanford, California, sponsored by: National Science Foundation, December 15-17, 1975. (Preprinted as Los Alamos Scientific Laboratory report LA-UR-75-2246.)

B. R. Dennis, J. H. Hill, E. L. Stephani and B. E. Todd, "Development of High Temperature Acoustic Instrumentation for Characterization of Hydraulic Fracture in Dry Hot Rock," to be published in Proc. 22nd Instrumentation Society of America Symposium, San Diego, California, May 1976.

Donald W. Brown, "The Potential for Hot Dry Rock Geothermal Energy in the Western United States," paper presented at 15th Annual ASME Symposium on Resource Recovery, Albuquerque, New Mexico, March 6-7, 1975.

A. William Laughlin, Roland A. Pettitt and Francis G. West, "Current Status of the Los Alamos Dry Hot Rock Geothermal Energy Experiment," paper presented 1975 Annual Meeting Geological Society of America, Salt Lake City, Utah, October 20-22, 1975.

A. W. Laughlin and A. C. Eddy, "Petrography and Chemistry of Precambrian Rocks from GT-2," paper presented 1975 Geological Society of America Annual Meeting, Salt Lake City, Utah, October 20-22, 1975.

Robert D. McFarland and Hugh D. Murphy, "Extracting Energy from Hydraulically-Fractured Geothermal Reservoirs," paper to be presented 11th Intersociety Energy Conversion Engineering Conference, State Line, Nevada, September 12-17, 1975.

A. W. Laughlin, "Tectonic Setting and Geology-Geochemistry of the LASL Fenton Hill Drill Site," paper presented Penrose Conference on the Geochronology of Metamorphic Rocks, Helen, Georgia, January 4-9, 1976.

Utilization Experiments

5.0 UTILIZATION EXPERIMENTS

Demonstration is the capstone of the Federal geothermal program, representing the final and decisive stage in commercialization of the new technologies to exploit known geothermal resources. Confidence in these new technologies will be provided by first-of-a-kind, large-scale, utilization experiments (demonstration power plants) with special instrumentation and equipment necessary to increase the level of understanding, reliability and operability of integrated geothermal systems. Demonstration plants will provide the private sector with engineering and operational experience for follow-on, commercial-scale power generating plants capable of producing energy at design cost. To be effective, the plants should become operational early enough to stimulate industrial development of follow-on commercial plants that will contribute to the achievement of national energy goals.

Utilization experiments performed in conjunction with industrial participants are anticipated to be initiated in FY 1978. The experiments are planned to be of sufficient size to demonstrate reservoir adequacy and to address pertinent environmental, legal and institutional problems.

The projects will be designed to: (1) demonstrate that near-term technologies are now ready for commercial-size plants to produce electrical energy from hydrothermal resources; (2) obtain realistic cost data from which production costs can be extrapolated with confidence; (3) provide adequate instrumentation to obtain reliable operating data; and (4) demonstrate reservoir deliverability and longevity.

In addition, the projects will address institutional concerns by: (1) providing opportunities for direct participation of the private sector in development and demonstration of geothermal power production; (2) demonstrating the potential for impact on the economy of domestic production of energy from geothermal resources; (3) encouraging the development of an integrated geothermal industry with trained manpower; and (4) accelerating commercial investment in geothermal development.

Environmental Control and Institutional Studies

6.0 ENVIRONMENTAL CONTROL AND INSTITUTIONAL STUDIES

The objectives of this subprogram are to determine environmental implications of large-scale geothermal energy utilization, and the means by which undesirable effects may be kept within acceptable limits; to provide the technological capability to meet environmental standards at reasonable costs; to analyze economic and institutional barriers to growth of a geothermal industry, and evaluate alternative options for their alleviation; and to encourage the utilization of geothermal technology through organization and dissemination of information to users in industry, commerce, laboratories, governments, and the public.

Project Title:	Preparation of General Environmental Assessments for the Hydrothermal, Geopressured and Hot Dry Rock Subprograms
Contract No:	W-7405-ENG-26
Contractor:	Oak Ridge National Laboratory Oak Ridge, Tennessee
Principal Investigator:	H. G. Arnold (615) 483-0321 FTS 550-0321
Program Manager:	Ronald R. Loose (202) 376-4905 FTS 376-4905
Project Objective:	Provide independent assessments of the potential environmental impacts associated with pursuit of geothermal resource development.
Funding:	FY 75 - -- FY 76/TQ - $124K
Contract Term:	2/1/76-9/30/77
Reports Issued:	None

Project Title: Preparation of General Environmental Assessments for the Hydrothermal, Geopressured and Hot Dry Rock Subprograms

Contract No: W-7405-ENG-26

SUMMARY

The contractor is assisting ERDA in the development of general environmental assessments for ERDA's hydrothermal, geopressure, and hot dry rock subprograms. The assessments will be structured in a manner which will readily allow subsequent expansion into environmental impact statements when such action is indicated by subprogram development.

Background studies and visits to geothermal sites leading to identification and understanding of environmental impact considerations related to specified geothermal resource subprogram development are in progress. Initial outlines for assessments have been prepared.

Project Title: Removal of Hydrogen Sulfide from Geothermal Steam

Contract No: E(45-1)-1830

Contractor: Battelle Pacific Northwest Laboratory
Richland, Washington

Principal Investigator: P. C. Walkup
(509) 946-2268
FTS 444-7411, Ext. 946-2268

Program Manager: Ronald R. Loose
(202) 376-4905
FTS 376-4905

Project Objective: Identify and evaluate a metal oxide hydrogen sulfide removal process for geothermal steam.

Funding: FY 75 - $ 50K
FY 76/TQ - $192K

Contract Term: 7/1/74-9/30/76

Reports Issued: None

Project Title: Removal of Hydrogen Sulfide from Geothermal Steam

Contract No: E(45-1)-1830

SUMMARY

The present project, initiated on April 1, 1975, is a three-phase research program having the objective of identifying and evaluating a process for removing H_2S from geothermal steam before its use for power generation. Phase I studies comprise analytical and experimental evaluations of potential metal oxide sorbent processes and selection of the most promising process. Phase II will determine the on-line feasibility of the process selected in Phase I. Phase III will assess the economic feasibility of the process and of transferring the process technology to industry. The processes being studied involve contacting steam with a sorbent to remove H_2S, and the regeneration of the sorbent to recover elemental sulfur or stable sulfur compounds.

The first six months have been spent in a literature search, sorbent preparation and evaluation, and construction of an experimental apparatus. ZnO was verified as a good candidate for H_2S adsorption by the literature search and laboratory experiments. However, regeneration of the sulfided sorbent proved to be difficult. Effort was then switched to formulating sorbents made of mixtures of different kinds of metal oxides. To date, two formulated sorbents evaluated with a gas adsorption apparatus in the laboratory have demonstrated better adsorption-regeneration capabilities than ZnO or sorbents from catalyst manufacturers. Large-scale gas adsorption equipment for use with simulated geothermal steam has been designed and built. Shakedown operation of the equipment is in progress. Confirmation that mixed oxide sorbents are practical is dependent upon experiments in this large-scale demonstration unit. However, it has been demonstrated that the applicability of pure metals or metal oxides as H_2S sorbents from steam is less likely than anticipated because of intermediate compound formation during oxidative regeneration.

Project Title: Raft River Environmental Program

Contract No: E(10-1)-1375

Contractor: Idaho National Engineering Laboratory
Idaho Falls, Idaho

Principal Investigator: J. F. Kunze
(208) 522-6640
FTS 583-1781

Program Manager: Ronald R. Loose
(202) 376-4905
FTS 376-4905

Project Objective: To provide comprehensive environmental data and information in support of the Raft River Geothermal Project.

Funding: FY 75 - --
FY 76/TQ - $85K

Contract Term: 7/1/76-9/30/77

Reports Issued: (See list after "Summary")

Project Title: Raft River Environmental Program

Contract No: E(10-1)-1375

SUMMARY

A comprehensive program of environmental studies is being conducted in support of the Raft River Geothermal Project being conducted under contract no. E(10-1)-1345 as reported in Section 3.1.2. The scope of the program includes the following study elements: socioeconomic and archeological surveys, subsidence and microseismic monitoring, air quality and water quality sampling, pollutant transport modeling, monitoring of biological impacts, monitoring and analysis of geothermal irrigation experiments, and investigations of mitigation and restoration techniques.

In addition to supporting the Raft River Geothermal Project, these environmental studies will reflect many of the conditions that would be encountered in the geothermally attractive areas throughout the West. It is expected that this program will generate environmental data having broad application and thus be of considerable value to future geothermal developments by reducing much of the environmental research that currently is required for each project.

Project Title: Raft River Environmental Program

Contract No: E(10-1)-1375

Reports Issued:

Spencer, S. G., "Environmental Report, Deep Geothermal Test Wells in the Raft River Valley," ANCR-1204 (January 1975).

Kumamoto, L. H., "Microseismicity Investigation of the Raft River Valley, Idaho," Colorado School of Mines, March 1, 1976.

Findholt, S., "Environmental Impact of Geothermal Development in the Raft River Valley," (interim report on biological surveys) March 1976.

Neudorfer, G. M., "Archeological Resources of the Southern Raft River Valley," December 1975.

Pearson, R., "Raft River Vegetation Study," February 1976.

Ursenbach, W. O., "Baseline Air Quality in the Raft River Basin," January 1976.

Speth, L. and Weber, L., "Neutron Activation Analysis of Soil, Flora, and Fauna of the Raft River Geothermal Site Prior to Warm Water Irrigation from Number Two Well," April 1976.

Project Title:	Program Plan for Controlling Subsidence Associated with Geothermal Projects
Contract No:	W-7405-ENG-48
Contractor:	Lawrence Berkeley Laboratory Berkeley, California
Principal Investigators:	Paul A. Witherspoon (415) 843-2740 ext. 5082 FTS 451-5082
	Terry L. Simkin (415) 843-2740 ext. 6217 FTS 451-6217
Program Manager:	Allan J. Jelacic (202) 376-4905 FTS 376-4905
Project Objective:	Develop a program plan of research leading to the understanding and control of geothermal-related subsidence.
Funding:	FY 75 - -- FY 76/TQ - $ 45K
Contract Term:	7/1/76-9/30/77
Reports Issued:	None

Project Title: Program Plan for Controlling Subsidence Associated with Geothermal Projects

Contract No: W-7405-ENG-48

SUMMARY

The objective of this project is to develop a program plan of research leading to the understanding and control of geothermal-related subsidence. The plan will consist of program elements and subelements ordered in a logical fashion with decision points and alternative courses of action. A detailed implementation schedule beginning with FY 1977 will be included. The schedule will seek to minimize the time required to attain the program goal, but will be consistent with funding and technical constraints.

In order to be useful in a practical sense, program subelements will contain one or more specific research topics or problems whose solution will serve the program plan. It is expected that these topics or problems will become research projects when the plan is implemented. An estimated schedule and budget for each potential research project will be included as part of the plan.

Project Title: Guidelines to the Preparation of Environmental Reports for Geothermal Development Projects

Contract No: W-31-109-ENG-38

Contractor: Argonne National Laboratory
Argonne, Illinois

Principal Investigator: P. F. Gustafson
(312) 739-7711
FTS 388-4517

Program Manager: Allan J. Jelacic
(202) 376-4905
FTS 376-4905

Project Objective: Provide reporting guidelines to those persons who are required to submit environmental impact information in connection with ERDA-supported geothermal projects.

Funding: FY 75 - --
FY 76/TQ - $ 97K

Contract Term: 2/1/76-9/30/77

Reports Issued: None

Project Title: Guidelines to the Preparation of Environmental Reports for Geothermal Development Projects

Contract No: W-31-109-ENG-38

SUMMARY

Reporting guidelines will be developed for all known environmental effects associated with geothermal research, development and demonstration projects. The guidelines are expected to be general purpose in nature and applicable to all geothermal projects. Reporting requirements will be scaled to the size of the geothermal project. Scaling instructions will be provided as an integral part of the guidelines. Certain data requirements of the reporting guidelines will be formulated to facilitate their incorporation into a computer data base at some future time.

The contractor has prepared a guide development plan which identifies the environmental and institutional concerns associated with preparation of environmental reports. The plan contains tables of legislative actions, rules and regulations, responsible agencies, and reporting requirements of 15 states with geothermal development potential. An impact matrix of geothermal development activities versus characteristics of the environment is also included. A detailed guide outline is in preparation.



Project Title:	Background Studies of Subsidence in the Gulf Coast Region
Contract No:	E(49-27)-1010
Contractor:	U.S. Department of the Interior Geological Survey Reston, Virginia
Principal Investigator:	Ben E. Lofgren (Water Resources Division, Sacramento, California) (916) 484-4258 FTS 468-4258
Program Manager:	Allan J. Jelacic (202) 376-4905 FTS 376-4905
Project Objective:	Collect and compile the historical record of subsidence measurements in the Texas-Louisiana Gulf Coast Region.
Funding:	FY 75 - -- FY 76/TQ - $9K
Contract Term:	5/11/76-8/30/76
Reports Issued:	None

Project Title: Background Studies of Subsidence in the Gulf Coast Region

Contract No: E(49-27)-1010

SUMMARY

During the course of the project, the contractor will investigate as many sources of subsidence-related data as practicable. Federal and State agencies are expected to be principal sources of data. However, county and municipal governments and private organizations, such as oil companies, will also be contacted.

The study will be limited to the Gulf Coast region of Texas (and possibly Louisiana) as defined by the landward boundary of Miocene deposits. The types of data to be collected will include:

(1) location and extent of vertical control networks;

(2) historical record of geodetic levelings;

(3) location of tide stations and stable reference benchmarks;

(4) historical record of mareograph observations;

(5) location of wells or principal areas of fluid production;

(6) historical record of fluid production including depth and identity of each withdrawal horizon, pumping rate, and fluid composition;

(7) available data on compressibility of sediments in the area and any fault activation that may have occurred.

Project Title: Control of Hydrogen Sulfide Emission from Geothermal Power Plants

Contract No: E(11-1)-2730

Contractor: EIC, Inc.
Newton, Massachusetts

Principal Investigator: W. W. Harvey
(617) 965-2710

Program Manager: Ronald R. Loose
(202) 376-4905
FTS 376-4905

Project Objective: To develop a wet scrubbing process which can economically reduce hydrogen sulfide concentrations in geothermal steam.

Funding: FY 75 - $200K
FY 76/TQ - $358K

Contract Term: 6/1/75-11/30/77

Reports Issued: W. W. Harvey, F. C. Brown, M. J. Turchan, "Control of Hydrogen Sulfide Emission from Geothermal Power Plants--Annual Status Report for Period 1 June 1975 to 31 May 1976" EIC Corporation report no. C00-2730-2 (July 1976)

Project Title: Control of Hydrogen Sulfide Emission from Geothermal Power Plants

Contract No: E(11-1)-2730

SUMMARY

A program was initiated on June 1, 1975, to develop an efficient process for the removal of H_2S from geothermal fluids. An evaluation of process chemistry and feasibility for a number of metal salts and solution compositions was conducted, with the selection of a preferred process option followed by bench-scale testing. Process steps being studied are scrubbing, regeneration, solids separation, and sulfur product disposal.

A sulfide slurry process involving the absorption of H_2S from steam and precipitation as copper sulfide from dilute copper sulfate solution has been adopted as the base-case removal process. Chemical equilbria and kinetics and mass-transfer rates appear favorable. Regeneration by a controlled roasting process and regeneration by a pressure oxygen leaching process are being investigated. Corrosion tests have been carried out and a bench-scale H_2S emission control system has been designed and operated. Steam scrubbing has confirmed the favorable thermodynamics and chemical kinetics of H_2S removal by reaction with aqueous copper ion. After scrubbing H_2S was not detectable. Precipitates are essentially pure copper sulfide and have favorable particle size.

Progress has been made in the comparative evaluation of selected alternate schemes for H_2S control. The results to date continue to indicate advantages of direct scrubbing of steam, with H_2S removal as insoluble sulfide, over other proposed approaches.

Project Title:	Survey of Environmental Research Programs Having Geothermal Applications
Contract No:	E(49-18)-2268*
Contractor:	The MITRE Corporation, METREK Division McLean, Virginia
Principal Investigator:	Ernest P. Krajeski (703) 790-6234
Program Manager:	Allan J. Jelacic (202) 376-4905 FTS 376-4905
Project Objective:	Survey and analyze Federal and privately sponsored environmental research programs applicable to geothermal development and recommend problems which require additional research.
Funding:	FY 75 - -- FY 76/TQ - $ 73K
Contract Term:	1/5/76-10/31/76
Reports Issued:	None

* This project encompasses the environmental task under the referenced contract.

Project Title: Survey of Environmental Research Programs Having Geothermal Applications

Contract No: E(49-18)-2268

SUMMARY

The contractor will undertake a literature survey of past research having some bearing on geothermal environmental effects. A survey of Federal agencies and private individuals engaged in environmental research will be conducted; the contractor will seek the opinions of qualified experts about research needs and priorities. The information will be compiled for ease of reference, analyzed, and used to develop research program plans leading to the solution of priority environmental problems.

Project Title: Investigation of Hydrogen Sulfide Removal from Simulated Geothermal Brines by Reactions with Oxygen

Contract No: E(11-1)-2797

Contractor: Dow Chemical, USA
Freeport, Texas

Principal Investigator: John S. Wilson
(713) 238-4153

Program Manager: Ronald R. Loose
(202) 376-4905
FTS 376-4905

Project Objective: Evaluate a hydrogen sulfide removal process for geothermal brines.

Funding: FY 75 - --
FY 76/TQ - $157K

Contract Term: 10/6/75-10/5/76

Reports Issued: None

Project Title: Investigation of Hydrogen Sulfide Removal from Simulated Geothermal Brines by Reactions with Oxygen

Contract No: E(11-1)-2797

SUMMARY

The Dow Chemical Company will study the kinetics and determine operational conditions of a process for reducing the H_2S content of hot geothermal brines through oxidation to free sulfur and sulfate by the direct addition of oxygen; and will determine the degree of corrosivity increase due to the oxygen addition. Experimental work with simulated brines will establish the degree of H_2S removal under various sulfide-oxygen ratios over a range of temperatures, dissolved solids concentrations and contact items. An important part of the study is to measure the corrosion rates of mild steel and selected alloys in the region of free oxygen or sulfide.

Construction and assembly of equipment has been completed. System shake down runs with brine have been conducted. Further runs to obtain constant and reproducible sulfide levels in the brine are being conducted.

Project Title: Geothermal Economic and Cost Benefit Studies

Contract No: E(45-1)-1830

Contractor: Battelle Pacific Northwest Laboratory
Richland, Washington

Principal Investigator: C. H. Bloomster
(509) 946-2442
FTS 444-7411, Ext. 946-2442

Program Manager: Randall C. Stephens
(202) 376-4897
FTS 376-4897

Project Objective: To develop an economic model and to provide economic analyses and evaluations covering all geothermal resources. The model and analyses include both electrical and non-electrical end uses.

Funding: FY 75 - $386K
FY 76/TQ - $490K

Contract Term: 7/1/74-9/30/77

Reports Issued: (see list after "Summary")

Project Title: Geothermal Economic and Cost Benefit Studies

Contract No: E(45-1)-1830

SUMMARY

The three principal objectives for this project are: (1) macroeconomics--to define the role of geothermal power in relation to competing resources; (2) microeconomics--to estimate in detail cost elements of geothermal power and heat; and (3) cost effectiveness and cost benefit studies--to determine the sensitivity of cost to technical and policy improvements and to quantify societal costs and benefits of geothermal development. To accomplish these objectives, GEOCOST (an economic model capable of performing economic analyses for all types of geothermal energy resources) has been developed to provide an economic basis for performing benefit-cost analyses for electric and non-electric applications.

In FY 76, the GEOCOST model was applied to detailed analyses of the sensitivity of power costs to resource characteristics and power recovery technologies. User's manuals have been prepared to facilitate use of the GEOCOST computer program throughout the geothermal community. The national benefits analysis will be expanded to include the results of the USGS geothermal resource assessment analysis in the supply projections for geothermal resources, and the GEOCOST model will be applied to determine the potential economic impacts of environmental and institutional policies.

A resource assessment economic analysis will be initiated to determine the economic value to the geothermal energy program of resource assessment data. This analysis will: (1) define the potential economic impacts associated with risks and uncertainties in resource assessment data; (2) define the extent to which inadequate resource assessment data limits geothermal energy expansion; and (3) assess the value of new and advanced resource assessment techniques.

The analysis of the potential national benefits of geothermal power was initiated in FY 76. An analysis of the critical resource requirements for geothermal energy development was completed. District heating data from Sandia Laboratories were incorporated into the GEOCOST model.

Analysis has been initiated to determine those cost factors most amenable to improvement through technological advances, and to quantify the sensitivity of cost to related parameters. This analysis will be applied to overall ERDA/DGE program planning.

Project Title: Geothermal Economic and Cost Benefit Studies

Contract No: E(45-1)-1830

Reports Issued:

BATTELLE PACIFIC NORTHWEST LABORATORIES REPORTS

"Economic Analysis of Geothermal Energy Costs," BNWL SA-5596 (November 1975).

"An Economic Model for Geothermal Cost Analysis," BNWL SA-5378.

C. H. Bloomster, et al., "GEOCOST: A Computer Program for Geothermal Cost Analysis," BNWL-1888 (February 1975).

H. D. Huber, C. H. Bloomster, R. A. Walter, "Users Manual for GEOCOST: A Computer Program for Geothermal Cost Analysis, Volume I-Steam Cycle Version," BNWL-1942-V1 (November 1975).

H. D. Huber, C. H. Bloomster, R. A. Walter, "Users Manual for GEOCOST: A Computer Program for Geothermal Cost Analysis, Volume II-Binary Cycle," BNWL-1942-V2 (March 1976).

D. W. Shannon, "Economic Impact of Corrosion and Scaling Problems in Geothermal Energy Systems," BNWL-1866 (January 1975).

C. H. Bloomster and C. A. Knutsen, "The Economics of Geothermal Electricity Generation from Hydrothermal Resource," BNWL-1989 (1975).

R. A. Walter, S. E. Wise, and C. H. Bloomster, "Thermodynamic Modeling of Geothermal Powerplants," BNWL-1911 (May 1975).

C. A. Knutsen, "Benefits of Stimulating Geothermal Energy Development with Tax and Research Subsidies," BNWL-SA-5934 (August 1976).

P. D. Cohn and C. H. Bloomster, "Capital Cost Models for Geothermal Power Plants," BNWL-1990 (July 1976).

Project Title:	Regional Operations Research for Geothermal Development in the State of California
Contract No:	E(04-3)-0959
Contractor:	NASA Pasadena, California
Work Performed by:	Jet Propulsion Laboratory California Institute of Technology Pasadena, California
Principal Investigator:	Casper F. Mohl (213) 354-2779 FTS 792-2779
Program Manager:	Robert E. Oliver (202) 376-4846 FTS 376-4846
Project Objective:	To develop a realistic scenario for the development of geothermal energy resources in California, together with a definition of the nature and timing of public actions required in order for the scenario to materialize.
Funding:	FY 75 - -- FY 76/TQ - $200K
Contract Term:	3/15/76-12/31/76
Reports Issued:	"Regional Operations Research for Geothermal Development in California - Preliminary Scenario for Geothermal Development in California," C. Davis, D. J. Kerrisk, L. Leibowitz, K. K. Tang, Jet Propulsion Laboratory report, July 1976.

Project Title: Regional Operations Research for Geothermal Development in the State of California

Contract No: E(04-3)-0959

SUMMARY

DGE is instituting a system of regional operations research projects through regional contractors who will formulate potential future geothermal energy resource development scenarios for the several regions of the United States. The regional contractors will also identify public actions which must be performed, together with the timing of such actions, in order for the aspired scenarios to materialize. The California regional operations research project initiated under this contract is the first of these regional projects.

A preliminary scenario for the development of geothermal energy resources in California has been developed, and implied public actions have been identified.

During the remainder of the project, detailed scenarios for the geothermal energy resource sites in Lake County and at Heber in the Imperial Valley will be developed and analyzed to identify specific public actions required for the scenarios to develop. In addition, a computer-based operations progress monitor will be developed to provide a convenient means for obtaining up-to-date information concerning the progress of the development of geothermal energy resources in California.

Project Title: Studies in Geophysics

Contract No: E(49-1)-3772

Contractor: Geophysics Research Board
National Academy of Sciences/
National Research Council
Washington, D.C.

Principal Investigator: P. J. Hart
(202) 389-6381

Program Manager: Larry Ball
(202) 376-4914
FTS 376-4914

Project Objective: To perform an independent examination of the national geothermal resource assessment activities and to examine critically the DGE program.

Funding: FY 75 - $ 4K
FY 76/TQ - $ 4K

Contract Term: 7/1/74-9/30/76

Reports Issued: None

Project Title: Studies in Geophysics

Contract No: E(49-1)-3772

SUMMARY

This is a small portion of a larger group of "mini-studies" in geosciences which will be done by the Geophysics Research Board.

Project Title: Support of the U.S. National Committee for Rock Mechanics

Contract No: E(49-1)-3880

Contractor: National Academy of Sciences/
National Research Council
Washington, D.C.

Principal Investigator: Albert N. Bove
(202) 389-6415

Program Manager: Morris Skalka
(202) 376-4912
FTS 376-4912

Project Objective: To coordinate the programs in the United States relating to the study of rock mechanics.

Funding: FY 75 - --
FY 76/TQ - $25K

Contract Term: 12/1/75-11/30/76

Reports Issued: None

Project Title: Support of the U.S. National Committee for Rock Mechanics

Contract No: E(49-1)-3880

SUMMARY

The U.S. National Committee for Rock Mechanics has organized its program into five major areas for which panels have been formed to consider problems and recommend solutions. During the course of the contract term, reports are prepared for publication. Panels cover the following subject areas: (1) rock mechanics problems in energy recovery and development; (2) rock mechanics problems in underground construction and tunneling; (3) rock mechanics problems related to seismology and earthquake engineering; (4) fundamental problems in rock mechanics and educational requirements; (5) domestic and international activities in rock mechanics.

The Committee's broad purpose of serving the interests of the U.S. rock mechanics community is accomplished in several ways and on both the domestic and international levels. Committee goals are accomplished through advisory studies and reports; coordination with domestic societies that have interests in rock mechanics; cosponsorship of and participation in the annual U.S. rock mechanics symposia; reviewing technical papers; reviewing the state of rock mechanics education and research; participation in the international symposia and congresses sponsored by the International Society for Rock Mechanics (ISRM) and in the ISRM Working Commission activities; and nomination of and advice to U.S. representatives sent to international meetings.

The Committee represents the United States in various international activities in rock mechanics largely through its affiliation with ISRM, and keeps U.S. scientists and engineers informed of meetings and other developments, nationally and internationally. It provides advisory studies and reports on problem areas in rock mechanics that are of concern to Federal and State agencies, industry and the rock mechanics community in general. It also advises the National Academy of Sciences/National Academy of Engineering, and those in the rock mechanics field in general, on the state-of-the-art in rock mechanics and the health and effectiveness of the overall research and applications effort in the field.

The full Committee meets at least once each year and its panels meet one or more times a year to carry out their individual programs.

Project Title: Operations Research and Systems Analysis for Geothermal Energy Program Planning

Contract No: E(49-18)-2268*

Contractor: The MITRE Corporation, METREK Division
McLean, Virginia

Principal Investigator: S. Goldstein
(703) 790-6632

Program Manager: Momtaz N. Mansour
(202) 376-4897
FTS 376-4897

Project Objective: To establish an overall framework for regional and national geothermal resource development, for integrating regional studies, for establishing a national planning perspective, for supporting national, Federal and ERDA planning activities, and for defining procedures and data requirements for monitoring progress toward program goals.

Funding: FY 75 - --
FY 76/TQ - $483K

Contract Term: 1/5/76-10/31/76

Reports Issued: "Management Plan for Operations Research and Systems Analysis Support to Division of Geothermal Energy, ERDA," MITRE Working Paper 11407, February 27, 1976

"Framework for the Analysis of Regional and National Geothermal Resource Development," MITRE Working Paper 11417, February 27, 1976

"Cost of Power Modeling for Electrical Generator from Hydrothermal Liquid-Dominated Resources," MITRE Working Paper 11676, June 28, 1976

"Geographic Factors for Use in Ranking Non-Electric Geothermal Applications," MITRE Working Paper 11658, June 7, 1976

"Participants in the National Geothermal Program," H. W. Joy, MITRE MTR-7243, July 1976

* This project encompasses the planning tasks under the referenced contract.

Project Title: Operations Research and Systems Analysis for Geothermal Energy Program Planning

Contract No: E(49-18)-2268

SUMMARY

A detailed framework for analysis of geothermal resource development at a national and regional level has been developed. Data needs, acquisition mechanisms, and analysis procedures for use in these studies have been identified.

To provide a national perspective for geothermal energy program planning, a variety of scenarios, based on rate of domestic economic growth, timing of development of advanced energy technologies, and energy import policies, have been constructed and analyzed for their national implications. The analysis includes assessment of capital, manpower, equipment, and material requirements, as well as the extent of exploration, land leasing rates, and economic, social and environmental impacts.

The project has identified participants in geothermal energy resource development, their roles, their methods of influence and key institutional problems which may impede geothermal energy development. The investigators will analyze the present Federal geothermal program and project critical program paths in relation to the various growth scenarios, identifying specific pilot and demonstration projects with regard to regional and national needs. Various implementation approaches with incentives for industrial utilization will be analyzed and milestones requiring interagency coordination identified.

The project will define criteria for measuring progress in developing geothermal resources and set up a network for acquisition and reduction of data from ERDA projects and contracts, other Federal agencies, and private industry. Special studies will address planning problems on the ERDA branch level, such as the implementation of Federal environmental statutes.

Project Title:	Economic Analyses of Geothermal Energy Development in the State of California
Contract No:	E(04-3)-0115
Contractor:	Stanford Research Institute Menlo Park, California
Principal Investigator:	Gopalachary Ramachandran (415) 326-6200, ext. 4441
Program Manager:	Robert E. Oliver (202) 376-4846 FTS 376-4846
Project Objective:	To provide economic analyses of the implications of the development scenarios provided by the Regional Operations Research for Geothermal Development in the State of California.
Funding:	FY 75 - -- FY 76/TQ - $198K
Contract Term:	3/15/76-12/31/76
Reports Issued:	None

Project Title: Economic Analyses of Geothermal Energy Development in the State of California

Contract No: E(04-3)-0115

SUMMARY

This project will support the Jet Propulsion Laboratory study, "Regional Operations Research for Geothermal Development in the State of California," being performed under contract number E(04-3)-0959 and reported in section 6.2. The project will provide the economic analyses of the implications of the scenarios developed in that study.

The cost of energy production, both electric and non-electric, from the geothermal resources considered in the development of the growth scenario will be analyzed. Parametric studies will be performed to determine the effects on the overall economics of power production due to variations in power plant design, resource characteristics, end uses, technology status, and environmental protection requirements.

Projections of market capture prospects for geothermal energy will be made, based on assumptions concerning the future costs of geothermal energy and alternative sources of energy. Cost-benefit analyses of alternative government programs will be performed. The analyses will include estimates of government expenditures, losses in revenues, and costs and benefits for energy producers and consumers.

A decision focused cost-benefit analysis of two site-specific detailed geothermal development scenarios will be performed. Benefits and costs to the region and subsequent impacts at the local, regional, and national levels will be quantitatively assessed. The costs and benefits to the region will include increased costs of public services such as roads, schools, increase in tax base, demographic shifts, and related factors.

Project Title: Geothermal Loan Guarantee Package

Contract No: E(04-3)-1279

Contractor: Coopers and Lybrand
San Francisco, California

Principal Investigators: Michael H. Heys
(415) 445-1200

Gerald L. Lanterman
(415) 834-5400

Program Manager: Lawrence Falick
(202) 376-4899
FTS 376-4899

Project Objective: To develop instructions for applicants for the proper filing of applications and periodic status reports in regard to projects guaranteed or to be guaranteed under the ERDA Geothermal Loan Guarantee Program.

Funding: FY 75 - --
FY 76/TQ - $ 48K

Contract Term: 5/28/76-8/16/76

Reports Issued: None

Project Title: Geothermal Loan Guarantee Package

Contract No: E(04-3)-1279

SUMMARY

The scope of work to be performed in connection with the loan guarantee package will be to develop the necessary forms, instruction manuals, definition of terms and, where necessary, commentary on the interpretation of regulations (10 CFR Part 790) as they apply to the ERDA Geothermal Loan Guarantee Program.

To achieve these objectives, the following four-step approach will be used:

Step 1--Develop System Concept Through the Interview Cycle

This step will entail in-depth interviews with key members of ERDA staff to develop overall design concepts and information requirements in order to establish an initial format for the Loan Guarantee Application package.

Step 2--Prepare Preliminary Package

After completion of Step 1, the contractor will proceed to the development and assembly of the loan guarantee package. After the preliminary package has been assembled and approved by ERDA, it will be sent to ERDA-selected industry participants and financial institutions for review and comments.

Step 3--Perform Industry and Lender Review

Meetings between ERDA-selected industry and lender participants and teams composed of both ERDA and contractor personnel will be held to elicit industry and lender input.

Step 4--Delivery of Final Application Package

Following agreement on changes to be made from Step 3, all material to be contained in the Loan Guarantee Package will be finalized.

Project Title:	The Geothermal Resource Industry: Profile and Incentives Analysis
Contract No:	E(04-3)-0113
Contractor:	University of Southern California School of Law Los Angeles, California
Principal Investigator:	Christopher D. Stone (213) 746-2180
Program Manager:	Randall C. Stephens (202) 376-4897 FTS 376-4897
Project Objective:	To develop an in-depth profile of the present status of the geothermal resource industry and assess policy options to stimulate investment in geothermal development.
Funding:	FY 75 - -- FY 76/TQ - $185K
Contract Term:	6/1/76-8/31/77
Reports Issued:	None

Project Title: The Geothermal Resource Industry: Profile and Incentives Analysis

Contract No: E(04-3)-0113

SUMMARY

In this project, an in-depth profile of the present status of the geothermal resource industry will be developed with emphasis on sources of capital, and alternative Federal Government policy options will be assessed for stimulation of increased investment in geothermal development.

To initiate the development of the in-depth profile, the investigators submitted preliminary issue papers discussing policy options and their impact on the geothermal resource industry in two areas. These preliminary papers dealt with alternative Federal tax policies and with vertical integration in utilities. Further analysis of these topics will continue, and other policies affecting investment devices will also be reviewed in-depth.

Project Title: State Water Law and Geothermal Resource Development

Contract No: E(11-1)-4016

Contractor: Indiana University School of Law
Bloomington, Indiana

Principal Investigator: A. Dan Tarlock
(812) 337-6455

Program Manager: Randall C. Stephens
(202) 376-4897
FTS 376-4897

Project Objective: The purpose of the project is to analyze the relationships and effects of State water law on geothermal resource development in Western States.

Funding: FY 75 - --
FY 76/TQ - $ 63K

Contract Term: 6/1/76-8/31/77

Reports Issued: None

Project Title: State Water Law and Geothermal Resource Development

Contract No: E(11-1)-4016

SUMMARY

The project will be initiated with a survey of current cases, legislation, and secondary literature dealing with water law to identify present doctrines and major areas of potential conflicts and problems. Through discussions and interviews with State regulatory officials and industry representatives, the significance of problem areas will be assessed and the impacts of alternative legal treatments will be determined.

An assessment will be made of the state of current scientific knowledge regarding technical questions that are relevant to the establishment of legal relationships between water and geothermal resources. The most significant unresolved technical questions will be identified, and the impact of technical uncertainties on establishment of legal regimes will be described.

A final report will be prepared describing the state of present water law in the Western States as it relates to geothermal resources, assessing the impacts of current doctrines on geothermal development and competing interests, proposing alternative legal structures, and describing the policy considerations favoring or opposing these alternatives.

Project Title:	National Geothermal Information Resource (GRID)
Contract No:	W-7405-ENG-48
Contractor:	Lawrence Berkeley Laboratory Berkeley, California
Principal Investigator:	Sidney Phillips (415) 843-2740, Ext. 5818 FTS 451-5818
Program Manager:	Seymour Shwiller (202) 376-4897 FTS 376-4897
Project Objective:	To provide a system for: data compilation; scientific evaluation and annotation; writing of reference abstracts, development and implementation of improved compilation; information-handling; and computerization procedures and techniques.
Funding:	FY 75 - -- FY 76/TQ - $ 75K
Contract Term:	7/1/75-9/30/77
Reports Issued:	S. L. Phillips, et. al., "Review of Geothermal Subsidence," Lawrence Berkeley Laboratory report LBL-3220 (September 1975)

Project Title: National Geothermal Information Resource (GRID)

Contract No: W-7405-ENG-48

SUMMARY

The primary mission of GRID is to act as the focal point for the collection, organization and dissemination of critically evaluated and analyzed data relevant to the utilization of geothermal energy. The data include both site-dependent and basic scientific information which are gathered from the published literature and through exchange agreements with participating U.S. and worldwide data bases. The geothermal information and numerical data are computer-filed and disseminated to the geothermal community in the following forms: (1) indexed and annotated bibliographies; (2) tabulated unevaluated numerical data; (3) tabulated evaluated numerical data; and (4) reports on a critical review of the current status of information in selected areas of geothermal science and technology. The data and reports are reviewed by acknowledged experts prior to general dissemination.

The following principal tasks are in progress: (1) development of the computer file bibliographic formats; (2) establish contacts for cooperative data exchange; (3) compilation and review of subsidence, hydrogen sulfide, exploration, sodium chloride basic properties; (4) site-dependent reservoir characteristics; and (5) proposal work plan for well-logging.

Project Title: Printing of Proceedings of the 2nd United Nations Symposium on the Development and Use of Geothermal Resources

Contract No: N/A (Letter to ERDA/San Francisco Operations Office)

Contractor: Lawrence Berkeley Laboratory
Berkeley, California

Principal Investigator: Charles Pezzotti
(415) 843-2740, Ext. 6003
FTS 451-6003

Program Manager: Seymour Shwiller
(202) 376-4897
FTS 376-4897

Project Objective: Provide copies of the proceedings to participants of the Symposium.

Funding: FY 75 - --
FY 76/TQ - $ 85K

Contract Term: 7/1/75-10/31/76

Reports Issued: None

Project Title: Printing of Proceedings of the 2nd United Nations Symposium on the Development and Use of Geothermal Resources

Contract No: N/A (Letter to ERDA/San Francisco Operations Office)

SUMMARY

To provide 2100 copies of the symposium proceedings to be distributed as follows:

1200 copies to participants
300 copies to ERDA
300 copies to the Secretariat of the United Nations
300 copies to the United States Organizing Committee, Inc.
P.O. Box 7798
San Francisco, California 94120

The symposium was hosted by the following U.S. Government agencies:

Department of the Interior
Department of State
National Science Foundation

by the State of California:

The Office of the Governor
State of California Resources Agency
The University of California

and by the Secretariat of the United Nations.

Publication and distribution of the proceedings is expected by October 1976.

Appendix A — Completed Contracts

Appendix A - Completed Contracts

Page

A.6 Environmental Control and Institutional Studies (continued)

Project Title: Rock-Melting "Subterrene" System Development

Contract No: W-7405-ENG-36

Contractor: Los Alamos Scientific Laboratory
Los Alamos, New Mexico

Principal Investigator: C. A. Bankston
(505) 667-6677
FTS 843-6677

Program Manager: Clifton Carwile
(202) 376-4912
FTS 376-4912

Project Objective: The primary objective of the Los Alamos Subterrene Project was the development of a novel drilling technology based upon the progressive local melting of rocks and soils.

Funding: FY 75 - $912K
FY 76 - $900K

Contract Term: 7/1/74-6/30/76

Date Completed: (Terminated 6/30/76)

Reports Issued: (see list after "Summary")

Project Title: Rock-Melting "Subterrene" System Development

Contract No: W-7405-ENG-36

SUMMARY

In the course of this project, which was terminated at the end of FY 76, a series of electrically heated, small-diameter prototype melting penetrators had been developed and tested in a wide variety of hard rock and soft ground formations. The long-term goal of the project was to develop technology and hardware which would ultimately lead to practical devices for penetrating into deep, hot, hard formations for geothermal energy exploration and extraction. The proposed method produces a liquid rock-melt that can be chilled to a glass and formed into a dense, strong, firmly attached hole lining. It is projected from the basic nature of the rock-melting process that it is ideally suited for the high-temperature problems encountered in deep drilling.

The critical engineering problems have been identified and a 5-year program plan which would culminate in a deep drilling demonstration has been developed.

Project Title: Rock-Melting "Subterrene" System Development

Contract No: W-7405-ENG-36

Reports Issued:

LOS ALAMOS SCIENTIFIC LABORATORY REPORTS

E. S. Robinson, R. M. Potter, B. B. McInteer, J. C. Rowley, D. E. Armstrong, R. L. Mills, and M. C. Smith, Editor, "A Preliminary Study of the Nuclear Subterrene," Los Alamos Scientific Laboratory report LA-4547 (April 1971).

R. G. Gido, "Subterrene Penetration Rate/Melting Power Relationship," Los Alamos Scientific Laboratory report LA-5204-MS (March 1973).

J. W. Neudecker, A. J. Giger, P. E. Armstrong, "Design and Development of Prototype Universal Extruding Subterrene Penetrators," Los Alamos Scientific Laboratory report LA-5205-MS (March 1973).

D. L. Sims, "Identification of Potential Applications for Rock-Melting Subterrenes," Los Alamos Scientific Laboratory report LA-5206-MS (February 1973).

D. J. Murphy and R. G. Gido, "Heat Loss Calculations for Small Diameter Subterrene Penetrators," Los Alamos Scientific Laboratory report LA-5207-MS (February 1973).

M. C. Krupka, "Phenomena Associated with the Process of Rock Melting - Application to the Subterrene System," Los Alamos Scientific Laboratory report LA-5208-MS (February 1973).

R. E. Williams, "Development and Construction of a Modularized Mobile Rock-Melting Subterrene Demonstration Unit," Los Alamos Scientific Laboratory report LA-5209-MS (March 1973).

P. E. Armstrong, "Subterrene Electrical Heater Design and Morphology," Los Alamos Scientific Laboratory report LA-5211-MS (February 1974).

J. W. Neudecker, "Design Description of Melting-Consolidating Prototype Subterrene Penetrators," Los Alamos Scientific Laboratory report LA-5212-MS (February 1973).

R. E. Williams and J. E. Griggs, "Use of the Rock-Melting Subterrene for Formation of Drainage Holes in Archaeological Sites," Los Alamos Scientific Laboratory report LA-5370-MS (August 1973).

Project Title: Rock-Melting "Subterrene" System Development

Contract No: W-7405-ENG-36

Reports Issued (continued)

D. L. Sims, "A Versatile Rock-Melting System for the Formation of Small-Diameter Horizontal Glass-Lined Holes," Los Alamos Scientific Laboratory report LA-5422-MS (October 1973).

J. W. Neudecker, "Conceptual Design of a Coring Subterrene Geoprospector," Los Alamos Scientific Laboratory report LA-5517-MS (February 1974).

John H. Altseimer, "Geothermal Well Technology and Potential Applications of Subterrene Devices - A Status Review," Los Alamos Scientific Laboratory report LA-5689 (August 1974).

W. A. Stark, Jr. and M. C. Krupka, "Chemical Corrosion of Molybdenum and Tungsten in Liquid Basalt, Tuff, and Granite with Application to Subterrene Penetrators," Los Alamos Scientific Laboratory report LA-5857-MS (February 1975).

W. C. Turner, "Unique Refractory Techniques for Fabricating Subterrene Penetrators," Los Alamos Scientific Laboratory report LA-6038-MS (September 1975).

M. C. Krupka, "Melting of Limestone Rocks," Los Alamos Scientific Laboratory memo S-31, (January 1972).

J. W. Neudecker, "Fifty-Foot Hole Melted by Two-Inch Diameter Subterrene," Los Alamos Scientific Laboratory memo S-37, (February 1972).

L. W. McDonough, "Eighty-Three Foot Subterrene Hole," Los Alamos Scientific Laboratory memo S-48, (June 1972).

J. W. Neudecker, "Melt Removal Methods in Universal Rock Melters," Los Alamos Scientific Laboratory memo S-53, (October 1972).

R. G. Gido, "Literature Review on Glass-Melt Handling," Los Alamos Scientific Laboratory memo S-54, (October 1972).

R. E. Williams, "Melting a 50mm Horizontal Hole in Tuff," Los Alamos Scientific Laboratory memo S-60, (December 1972).

Project Title: Rock-Melting "Subterrene" System Development

Contract No: W-7405-ENG-36

Reports Issued (continued)

A. J. Giger, "Universal Rock Drill Development," Los Alamos Scientific Laboratory memo S-61, (January 1973).

J. H. Altseimer, "Rock Melting Systems for Producing Deep Geothermal Wells--A Preliminary Review," Los Alamos Scientific Laboratory technical brief, (September 1975).

PUBLICATIONS

R. J. Hanlod, "The Subterrene Rock Melting Excavation Program," Proceedings of the 15th Symposium on Rock Mechanics, National Committee on Rock Mechanics (National Academy of Science), South Dakota School of Mines and Technology, Custer, South Dakota, September 17-19, 1973.

J. C. Rowley, R. J. Hanold, C. A. Bankston and J. W. Neudecker, "Rock Melting Subterrenes--Their Role in Future Technology," Proceedings of 1974 Rapid Excavation and Tunneling Conference, Volume 2, American Institute of Mining Engineers, San Francisco, California, June 24-27, 1974.

J. C. Rowley, "Rock Melting Applied to Excavation and Tunneling," Proceedings of the 3rd International Congress, International Society of Rock Mechanics, Denver, Colorado, September 1-7, 1974.

J. C. Rowley, "Rock Melting Technology and Geothermal Drilling," Proceedings of the Conference on Research for Development of Geothermal Energy Resources, National Science Foundation and Atomic Energy Commission, California Institute of Technology, Pasadena, California, September 23, 1974.

Project Title: High Temperature Amplifier Development Program

Contract No: E(04-3)-1184

Contractor: Mechanics Research, Inc.
Los Angeles, California

Principal Investigator: Ronald D. Kelly
(213) 670-4650

Program Manager: Larry Ball
(202) 376-4914
FTS 376-4914

Project Objective: To design and build an amplifier for use in geothermal logging sondes with a temperature capability of 250°C.

Funding: FY 75 - --
FY 76 - $33K

Contract Term: 1/76-4/76

Date Completed: 5/76

Reports Issued: W. Cannon, "Development of a Prototype High Temperature Amplifier for Geothermal Well Logging--Final Report," Mechanics Research report MRI-2870, (May 1976).

Project Title: High Temperature Amplifier Development Program

Contract No: E(04-3)-1184

SUMMARY

An amplifier was designed and tested both in the laboratory and in a hot borehole. The design used commercial ceramic tubes and was built for inclusion in a sealed sonde. The basic amplifier characteristics are:

1. Continuous operation at 250°C (a 1000 hour life test was accomplished consisting of cycles of 48 hours at 260°C and 2 hours at room temperature).
2. Nominal gain of 40 db (45 db was achieved in direct coupled mode and 31 db with AC coupling).
3. Flat frequency response from 1 Hz to above 40 kHz. (A typical logging cable will limit the response to about 1.2 kHz.)
4. Packaged to fit within a 3 1/2 inch diameter sonde. (The amplifier circuit board is mounted in a cylindrical shell 8 1/2 inches long and 3 inches in diameter.)

MRI intend to make the amplifier available commercially.

Project Title:	Feasibility of Using a Magnetohydrodynamic Generator for Electromagnetic Soundings of the Earth
Contract No:	E(45-1)-2426*
Contractor:	Montana College of Mineral Science and Technology Butte, Montana
Principal Investigator:	David Fleming (406) 792-8321, ext. 278
Program Manager:	Larry Ball (202) 376-4914 FTS 376-4914
Project Objective:	To investigate the feasibility of using a magnetohydrodynamic (MHD) generator to evaluate geothermal areas through electromagnetic soundings of the earth.
Funding:	FY 75 - -- FY 76/TQ - $8K
Contract Term:	3/15/76-7/15/76
Date Completed:	7/15/76
Reports Issued:	Final report being published.

* This project encompasses Task Agreement No. 1 under the referenced contract.

Project Title: Feasibility of Using a Magnetohydrodynamic Generator for Electromagnetic Soundings of the Earth

Contract No: E(45-1)-2426

SUMMARY

There are numerous geothermal areas which could be more clearly delineated through the use of advanced electromagnetic soundings made from the surface. The depth and resolution of present systems are largely noise or frequency/wave length limited. The objective of this study is to consider the use of more exotic receivers in conjunction with a high powered source operating in the time domain.

The feasibility study accomplished some basic engineering on the use of an MHD pulse generator in conjunction with pulse stacking receivers. The Russians have built and successfully used MHD generators for geophysical prospecting. Thus, technically, the concept is feasible.

Five institutions are proposing to cooperate on a program to provide (build or lease) a pulse generator with compatible receivers for the U.S. The program would be coordinated by the Institute for Electromagnetic Research in Colorado.

Project Title: Accelerated Assessment of the Geothermal Resources of the U.S.

Contract No: E(49-27)-1001

Contractor: U.S. Department of the Interior
Geological Survey
Office of Geochemistry and Geophysics
Reston, Virginia

Principal Investigator: Richard Fiske
(703) 860-6584
FTS 928-6584

Program Manager: J. W. Salisbury
(202) 376-4914
FTS 376-4914

Project Objective: To accelerate geothermal resource assessment.

Funding: FY 75 - $343K
FY 76 - --

Contract Term: 2/26/75-12/31/75

Date Completed: 12/31/75

Reports Issued: Assessment of the Geothermal Resources of the United States - 1975. Editors: D. E. White and D. L. Williams, U.S. Geological Survey Circular 726, July 1975.

Open Files Reports - data sheets in individual geothermal systems, U.S. Geological Survey, Menlo Park, California.

Project Title: Accelerated Assessment of the Geothermal Resources of the U.S.

Contract No: E(49-27)-1001

SUMMARY

This project was designed to provide as detailed an assessment of the geothermal resources of the U.S. as data available in early 1975 would permit. Most of the work was completed and published as USGS Circular 726. The remainder was subcontracted to The Analytical Sciences Corporation (TASC) to perform a statistical (pattern recognition) assessment study utilizing the various types of detailed geophysical and geological data available in the State of Nevada.

The work performed on this project, and published as USGS Circular 726, consisted of a careful assimilation of available geological, geophysical, geochemical and hydrologic data. The USGS used this to determine the distribution and magnitude of the heat in the ground "resource base." Finally they made a simple technological and economic analysis of what part of the resource base was recoverable as thermal and electric energy.

Project Title: Geological-Geophysical Evaluation of the Hot Springs Area, Bath County, Virginia

Contract No: E(40-1)-4920

Contractor: Virginia Polytechnic Institute and State University
Blacksburg, Virginia

Principal Investigator: John K. Costain
(703) 951-6310

Program Manager: Clayton R. Nichols
(202) 376-4914
FTS 376-4914

Project Objective: To determine the character and origin of hot springs in northwestern Virginia.

Funding: FY 75 - $ 50K
FY 76 - --

Contract Term: 6/1/75-4/30/76

Date Completed: 5/19/76

Reports Issued: "The Los Alamos Scientific Laboratory's Dry Hot Rock Experiment: Engineering and Scientific Studies," presented at the 1976 Spring Meeting of the American Geophysical Union, Washington, D.C., April 12-15, 1976 and reported in Transactions of the American Geophysical Union, Volume 57, No. 4, April 1976, page 353

John K. Costain, "Geological and Geophysical Study of the Origin of the Warm Springs in Bath County, Virginia--Final Report," with Appendix by G. V. Keller and R. A. Crewdson, Virginia Polytechnic Institute and State University.

Project Title: Geological-Geophysical Evaluation of the Hot Springs Area, Bath County, Virginia

Contract No: E(40-1)-4920

SUMMARY

It is postulated from known geological and geophysical data that the conditions required for the deep circulation of meteoric water may be present in this part of the folded Appalachians and the heat may be derived from plutonic radiogenic sources. The hottest thermal springs in the Eastern United States are found at or near the junction or termination of major structural trends, and in the vicinity of geophysical anomalies. Work underway includes: (1) preparation of detailed geologic map on an area approximately 20 x 10 miles in order to define the structure, jointing, and lithologic units, and the influence of regional strain patterns on the origin of the hot springs; (2) interpretation of 400 sq. miles of rotating dipole-bipole deep electrical resistivity survey for the purpose of determining the presence of zones of low-resistivity; and (3) drilling to determine the true geothermal gradient and heat flow in the area. These data will be combined with available reflection seismology profiles which will indicate sediment thickness and regional structure. Modeling of the preliminary data seems to be compatible with a deep circulation and radiogenic heat source at 15-20 Km depth.

A preliminary geologic map and structural cross-sections have been prepared for the Warm Springs anticline and surrounding region. A reconnaissance electrical resistivity bipole-dipole survey revealed resistivity lows which may be associated with the 38th parallel fracture zone. Heat flow values have been obtained at two locations.

Project Title: Evaluation of a Geothermal Area of Abnormally High Heat Flow at Marysville, Montana

Contract No: E(45-1)-1830

Contractor: Battelle Pacific Northwest Laboratories
Richland, Washington

Principal Investigator: Donald Stewart
(509) 946-2681
FTS 444-7411, Ext. 946-2681

Program Manager: David B. Lombard
(202) 376-4902
FTS 376-4902

Project Objective: Determine the nature of the Marysville geothermal anomaly and assess its energy potential.

Funding: FY 75 - $1,025K
FY 76 - --

Contract Term: 6/73-6/75

Date Completed: 6/75

Reports Issued: William P. McSpadden, Project Manager, "The Marysville, Montana Geothermal Project--Final Report," Battelle Pacific Northwest Laboratories, report number 23111-01410 (September 1975)

Project Title: Evaluation of a Geothermal Area of Abnormally High Heat Flow at Marysville, Montana

Contract No: E(45-1)-1830

SUMMARY

Heat flow measurements made in the vicinity of Marysville, Montana, under NSF and USGS sponsorship from 1966 through 1973 showed extremely high geothermal gradients (up to 240°C/kilometer) with no surface manifestations within approximately 20 miles. A project to characterize this heat flow anomaly and assess its energy potential was initiated by NSF and continued under ERDA. The objective was to test the hypothesis of a hot dry rock reservoir near Marysville and to assess the nature of that reservoir for energy extraction and electric power generation.

The deep hole was drilled to a total depth of about 7000 feet in 1974, considerably exceeding the initial target depth of 6000 ft. Drilling was continued because the expected large temperature increases at depth were not encountered. Fracture zones intersected by the hole were found to produce considerable water. The flow of water in the hole was many times the minimum rate that would be required to mask any geothermal gradient of the expected magnitude. Thus the deep hole has not yet confirmed or disproven the existence of a near-surface magma chamber; however, it is at least somewhat deeper than anticipated.

It was concluded that the hole had penetrated a hydrothermal convection system at about 95°C (200°F), and that this system was responsible for the high heat flow and other geophysical anomalies observed at the ground surface. The contractor and USGS continued to make temperature measurements in the hole in 1975, but there are no ERDA plans for future major projects at the Marysville site since, at the low temperatures (about 95°C), commercial development does not appear feasible.

Project Title:	Geothermal Resource Utilization Technology: Geothermal Energy Development -- Geopressure
Contract No:	W-7405-ENG-48
Contractor:	Lawrence Livermore Laboratory Livermore, California
Principal Investigator:	A. L. Austin (415) 447-1100, Ext. 3946 FTS 451-3946
Program Manager:	Keith Westhusing (David B. Lombard) (202) 376-4902 FTS 376-4902
Project Objective:	To develop advanced utilization technologies specifically applicable to recovery and conversion of energy from geopressured resources.
Funding:	FY 75 - $ 34K FY 76 - --
Contract Term:	7/1/74-6/30/75
Date Completed:	6/30/75
Reports Issued:	Texas Bureau of Economic Geology Geological Circular No. 75-1, "Geothermal Resources, Frio Formation, South Texas" (1975)

Project Title: Geothermal Resource Utilization Technology: Geothermal Energy Development -- Geopressure

Contract No: W-7405-ENG-48

SUMMARY

This study had two important results: First, it demonstrated the power and utility of a new assessment technique for geopressured geothermal resources, namely the integration of existing well log data with sand facie analysis to identify regional "fairways" where geothermal aquifers are likely to occur. Second, it identified two such fairways in south Texas.

Project Title: Development of an Assessment Methodology for Geopressured Zones of the Upper Gulf Coast Based on a Study of Abnormally Pressured Gas Fields in South Texas

Contract No: E(11-1)-2687

Contractor: Southwest Research Institute
San Antonio, Texas

Principal Investigator: Robert K. Swanson
(512) 684-5111

Program Manager: Keith Westhusing
(202) 376-4902
FTS 376-4902

Project Objective: To investigate the value of production analysis in abnormally pressured hydrocarbon deposits as a tool for defining the characteristics of adjacent geopressured aquifers.

Funding: FY 75 - $129K
FY 76/TQ - --

Contract Terms: 6/1/75-8/31/76

Date Completed: 8/31/76

Reports Issued: Preliminary report in "Proceedings of the Second Geopressured Geothermal Energy Conference," Center for Energy Studies, University of Texas at Austin, February 23-25, 1976 (5 volumes), Myron H. Dorfman and Richard W. Deller, editors

R. K. Swanson, P. Oetking, J. S. Osoba, R. C. Hagens, "Development of an Assessment Methodology for Geopressured Zones at the Upper Gulf Coast Based on a Study of Abnormally Pressured Gas Fields in South Texas--Final Report" Southwest Research Institute Report COO-2687-5 (August 1976)

Project Title: Development of an Assessment Methodology for Geopressured Zones of the Upper Gulf Coast Based on a Study of Abnormally Pressured Gas Fields in South Texas

Contract No: E(11-1)-2687

SUMMARY

The purpose of this program was to establish a methodology for assessment of the deep geopressured zone on the Gulf Coast, based on a detailed examination of south Texas gas fields which have produced substantial quantities of fluids from these zones. Of principal importance to this effort was the identification of the number and location of geopressured producing fields in the study region, which included the extreme south Texas counties of Hidalgo, Brooks, Cameron, Willacy,Kenedy, and Live Oak.

The first significant task in the project was the location of all producing fields in the region. In order to identify the geopressured production, all producing wells in each of the listed fields were identified. Well logs were obtained from wells from each of the listed fields. Geologic investigation of each of the identified geopressured fields was undertaken, depending upon the degree of control and other factors. Available reservoir information from each of the fields was obtained from a variety of sources, including Railroad Commission production records, operating company completion data, well test records, and scout cards.

From this study, a well-developed assessment methodology has emerged which is applicable to broad areas of the Gulf Coast. In addition, the study of gas fields in the extreme south Texas region has produced some limited conclusions about the geothermal potential of the region. Within the limitations of this study, the effective reservoir permeabilities in extreme south Texas appear to be quite low, averaging about 1 md. As a result, it does not appear that the geopressured formations in the extreme south Texas region will support flow rates high enough to be economically attractive without a major advance in stimulation technology.

Project Title: Preliminary Evaluation of Geothermal Resources of The Middle Texas Gulf Coast - Geopressured Evaluation

Contract No: E(40-1)-4882

Contractor: University of Texas at Austin
Austin, Texas

Principal Investigator: Charles G. Groat
(512) 471-1534

Program Manager: Keith Westhusing
(202) 376-4902
FTS 376-4902

Project Objective: To develop a means for assessing geopressured aquifers by analyzing existing geological and geophysical data and to delineate large volume geopressured sand areas along the Middle Texas Gulf Coast.

Funding: FY 75 - $ 40K
FY 76 - --

Contract Term: 1/1/75-7/31/75

Date Completed: 7/31/75

Reports Issued: D. G. Bebout, O. K. Agagu, M. H. Dorfman, "Geothermal Resources, Frio Formation, Middle Texas Gulf Coast," University of Texas Bureau of Economic Geology Circular No. 75-8 (1975).

Volume II, "Resource Assessment" of "Proceedings of the Second Geopressured Geothermal Energy Conference," Center for Energy Studies, University of Texas at Austin, February 23-25, 1976 (5 volumes), Myron H. Dorfman and Richard W. Deller, editors

Project Title: Preliminary Evaluation of Geothermal Resources of The Middle Texas Gulf Coast - Geopressured Evaluation

Contract No: E(40-1)-4882

SUMMARY

Beginning with existing well log data, active seismic profiles, and micropaleoentological analyses, investigators reconstructed depositional histories of sands that became geopressured aquifers, assessing in the process their potential value as geothermal resources.

The analysis of the Frio formation on the Middle Texas coast delineated several regions that appear to have a favorable potential for geothermal development. Maps and sections of the Frio formation which localize areas of large volume sands were constructed.

Project Title: U.S. Gulf Coast Geopressured Geothermal Resource Management and Scope-of-Work Study for Generation of Electric Power

Contract No: E(40-1)-4900

Contractor: University of Texas at Austin
Austin, Texas

Principal Investigator: Myron H. Dorfman
(512) 471-3220

Program Manager: Keith Westhusing
(202) 376-4902
FTS 376-4902

Project Objective: To establish criteria for utilization of geopressured geothermal reservoirs and make preliminary plans for a resource test facility.

Funding: FY 75 - $244
FY 76 - $ 55

Contract Term: 5/31/76-3/31/76

Date Completed: 3/31/76

Reports Issued: "Proceedings of the Second Geopressured Geothermal Energy Conference," Center for Energy Studies, University of Texas at Austin, February 23-25, 1976 (5 volumes), Myron H. Dorfman and Richard W. Deller, editors

Vol. I, "Summary and Future Projections,"
Vol. II, "Resource Assessment,"
Vol. III, "Reservoir Research and Technology,"
Vol. IV, "Surface Technology and Resource Utilization,"
Vol. V, "Legal, Institutional and Environmental,"

Project Title: U.S. Gulf Coast Geopressured Geothermal Resource Management and Scope-of-Work Study for Generation of Electric Power

Contract No: E(40-1)-4900

SUMMARY

This project involved a system study of the geopressured geothermal resources of the U.S. Gulf Coast and preliminary planning for a geopressured resource test facility. The system analysis determined boundary conditions and criteria for utilization of the resource, identified alternative approaches to such utilization, and outlined needed technology developments. The test facility planning involved identification of potential site areas, evaluation of environmental, legal, and institutional concerns, definition of user requirements, conceptual design activities, and provision of scopes, schedules, and cost projections for development of the test facility.

The system analysis and facility planning project elements were each divided into four tasks, one each in the categories of Resource Assessment; Advanced Research and Technology; Environmental, Legal, and Institutional Considerations; and Resource Utilization.

The outputs of this project were:

1. An analysis of the energy potential, feasibility of development, and barriers to rapid utilization of the Gulf Coast geopressured geothermal resource, together with recommendations for action to surmount the barriers.

2. A preliminary plan and cost estimate for establishing a geopressured resource test facility, including several site options, plus a recommended team and detailed plan to carry out the next phase.

The project identified key technical, legal, institutional, and environmental uncertainties. Specific approaches to many of the problems were planned. One principal recommendation is for the design and construction of a geothermal well to give long term production data on on geopressured brines.

The results of the project were published in the five volumes of the "Proceedings of the Second Geopressured Geothermal Energy Conference."

Project Title:	Geothermal Resource Study in the Salton Sea Region of California
Contract No:	E(04-3)-1086
Contractor:	California Institute of Technology Pasadena, California
Principal Investigator:	Martin Goldsmith (213) 795-6811
Program Manager:	Ronald R. Loose (202) 376-4905 FTS 376-4905
Project Objective:	Provide carefully researched recommendations to the National Science Foundation as to requirements for research and experimental facilities in the high temperature, high salinity geothermal resource in the Salton Sea region of California.
Funding:	FY 75 - $ 88K FY 76 - --
Contract Term:	11/15/74-10/31/75
Date Completed:	10/31/75
Reports Issued:	(see list after "Summary")

Project Title: Geothermal Resource Study in the Salton Sea Region of California

Contract No: E(04-3)-1086

SUMMARY

This investigation was directed at definition of and support for a geothermal resource demonstration program to be conducted at that part of the Salton Sea region designated as a Known Geothermal Resource Area (Salton Sea KGRA). The originating agency was NSF/RANN, but in March 1975 the responsibility for the project was transferred to ERDA.

Engineering studies indicate that for high-temperature reservoirs the technique of pumping wells was found to be inferior to flashing flow (self-flow), as theory suggests a considerable advantage to be gained by increasing well diameter in the upper (flashing) parts of the well bore. This technique may offer a major savings in field development cost. For high-temperature reservoirs it was found that multiple-flash direct steam systems offer superior performance as compared to binary processes. Total-flow expanders offer promise. Even for low-temperature reservoirs, binary processes offer no significant theoretical performance advantage as compared to flash processes.

A review of trace element analyses of Salton Sea KGRA brines indicates that more sophisticated sampling and analytic techniques will have to be applied to be sure that minor constituent content is properly understood. Generally, environmental problems will come from volatile species. It was found that much of the existing useful empirical engineering information concerning scale and corrosion is not available in the open literature.

A geology investigation was to have been provided by faculty consultants from University of California at Riverside, but this investigation has proven to be unnecessary. The current geologic knowledge of the Salton Sea KGRA was recently published in the Ph.D. dissertation of Randall.

Consultants (Petroleum Engineering group at Stanford University) report that methods appropriate to evaluation of the Salton Sea reservoir are contained in the paper "Pressure Transient Analysis for Geothermal Wells" by Henry J. Ramey, delivered at the Second UN Geothermal Symposium in San Francisco.

Project Title: Geothermal Resource Study in the Salton Sea Region of California

Contract No: E(04-3)-1086

SUMMARY (continued)

A legal and institutional study has found that the problems are poorly documented in the literature, and it is not possible on the basis of the published record to define specific changes in the law or institutions pertaining to geothermal development.

The major difficulties to be resolved at the Salton Sea KGRA involve the unusual chemical nature of the brine. No other U.S. geothermal reservoir has been found to share these characteristics. Therefore, the Salton Sea is a poor location for a laboratory to serve as a general resource for other geothermal developments. The program at the Salton Sea should be directed to the problems of that location.

Project Title: Geothermal Resource Study in the Salton Sea Region of California

Contract No: E(04-3)-1086

Reports Issued:

CALIFORNIA INSTITUTE OF TECHNOLOGY REPORTS

Martin Goldsmith, "Summary Report, Geothermal Research Study in the Salton Sea Region of California," California Institute of Technology (October 1975).

Andrew Eaten, "Trace Element Problems, Geothermal Research Study in the Salton Sea Region of California," California Institute of Technology (July 1975).

M. R. Bates, J. E. Krier, and W. D. Montgomery, "Legal and Institutional Factors, Geothermal Research Study in the Salton Sea Region of California," California Institute of Technology (June 1975).

Michael R. Hoffman, "Brine Chemistry - Scaling and Corrosion - Geothermal Research Study in the Salton Sea Region of California," California Institute of Technology report EQL Memorandum No. 14 (July 1975).

David G. Elliott, "Comparison of Brine Production Methods and Conversion Processes for Geothermal Electric Power Generation," California Institute of Technology EQL Report No. 10 (July 1975).

Henry J. Ramey, "Pressure Transient Analysis for Geothermal Wells," Proceedings of the Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, May 20-29, 1975 (to be published).

Walter Randall, "An Analysis of the Subsurface Structure and Stratigraphy of the Salton Sea Geothermal Anomaly, Imperial Valley, California," Ph.D. dissertation, University of California, Riverside, California (December 1974)

Project Title:	Geothermal Program Definition Project (GPDP)
Contract No:	E(49-27)-1004
Contractor:	NASA Pasadena, California
Work Performed by:	Jet Propulsion Laboratory California Institute of Technology Pasadena, California
Principal Investigator:	Allan Conrad (213) 354-3327 FTS 792-3327
Program Manager:	Momtaz N. Mansour (P. Kruger) (202) 376-4897 FTS 376-4897
Project Objective:	To develop a Comprehensive National plan, for geothermal energy development in fulfillment of the requirements of PL 93-410.
Funding:	FY 75 - $636K FY 76 - $296K
Contract Term:	2/1/75-1/31/76
Date Completed:	1/31/76
Reports Issued:	"Program Definition for the Development of Geothermal Energy," NASA/JPL report 5040-6 (August 1975)

Project Title: Geothermal Program Definition Project (GPDP)

Contract No: E(49-27)-1004

SUMMARY

The goal for the National Geothermal Energy Development Program is to achieve a utilization of geothermal energy equivalent to one million barrels of oil per day by 1985. The objective of the Federal Government program is to stimulate industry by creating favorable conditions for making the necessary commitment.

This project stressed the discovery and development of hydrothermal systems in meeting the 1985 goal. Geopressured systems were also considered. In addition, the project considered the advancement of the technology and the development of hot dry rock, normal temperature gradient and magma systems to enable the continuation of a viable, dynamic growth pattern in geothermal energy use after 1985.

Nontechnological issues received particular attention because they are presently the major factors inhibiting rapid growth of geothermal exploration. Actions to overcome both technological and nontechnological impediments were evaluated.

This project provided the data base for preparation of the Geothermal RD&D Program Definition Report ERDA-86.

Project Title: Planning Support for Geothermal Energy Program Activities

Contract No: N/A (purchase order)

Contractor: Bechtel Corporation
San Francisco, California

Principal Investigator: Lawrence O. Beaulaurier
(415) 764-5914

Program Manager: Momtaz N. Mansour (P. Kruger)
(202) 376-4897
FTS 376-4897

Project Objective: To provide assistance to the Division of Geothermal Energy.

Funding: FY 75 - $ 6K
FY 76 - --

Contract Term: 2/75-6/75

Date Completed: 6/75

Reports Issued: "A National Plan for Energy Research, Development and Demonstration," ERDA report ERDA-48 (June 1975)

Project Title: Planning Support for Geothermal Energy Program Activities

Contract No: N/A (purchase order)

SUMMARY

The contractor provided support to the ERDA Division of Geothermal Energy in the preparation of ERDA-48, "A National Plan for Energy Research, Development and Demonstration."

Project Title:	Technical Support and Services for Development of Non-Electric Geothermal Applications Program
Contract No:	E(11-1)-2693
Contractor:	The MITRE Corporation, METREK Division McLean, Virginia
Principal Investigator:	Martin Scholl (703) 790-6559
Program Manager:	Donald H. Clements (202) 376-4902 FTS 376-4902
Project Objective:	To provide technical support and services for development of plans for implementing a non-electric applications program.
Funding:	FY 75 - $ 28K FY 76 - $ 24K
Contract Term:	6/1/75-3/31/76
Date Completed:	3/31/76
Reports Issued:	None

Project Title: Technical Support and Services for Development of Non-Electric Geothermal Applications Program

Contract No: E(11-1)-2693

SUMMARY

ERDA statutes and geothermal program objectives relevant to non-electric applications of geothermal energy, and open literature on industrial uses of geothermal heat will be reviewed to develop a basis for ranking of energy impacts of various non-electric applications. Work involves development of: (1) supporting documentation for preparation of proposal solicitations; (2) a scope of work for geothermal space heating and cooling handbook; and (3) detailed short-range plans for implementing the objectives of a non-electric geothermal applications program.

A set of guidelines has been developed which may be used in establishing the criteria for the proposal evaluation and selection procedure associated with solicitation of proposals in the area of non-electric applications of geothermal heat. Supporting documentation for the preparation of research investigation announcements have been provided to the sponsor.

Project Title: Support to ERDA Geothermal Energy Program Planning

Contract No: E(49-1)-3764

Contractor: The MITRE Corporation, METREK Division
McLean, Virginia

Principal Investigator: L. Goldberg
(703) 790-6000

Program Manager: Momtaz N. Mansour (P. Kruger)
(202) 376-4897
FTS 376-4897

Project Objective: To provide data on how geothermal energy RD&D program objectives, strategies, and implementation plans will be achieved.

Funding: FY 75 - $ 37K
FY 76 - $ 72K

Contract Term: 2/5/75-10/30/75

Date Completed: 10/30/75

Reports Issued: "Geothermal RD&D Program Definition Report," ERDA/DGE report ERDA-86 (October 1975)

Project Title: Support to ERDA Geothermal Energy Program Planning

Contract No: E(49-1)-3764

SUMMARY

Initial emphasis was placed on providing technical assistance in preparation of inputs to the program planning process to meet the June 30, 1975 Congressional submission deadline. Specifically, technical assistance provided data on how geothermal energy RD&D program objectives, strategies and implementation plans will be achieved and an analysis of required program resources was performed.

To supplement the overall planning effort, MITRE developed detailed program description statements and developed a longer term program planning information base to facilitate refinement of the preliminary plan, development of future program plans, and to indicate how programs and plans are to be fulfilled.

Procedures were developed to update program planning information base on a regular basis throughout the year, for the purpose of facilitating subsequent planning and budgeting exercises. The information base established in this project will facilitate ongoing total program integration, identification of common or overlooked RD&D areas, and establishment of program priorities.



Project Title: Experimental Geothermal Research Facilities Study (Phase 0)

Contract No: E(04-3)-1085

Contractor: TRW Systems Group, TRW, Inc.
Redondo Beach, California

Principal Investigator: R. H. Douglass
(213) 535-4321

Program Manager: A. G. Follett (Louis B. Werner)
(202) 376-4905
FTS 376-4905

Project Objective: To identify a representative liquid-dominated geothermal reservoir of moderate temperature and salinity, perform preliminary engineering design of an appropriate energy conversion system, identify critical technology, and plan for implementation of experimental facilities.

Funding: FY 75 - $ 15K*
FY 76 - --

Contract Term: 11/1/74-3/31/75

Date Completed: 3/31/75

Reports Issued: "Experimental Geothermal Research Facilities Study (Phase 0)," Volumes I and II, TRW Systems Group Final Report No. 26405-6001-RU-00 prepared for the National Science Foundation (December 31, 1974)

* Architectural Engineer Portion only - Phase 0 study was not transferred from NSF to ERDA.

Project Title: Experimental Geothermal Research Facilities Study (Phase 0)

Contract No: E(04-3)-1085

SUMMARY

The study comprised Phase 0 of a project for Experimental Geothermal Research Facilities, performed by TRW Systems Group under Grant No. GI-44149 of the National Science Foundation's overall program of Research Applied to National Needs (RANN). The study focused on identification of a representative liquid-dominated geothermal reservoir of moderate temperature and salinity, preliminary engineering design of an appropriate energy conversion system, identification of critical technology, and planning for implementation of experimental facilities. Significant considerations included development of liaison with the industrial sector to ensure responsiveness to their views in facility requirements and planning and incorporation of environmental and socio-economic factors.

Project Title: Planning Support to Division of Geothermal Energy, Energy Research and Development Administration

Contract No: N/A (purchase order)

Contractor: TRW Systems Group, TRW, Inc.
Redondo Beach, California

Principal Investigator: Robert Williams
893-2000, Ext. 2114 (McLean, Virginia)

Program Manager: Momtaz Mansour (P. Kruger)
(202) 376-4897
FTS 376-4897

Project Objective: Supply the necessary personnel to support the program definition and planning activities of the Division of Geothermal Energy of the Energy Research and Development Administration (ERDA).

Funding: FY 75 - --
FY 76 - $111K

Contract Term: 2/26/75-6/30/75

Date Completed: 6/30/75

Reports Issued: "A National Plan for Energy Research, Development and Demonstration," ERDA report ERDA-48 (June 1975)

Project Title: Planning Support to Division of Geothermal Energy, Energy Research and Development Administration

Contract No: N/A (purchase order)

SUMMARY

The contractor provided support to the ERDA Division of Geothermal Energy in the preparation of ERDA-48, "A National Plan for Energy Research, Development and Demonstration."

Project Title:	Conference on Geopressured Geothermal Energy: Research and Development
Contract No:	E(40-1)-4886
Contractor:	University of Texas at Austin Austin, Texas
Principal Investigator:	Myron Dorfman (512) 471-3220
Program Manager:	Keith Westhusing (David B. Lombard) (202) 376-4902 FTS 376-4902
Project Objective:	To involve researchers and users in the planning and development of a research program in geopressured geothermal resources.
Funding:	FY 75 - $ 15K FY 76 - --
Contract Term:	2/15/75-11/15/75
Date Completed:	11/15/75
Reports Issued:	Myron H. Dorfman and Richard W. Deller, editors, "Proceedings - First Geopressured Geothermal Energy Conference," Center for Energy Studies, University of Texas at Austin, June 2-4, 1975

Project Title: Conference on Geopressured Geothermal Energy: Research and Development

Contract No: E(40-1)-4886

SUMMARY

The Center for Energy Studies arranged and managed a limited attendance conference on geopressured geothermal energy at the University of Texas, Austin, on June 2-4, 1975. The purpose of the meeting was to involve researchers and users in the development of a national geopressured geothermal effort. The conference format included five half-day sessions with invited speakers and a half-day panel discussion. Proceedings have been published.

Project Title: Support for Preparation of Geothermal Energy Program Approval Document

Contract No: Purchase Order WA 76-2042

Contractor: Systems Consultants, Inc.
Washington, D.C.

Principal Investigator: Frank Snow
(202) 333-6800

Program Manager: Randall Stephens
(202) 376-4897
FTS 376-4897

Project Objective: Provide support to the Division of Geothermal Energy in the preparation of the Geothermal Energy Program Approval Document.

Funding: FY 75 - --
FY 76 - $ 7K

Contract Term: 10/75-11/75

Date Completed: (Terminated 11/13/75)

Reports Issued: None

Project Title: Support for Preparation of Geothermal Energy Program Approval Document

Contract No: Purchase Order WA 76-2042

SUMMARY

The project was terminated when the deadline for completion of the Geothermal Energy Program Approval Document was relaxed. Only a first rough draft of the document was produced.

Project Title: Survey-Worldwide Geothermal Information

Contract No: E(49-18)-2359

Contractor: The Franklin Institute Research Laboratories
Rockville, Maryland

Principal Investigator: Helis Miido
(215) 448-1465 (Philadelphia, Pennsylvania)

Program Manager: Seymour Shwiller
(202) 376-4897
FTS 376-4897

Project Objective: To provide a base for ERDA geothermal energy information dissemination activities through a survey of worldwide geothermal literature and development of information dissemination tools.

Funding: FY 75 - --
FY 76/TQ - $ 19K

Contract Term: 4/26/76-8/13/76

Date Completed: 8/31/76

Reports Issued: None

Project Title: Survey-Worldwide Geothermal Information

Contract No: E(49-18)-2359

SUMMARY

This project consists of a worldwide geothermal literature survey to provide a base for ERDA geothermal energy information dissemination activities. The work is to be accomplished in two phases: investigation of available information services and design of information dissemination tools.

In Phase 1, a subject screening list was developed, a core list of serial publications containing geothermal energy information was generated and correlated with the ERDA-TIC serial publications list. From these lists and a listing of other than serial sources, the total estimated annual volume of information from all sources was developed. Phase 2 will include recommendations for the collection, processing and dissemination of the entire global collection of geothermal energy information.

Appendix B — Alphabetical List of Contractors

Appendix B - Alphabetical List of Contractors

Contractors are categorized in this appendix as follows:

Each project pursued by each contractor is identified in Appendix B by the page on which the summary appears in this report.

B.1 ERDA Laboratories*

B.1 ERDA Laboratories (cont.)

* All projects performed by each laboratory are identified by the same contract number, unique to that laboratory.

B.2 Interagency Agreements*

* Work under an interagency agreement is performed by the agency itself or by an outside institution as identified in the Project Summary.

B.3 Industrial and Other Contractors

B.3 Industrial and Other Contractors (cont.)

	Summaries on pages:
General Electric Company R&D Center P.O. Box 43 Schenectady, New York 12301	1-8, 1-44
Mechanics Research, Incorporated 9841 Airport Boulevard Los Angeles, California 90045	A-6
The MITRE Corporation, METREK Division Westgate Research Park McLean, Virginia 22101	6-11, 6-18, A-19, A-20
Occidental Research Corporation (formerly Garrett Research and Development Company, Incorporated) 1855 Carrion Road La Verne, California 91750	1-38
Osborn-Hodges-Roberts-Wieland Engineering P.O. Box 4266 Bryan, Texas 77801	2-33
R&D Associates P.O. Box 9695 Marina del Rey, California 90291	2-21
Raytheon Company Equipment Development Laboratories 520 Boston Post Road Sudbury, Massachusetts 01776	1-14
San Diego Gas and Electric Company P.O. Drawer 28510 San Diego, California 92112	3-8
Southwest Research Institute P.O. Drawer 28510 San Antonio, Texas 78284	A-12
Sperry Rand Corporation Sperry Research Center 100 North Road Sudbury, Massachusetts 01776	1-9, 1-10, 1-49

B.3 Industrial and Other Contractors (cont.)

	Summaries on pages:
Stanford Research Institute 333 Ravenswood Avenue Menlo Park, California 94025	6-19
City of Susanville 66 North Lassen Street Susanville, California 96130	3-14
Systems Consultants, Inc. 1050 31st Street, NW. Washington, D.C. 20007	A-24
Systems, Science and Software P.O. Box 1620 La Jolla, California 92037	2-7, 2-20
Terra Tek, Incorporated 420 Wakara Way Salt Lake City, Utah 84108	1-11, 1-12
TRW Systems Group, TRW, Inc. One Space Park Redondo Beach, California 90278	3-7, A-21, A-22
Weidlinger Associates 110 East 59th Street New York, New York 10022	1-46

B.4 Universities

	Summaries on pages:
University of Alaska Fairbanks, Alaska 99701	2-10
University of Arizona Tucson, Arizona 85721	2-33
Brown University Providence, Rhode Island 02912	1-48
California Institute of Technology Pasadena, California 91109	A-15
Jet Propulsion Laboratory (JPL) California Institute of Technology 4800 Oak Grove Drive Pasadena, California 91103	1-24, 1-43, 6-15, A-17
University of California, Riverside Research Office Riverside, California 92502	2-17
Case Western Reserve University 10900 Euclid Avenue Cleveland, Ohio 44106	1-25
Colorado School of Mines Department of Geophysics Golden, Colorado 80401	2-9
Denver Research Institute University of Denver Denver, Colorado 80210	1-50
University of Hawaii 2540 Dole Street Honolulu, Hawaii 96822	3-11
Applied Physics Laboratory The Johns Hopkins University Johns Hopkins Road Laurel, Maryland 20810	2-19

B.4 Universities (cont.)

	Summaries on pages:
Indiana University School of Law P.O. Box F Bloomington, Indiana 47401	6-22
Louisiana State University Baton Rouge, Louisiana 70803	4-3
University of Maine at Orono Orono, Maine 04473	2-24
McNeese State University Lake Charles, Louisiana 70601	2-34
University of Missouri Buehler Building Rolla, Missouri 65401	1-16
Montana College of Mineral Science and Technology Butte, Montana 59701	2-31, A-7
Nevada Bureau of Mines and Geology University of Nevada at Reno Reno, Nevada 89557	2-11
University of New Hampshire Department of Resources and Economic Development Durham, New Hampshire 03824	2-25
New Mexico Bureau of Mines and Mineral Resources New Mexico Institute of Mining and Technology Socorro, New Mexico 87801	2-22
University of the State of New York Geological Survey Education Building Albany, New York 12234	2-26
University of Oklahoma Norman, Oklahoma 73069	1-47
Oregon Institute of Technology Klamath Falls, Oregon 97601	3-15

B.4 Universities (cont.)

	Summaries on pages:
Oregon State University Corvallis, Oregon 97331	2-27
University of Southern California Law Center University Park Los Angeles, California 90007	6-21
Bureau of Economic Geology University of Texas at Austin Austin, Texas 78712	2-29, 4-4, A-13
Center for Energy Studies University of Texas at Austin Austin, Texas 78712	2-28, A-14, A-23
University of Utah Salt Lake City, Utah 84112	1-39
Virginia Polytechnic Institute and State University Department of Geological Service 4044 Derring Hall Blacksburg, Virginia 24061	2-30, A-9

Appendix C — List of Principal Investigators

Appendix C - List of Principal Investigators

Each project in which each Principal Investigator is engaged is identified in Appendix C by the page on which the summary appears in this report.

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R. F. Fulton Lawrence Berkeley Laboratory	1-34
L. Glover III Virginia Polytechnic Institute	2-30
L. Goldberg The MITRE Corporation, METREK Division	A-20
Martin Goldsmith California Institute of Technology	A-15
S. Goldstein The MITRE Corporation, METREK Division	6-18
Pierre Goupillaud Systems, Science and Software	2-20
Sidney J. Green Terra Tek, Inc.	1-11, 1-12
John Griess Oak Ridge National Laboratory	1-21
Charles G. Groat University of Texas at Austin	2-29, 4-4, A-13
P. F. Gustafson Argonne National Laboratory	6-8
P. J. Hart Geophysics Research Board National Academy of Sciences/ National Research Council	6-16
W. W. Harvey EIC Incorporated	1-30, 6-10
Murray F. Hawkins Louisiana State University	4-3

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L. Hays Biphase Engines, Inc.	1-45
Michael H. Heys Coopers and Lybrand	6-20
L. E. Hibbs, Jr. General Electric Company	1-8
A. A. Hochrein, Jr. Daedalean Associates, Inc.	1-15
H. W. Hoffman Oak Ridge National Laboratory	1-32
F. Holzer Lawrence Livermore Laboratory	3-3
Yngvar W. Isachsen University of the State of New York	2-26
Harold R. Jacobs University of Utah	1-39
J. S. Kahn Lawrence Livermore Laboratory	2-13
O. Carrol Karkalits McNeese State University	2-34
George V. Keller Colorado School of Mines	2-9
Ronald D. Kelly Mechanics Research, Inc.	A-6
Joseph Kestin Brown University	1-48
W. Scott Keys U.S. Department of the Interior Geological Survey	2-6
Roy M. Knapp University of Texas at Austin	2-28

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Myer Kolker Raytheon Company	1-14
Ernest P. Krajeski The MITRE Corporation, METREK Division	6-11
L. E. Kukacka Brookhaven National Laboratory	1-18, 1-19
J. F. Kunze Idaho National Engineering Laboratory	3-9, 6-5
Gerald L. Lanterman Coopers and Lybrand	6-20
John G. Lewis R&D Associates	2-21
Ben E. Lofgren U.S. Department of the Interior Geological Survey	6-9
Gilbert Lombard San Diego Gas and Electric Company	3-8
Alfred B. Longyear City of Susanville, California	3-14
Ernest E. Martinelli R&D Associates	2-21
Warren D. McBee Sperry Research Center	1-9, 1-10, 1-49
Byron McCormick Los Alamos Scientific Laboratory	2-4
Thomas McGetchin Los Alamos Scientific Laboratory	1-51
Richard A. McKay Jet Propulsion Laboratory	1-43
Helis Miido The Franklin Institute Research Laboratories	A-25

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K. Mirk Lawrence Berkeley Laboratory	1-34, 3-4
Casper Mohl Jet Propulsion Laboratory	6-15
Frank Morrison Lawrence Berkeley Laboratory	2-15
William A. Mueller Jet Propulsion Laboratory	1-24
R. Murphy Oak Ridge National Laboratory	1-32
B. C. Musgrave Idaho National Engineering Laboratory	1-33
Melvin M. Newsom Sandia Laboratories	1-6, 2-5
Denis Norton University of Arizona	2-23
Gary R. Olhoeft U.S. Department of the Interior Geological Survey	2-8
Philip H. Osberg University of Maine at Orono	2-24
W. F. Osborn Osborn-Hodges-Roberts-Wieland Engineering	2-33
R. O. Pearson TRW Systems Group, TRW, Inc.	3-7
Charles Pezzotti Lawrence Berkeley Laboratory	6-24
Sidney Phillips Lawrence Berkeley Laboratory	6-23
George R. Pickett Colorado School of Mines	2-9

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E. W. Reece Sandia Laboratories	1-5, 1-7
Gordon Reistad Oregon Institute of Technology	3-15
Marshall Reiter New Mexico Bureau of Mines and Mineral Resources	2-22
Laurence Ross University of Denver Research Institute	1-50
Ivan S. Sandler Weidlinger Associates	1-46
Martin Scholl The MITRE Corporation, METREK Division	A-19
R. J. Schultz Idaho National Engineering Laboratory	3-12
D. W. Shannon Battelle Pacific Northwest Laboratory	1-22, 1-23, 1-28
John W. Shupe University of Hawaii	3-11
Terry L. Simkin Lawrence Berkeley Laboratory	6-7
Anker Sims The Ben Holt Company	1-36
A. K. Sinha Virginia Polytechnic Institute	2-30
M. C. Smith Los Alamos Scientific Laboratory	2-12
Frank Snow Systems Consultants, Inc.	A-24

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Kenneth E. Starling University of Oklahoma	1-47
M. Steinberg Brookhaven National Laboratory	1-18, 1-19
Donald Stewart Battelle Pacific Northwest Laboratory	A-10
Glenn W. Stewart University of New Hampshire	2-25
Roger Stoker Idaho National Engineering Laboratory	2-14
A. M. Stone Johns Hopkins University Applied Physics Laboratory	2-19
Christopher D. Stone University of Southern California	6-21
David A. Summers University of Missouri	1-16
Bill Suratt DSS Engineers	1-37
Robert K. Swanson Southwest Research Institute	A-12
G. E. Tardiff Lawrence Livermore Laboratory	
A. Dan Tarlock Indiana University	6-22
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A. R. Troiano Case Western Reserve University	1-25
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Appendix D — Projects by States

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All projects summarized in this report are arranged in Appendix D by the state address of the contractor. Each project is identified by the page on which the summary appears in this report.

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