FY 1989
Annual Operating Plan

Geothermal Technology Division
U. S. Department of Energy

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FY 1989 ANNUAL OPERATING PLAN

GEOTHERMAL TECHNOLOGY DIVISION
U.S. DEPARTMENT OF ENERGY

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I. INTRODUCTION

PURPOSE

This Annual Operating Plan describes the technical operational plan of the Geothermal Technology Division (GTD) of the U.S. Department of Energy (DOE) for Fiscal Year 1989. This document provides descriptions of approaches, objectives and priorities, control measures and milestones, and review and evaluation procedures.

DESCRIPTION OF THE GEOTHERMAL PROGRAM

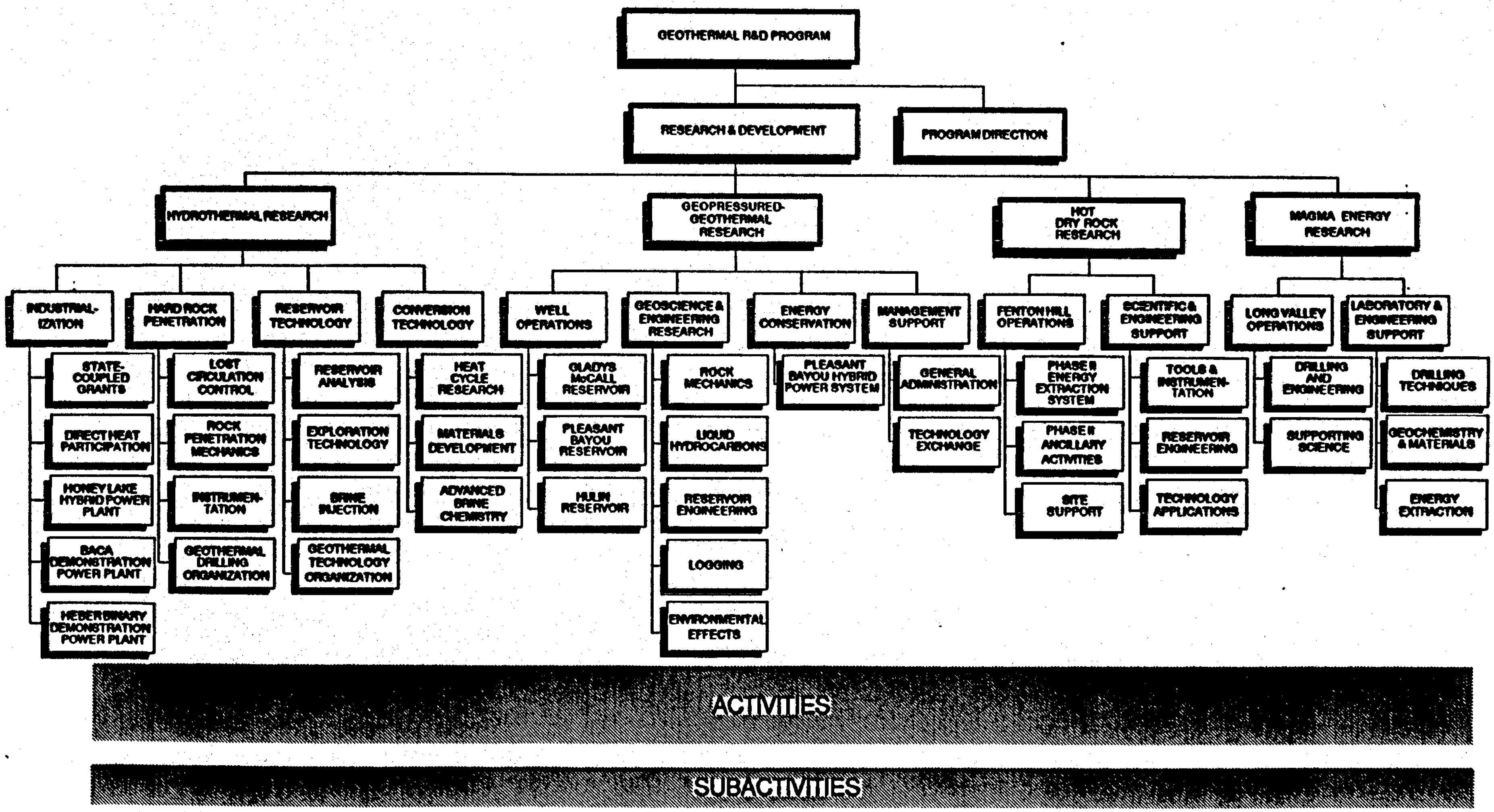
Since the inception of the Geothermal Program in 1971, the federal government and private industry have developed an extensive geothermal knowledge base, and industry has succeeded in establishing an industrial infrastructure capable of applying research results in the marketplace. This accumulation of technical information has provided a basis for identifying the critical technical barriers to cost-competitive geothermal power generation and for assessing long-term research options. Private sector cooperation in planning and prioritizing geothermal program elements contributes to the process by indicating desirable improvements in technology. This input is critical in a balanced, logical strategy for the Program that emphasizes high risk research directed toward a significant long-term role for geothermal energy in the U.S. electric power economy, and which addresses carefully defined, near-term research to maintain industrial momentum in geothermal resource development.

In accordance with legislative mandates and policy guidance, the Geothermal Program sponsors high-risk, potentially high payoff research and development in geothermal energy technology which will result in a technology base from which private enterprise can choose options for further development and competitive application in U.S. electric power markets.

The Geothermal Energy R&D Program contains four categories that parallel the resource types - Hydrothermal, Geopressured, Hot Dry Rock, and Magma. These categories, as shown in Table 1, are further subdivided into tasks, projects and lastly activities.

The Hydrothermal category embraces four interrelated research areas. The Industrialization task provides an opportunity for individual states to cooperatively assist in hydrothermal resource assessments and direct heat projects. The Reservoir Technology task supports research that will improve geophysical interpretation and modeling techniques; improve injectivity and extend well life; and cooperatively fund industry research through the Geothermal Technology Organization. The Hard Rock Penetration task improves lost circulation methodologies and materials; advances rock penetration mechanics; and improves downhole instrumentation. This task also includes priority research cost-shared with industry through the auspices of the Geothermal Drilling Organization. The Conversion Technology task improves

Table 1
PROGRAM HIERARCHY
GEOTHERMAL R&D



geofluid efficiencies in binary plants; reduces cooling water makeup requirements; develops advanced geothermal materials; and advances an understanding of the thermodynamic behavior of geothermal brines.

Geopressured research includes four tasks. The Well Operations task verifies the reliability of geopressured-geothermal reservoirs through long-term research testing. The Geoscience and Engineering Support task involves the development of predictive models for reservoir performance. The Energy Conversion task supports construction and operation of the Pleasant Bayou Hybrid Power System in Texas, which will use geopressured brines to produce electric power - the first plant of it's kind in the world. The Management Support task provides general administration and technology exchange activities.

The Hot Dry Rock category includes two tasks. The Fenton Hill Operations task supports the second phase of the energy extraction system along with necessary ancillary activities at the Fenton Hill Hot Dry Rock site. The Scientific and Engineering Support task involves design and modification of tools and instrumentation, reservoir engineering work, and other technology support activities.

Magma, like its Hot Dry Rock counterpart, is divided into two tasks. The Long Valley Operations task supports the drilling and engineering of a multiphased magma well at Long Valley caldera in California, including essential geoscience support activities. The Laboratory and Engineering Support task encompasses research on drilling techniques, geochemistry and materials, and energy extraction.

POLICY OF THE GEOTHERMAL PROGRAM

The Geothermal Program embraces scientific and engineering research designed to produce high potential payoffs that are either high risk or lie too far in the future for industry to be willing to undertake without Federal cooperation and support.

The Program is continuing to support the longer-term, high-risk research and development that generally supports technology development and application by the private sector. Basic and cross-cutting research in these areas will continue to be funded.

In addition, increased emphasis is being given to assuring that all applied research and development incorporate a program delivery mechanism emphasizing cooperative R&D ventures with industry in broad technology areas. Funding will not be provided, however, for product development, demonstrations, or other efforts to influence or "push" the market in favor of particular technologies.

The Geothermal Program has long advanced the government/private sector partnership approach to technology development and technology transfer as a preferred R&D mechanism, and some degree of cooperation with one or more entities is now a feature of a majority of the program elements. The initiative will institutionalize this practice, and will extend it to other R&D areas. Several benefits are expected to arise from this initiative.

First, industry's ability to share project costs will indicate the engineering and economic desirability of pursuing specific R&D objectives. It will also indicate confidence on the part of industry scientists and engineers that those objectives are technically attainable in the near-term. Support of such objectives in the form of cost-shared R&D is an appropriate federal role since the U.S. geothermal industry is relatively small, highly fragmented, and represents only a small market for commercial geosciences and conversion technology, compared to other energy extraction (e.g., oil and gas) and conversion markets. Increased cooperative projects will give the private sector an even greater role in setting R&D priorities and thus assures greater relevance to the marketplace.

In addition, while technology transfer has been an integral part of geothermal technology R&D since the inception of the Program -- through cooperative projects as well as more passive forms such as reports, workshops, and conferences -- increased joint ventures will increase the active form of transfer by encouraging potential beneficiaries of the research to become direct participants from the beginning.

Industry's cost-shared R&D participation will be focused largely on hydrothermal technologies that can be of early benefit to the industry using this technology. The one exception is industry's participation in electric power generation experiments with geopressured brines.

The research on geopressured wells with attendant reservoir investigations and of hot dry rock and magma technologies fall in the long-term, high-risk, high-payoff category.

FY 1988 MAJOR ACCOMPLISHMENTS OF THE GEOTHERMAL PROGRAM

The following are major accomplishments of the 4 research categories completed during FY 1988.

HYDROTHERMAL RESEARCH

- Applied P- and S-wave vertical seismic profiling techniques to map fracture orientations at The Geysers and at the Salton Sea Geothermal fields.
- Developed methodologies to integrate geological, geophysical, geochemical and reservoir engineering data to establish the hydrogeologic regime in hydrothermal systems before and during exploitation.
- Completed models for the interpretation of injection tests in fractured reservoirs.

- Successfully sited discovery well in St. Lucia based on integrated model approach.
- Selected first cost-shared research activity and deployed seismic systems at The Geysers through the Geothermal Technology Organization.
- Field test of the prototype radar tool in a fractured rock quarry provided evidence that this directional tool can detect distinct targets in non-uniform geologic media.
- Completed laboratory scale model of drill string transmission system which showed excellent agreement between theory and lab data.
- Assembled high temperature borehole televiewer and successfully demonstrated operation in a hot Unocal well in Long Valley.
- New site selected relocation of Heat Cycle Research Facility.
- Completed design work on the test unit for investigating the fouling resistance of the polymer-concrete lined heat exchanger tubes.
- Completed the interim brine equilibrium model for silica, calcite, and carbon dioxide.

GEOPRESSURED-GEOTHERMAL RESEARCH

- Pleasant Bayou surface facilities were constructed and flow testing begun.
- Completed two year production test at the Gladys McCall well, after two scale inhibitor treatments and production of 16.2 million barrels of brine with no evidence of scaling.
- Completed a study on the principal effects of irreversible rock compaction.

HOT DRY ROCK RESEARCH

- Completed repair of Wellbore EE-2 by redrilling into existing reservoir to improve pressure capability and provide for logging at greater depth for the Long-Term Flow Test. Completed well with new full-length 7-in. casing.
- Procured some components and continued installation work on the surface system for the Long-Term Flow Test.

MAGMA RESEARCH

- Finalized site of Long Valley exploratory well.
- Completed initial site preparation for Long Valley well.
- Completed initial surface power conversion studies for realistic power cycles.

II. GEOTHERMAL PROJECT OBJECTIVES AS OF FISCAL YEAR 1989

The following section details the project objectives for the FY 1989 research year. These objectives set the standards which are pursued throughout the year by individual activity milestones (see Section III). The objectives collectively define task objectives that will ultimately reflect the overall category objectives of the entire research program.

HYDROTHERMAL RESEARCH

1. <u>Industrialization</u>

   a. State-Coupled Grants

      - State reservoir studies through FY 1989 (prior year funding).

   b. Direct-Heat Participation

      - Technical assistance for direct heat projects through FY 1989 (prior year funding).

   c. Honey Lake Hybrid Power Plant

      - Mutual termination of project in FY 1989.

   d. Baca Demonstration Power Plant

      - Equipment sales during FY 1989.

   e. Heber Binary Demonstration Power Plant

      - Plant divesture during FY 1989.

2. <u>Reservoir Technology</u>

   a. Reservoir Analysis

      - Improve production well siting accuracy for both reservoir identification and confirmation wells.

      - Decrease the uncertainty associated with reservoir long-term decline predictions of temperature, pressure, and flow rate.

   b. Exploration Technology

      - Improve methods of detecting and confirming reservoirs in the Cascades and other young volcanic areas.

      - Increase the success rate of siting exploration wells .

c. Brine Injection

- Decrease the uncertainty associated with reservoir long-term decline predictions of temperature, pressure and flow rate.

d. Geothermal Technology Organization

- Cost-share research with industry to allow access to operating fields where new methods and equipment can be tested.

3. <u>Hard Rock Penetration</u>

a. Lost Circulation Control

- Reduce costs associated with lost circulation episodes.

b. Rock Penetration Mechanics

- Reduce deep coring costs.

- Reduce costs of deep wells and directionally drilled wells.

c. Instrumentation

- Improve well siting accuracy through better identification of fractures.

- Decrease cost of drilling production-related geothermal wells through more accurate completion-zone siting.

- Decrease the uncertainties in measurements of downhole and well head temperature, pressure, and flow measurements.

c. Geothermal Drilling Organization

- Develop and transfer related, cost-shared technology to effect an additional reduction in well costs.

4. <u>Conversion Technology</u>

a. Heat Cycle Research

- Increase net geothermal fluid effectiveness of binary plants.

- Increase net geothermal fluid effectiveness of conventional binary plants through the utilization of supersaturated vapor turbine expansions.

- Reduce heat rejection system cooling water make-up requirements for geothermal power plants, while retaining performance comparable with conventional wet cooling.

b. Materials Development

- Reduce costs associated with lost circulation episodes.
- Develop well-cementing materials with a service lifetime of 30 years at 400-600°C.
- Develop a corrosion-resistant and low-fouling heat exchanger tube material costing no more than three times that of carbon steel tubes.

c. Advanced Brine Chemistry

- Reduce geothermal production well maintenance costs related to scale deposition.
- Reduce geothermal field surface equipment costs related to scale deposition.
- Reduce geothermal power plant maintenance and equipment replacement costs related to scale deposition.
- Reduce costs of surface disposal of sludge from geothermal brines.

GEOPRESSURED-GEOTHERMAL RESEARCH

1. <u>Well Operations</u>

a. Gladys McCall Reservoir

- To evaluate the buildup of shut-in tubing pressure.

b. Pleasant Bayou Reservoir

- Prove the long-term injectability of large volumes of spent fluid into injection wells.
- Develop a modified scale inhibition procedure.
- Develop surface fluid-handling facilities (pumps, separators, valves, compressors, etc.) which can be safely operated from a remote monitoring location.

- Develop materials specifications, equipment specifications, and maintenance procedures which will guarantee over 95 percent annual availability with only a two-week annual shutdown for routine maintenance.

c. Hulin Reservoir

- Prepare well for future tests by workover.

2. <u>Geoscience and Engineering Support</u>

a. Rock Mechanics

- Determine the drive mechanisms for the design well reservoirs.

- Develop a test procedure which has sufficient accuracy to predict the capability of any geopressured reservoir to be produced for a period of five times as long as the test period.

b. Liquid Hydrocarbons

- Determine source and flow mechanisms for the liquid hydrocarbons and methane being obtained from producing geopressured reservoirs.

c. Reservoir Engineering

- Develop techniques to increase confidence in the ability to locate and evaluate geopressured resources. These techniques should be of sufficient quality that at least 90 percent of wells recompleted for geopressured-geothermal development are subsequently shown to be economic.

d. Logging

- Determine the effect of rock wettability and shale content on rock resistivity.

e. Environmental Effects

- Determine if fluids can be disposed of in an environmentally acceptable manner.

3. <u>Energy Conversion</u>

a. Pleasant Bayou Hybrid Power System

- Develop hybrid conversion technology with thermal efficiency at least 20 percent greater than that from separate combustion and geothermal power cycles.

4. <u>Management Support</u>

a. General Administration

- Technical and managerial support to DOE-ID.

b. Technology Exchange

- Provide transfer of new technologies.

HOT DRY ROCK RESEARCH

1. <u>Fenton Hill Operations</u>

a. Phase II Energy Extraction System

- Evaluate the large Phase II reservoir at Fenton Hill to determine its drawdown characteristics.

- Develop cement formulations that result in low-density, moderate-strength, zero free-water cements for casings.

b. Phase II Ancillary Activities

- Verify that the environmental and social consequences of HDR development are acceptable.

- Complete studies on water-rock interactions and their effects on flow through a hot dry rock reservoir.

c. Site Support

- Maintain the site in the condition necessary to perform planned experimental operations.

2. <u>Scientific and Engineering Support</u>

a. Tools and Instrumentation

- Improve instrumentation and hardware to control, locate, and measure fracture propagation in hot dry rock reservoirs.

- Establish reservoir-mapping techniques to locate drilling targets for production wells.

b. Reservoir Engineering

- Develop technology to monitor changes in reservoir volume and temperature and confirm monitoring data using tracers.
- Complete detailed reservoir analyses and confirm modeling of hydraulic and thermal performance of the Phase II system.
- Determine means to locate accurately the intersection of fractures with the wellbore.

c. Technology Applications

- Determine if the performance of the Fenton Hill Phase II reservoir, when considered as a unit reservoir in a commercial-scale project, could support production of electricity at an economical busbar cost.

MAGMA RESEARCH

1. <u>Long Valley Operations</u>

a. Drilling and Engineering

- Understand the nature of geophysical anomalies at the Long Valley caldera using actual well observation data, and verify the depth and lateral extent of a magma body.

b. Supporting Science

- Confirm the existence of magma at drillable depths, evaluate drilling problems, and assess materials compatibility.

2. <u>Laboratory and Engineering Support</u>

a. Drilling Techniques

- Design and develop technology capable of drilling into molten magma at temperatures of at least 900°C and total depths of at least 5 km.

b. Geochemistry and Materials

- Evaluate performance of materials in the corrosive and volatile rich magma environment for use in drilling tools.

- Predict rates for dissolution of silicate minerals and the composition of fluid in rock-to-water heat exchanger system, and evaluate the potential for loss of permeability due to precipitation of secondary minerals.

- Evaluate magma degassing hazards associated with drilling and energy extraction at Long Valley, California.

c. Energy Extraction

- Evaluate heat transfer effectiveness between a magma body and water circulating in the energy extraction wellbore.

III. OPERATING PLAN ACTIVITY MILESTONES
FY 1989

HYDROTHERMAL RESEARCH

1. <u>Industrialization</u>

   a. State-Coupled Grants

      - Continue state reservoir studies through FY 89.

   b. Direct Heat Participation

      - Continue technical assistance for direct heat projects through FY 89.

   c. Honey Lake Hybrid Power Plant

      - Complete mutual termination of project by 9/89.

   d. Baca Demonstration Power Plant

      - Complete equipment sales by 9/89.

   e. Heber Binary Demonstration Power Plant

      - Accomplish final plant divesture by 9/89.

2. <u>Reservoir Technology</u>

   a. Reservoir Analysis

      - Complete the development of conceptual models for fluid and heat transfer in fractured two-phase reservoirs - 9/89.

      - Finish testing advanced geophysical borehole techniques - 9/89.

   b. Exploration Technology

      - Complete development of algorithms to model the resistivity and AMT response to fractures and permeable zones - 9/89.

      - Complete construction of the field system to measure resistivity and audio magnetotellurics - 9/89.

   c. Brine Injection

      - Provide FRACSL code and users manual to industry - 1/89.

- Complete field testing of tracers and demonstration of analytical methods for Dixie Valley reservoir - 4/89.

- Complete models of injection plumes and heat extraction in fractured two-phase reservoirs - 9/89.

d. Geothermal Technology Organization

- Complete negotiations of additional cost-shared projects through the Geothermal Technology Organization - 9/89.

3. <u>Hard Rock Penetration</u>

a. Lost Circulation Control

- Complete analysis of transient wellbore hydraulics during loss of circulation and determine potential for characterizing loss zones using measured hydraulic parameters - 9/89.

- Complete screening and material properties tests on candidate high temperature bridging materials - 8/89.

- Initiate analysis and testing of temperature-setting cements - 3/89.

- Complete concepts and supporting analysis for emplacing and containing polymers in severe loss zones - 9/89.

b. Rock Penetration Mechanics

- Purchase several joints of prototype insulated drill pipe - 12/88.

- Complete laboratory evaluation of prototype pipe - 7/89.

- Determine advanced drilling/coring concept that can be developed with industry participation and support - 3/89.

- Complete fabrication and analysis of scale models of drill string transducers - 1/89.

- Complete fabrication and analysis of drill collar transducer - 6/89.

- Design and begin construction of full scale transducers - 9/89.

c. Instrumentation

- Initiate design of overall concept for a versatile downhole modular instrumentation system - 4/89.
- Complete detailed design of microprocessor/memory module - 9/89.
- Complete feasibility study of new mechanical design for radar tool using a modular concept with variable antenna spacing and diameter less than or equal to 5 inches - 12/88.
- Complete final report on first prototype radar tool - 3/89.
- Prepare proposal for second generation prototype tool and determine industry interest in cosponsorship - 7/89.
- Upgrade electrical design of radar tool sampling circuit and avalanche transistor circuit to reduce electrical noise - 9/89.

d. Geothermal Drilling Organization

- Finalize logging arrangements for borehole televiewer - 3/89.
- Determine future test plan for urethane foam tool - 11/88.
- Complete field tests of drill pipe protectors - 6/89.
- Fabricate high temperature rotating head seals - 5/89.
- Field test rotating head seals - 9/89.

4. <u>Conversion Technology</u>

a. Heat Cycle Research

- Complete installation of the two dimensional nozzle and laser droplet illumination system at the HCRF - 12/88.
- Report results of analysis of data collected at the first nonvertical condenser attitude - 12/88.
- Complete the installation of the HCRF at the GEO McCabe plant - 12/88.
- Complete installation of the fouling test unit at the selected site - 1/89.

- Resume operation of the HCRF at the GEO location - 1/89
- Receive and install the reaction turbine at the HCRF - 3/89.
- Complete the investigation of the condensation behavior of the supersaturated turbine expansions with an isobutane working fluid - 7/89.
- Complete the testing of the resistance of the polymer-concrete lined tubes to fouling - 7/89.
- Complete the scoping study of the advanced heat rejection systems and select a system for further investigation - 9/89.
- Issue an informal report on polymer-concrete lined tubes to fouling - 9/89.

b. Materials Development

- Selection of best candidate material for lightweight CO_2-resistant well cement - 10/88.
- Completion of 1 yr downhole exposure testing in low CO_2 containing brine at 300°C - 4/89.
- Identify best candidate material for magma (500°C) well cement - 5/89.
- Verify pumpability of lightweight CO_2-resistant well cement - 7/89.
- Peer-review publication on CO_2-resistant cements and magma cements - 9/89.
- Selection of field test site for prototype heat exchanger test - 10/88.
- Commence field test of prototype heat exchanger - 11/88.
- Complete field test of prototype heat exchanger - 2/89.
- Complete BNL section for Annual Report on PC-lined heat exchanger tubes. Report to be issued by INEL - 3/89.
- Select site for prototype binary heat exchanger test - 7/89.
- Peer-review publication on PC surface modifications to reduce scale accumulation - 9/89.

c. Advanced Brine Chemistry

- Report preliminary results of different cultures under scaled-up conditions in the flat and/or fluidized bed type reactors - 12/88.
- Initiate detailed analyses of the brine and solids samples and the particle meter readings taken at the SSSDP site - 12/88.
- Analysis of BNL waste research data generated in summer FY 88, fall FY 88, and winter of FY 89 - 4/89.
- Initiate preparation of peer-reviewed paper dealing with variations in bioprocessing conditions - 5/89.
- Principal Investigators to provide input to AOP to DOE-ID Operations Office for preparation of consolidated Conversion Technology AOP - 4/89.
- Set-up laboratory equipment to conduct experiments in support of the theoretical brine modeling efforts - 7/89.
- Report on effects of different mixed cultures under scaled-up conditions - 8/89.
- Prepare input to draft Brine Chemistry Users Manual - 9/89.
- PNL to publish detailed results of the SSSDP field tests - 9/89.

GEOPRESSURED-GEOTHERMAL RESEARCH

1. Well Operations

a. Gladys McCall Reservoir

- Complete pressure buildup monitoring at well site - 9/89.

b. Pleasant Bayou Reservoir

- Initiate long term flow tests - 9/89

c. Hulin Reservoir

- Complete workover and update test plan - 12/88.

2. <u>Geoscience and Engineering Support</u>

a. Rock Mechanics

- Complete strength and mechanical property testing of Pleasant Bayou cores - 9/89.
- Complete compaction and creep testing of Gladys McCall cores - 9/89.
- Additional creep testing capabilities developed - 9/89.
- Tested tensile behavior on geopressured-geothermal sandstones - 9/89.

b. Liquid Hydrocarbons

- Measure solubility of certain aromatic hydrocarbons - 9/89.
- Sampling of brine and cryocondensates completed - 9/89.
- Correlation completed of cryocondensate yields with well operations - 9/89.
- Operational wells monitored for aliphatic hydrocarbon production.
- Correlate hydrocarbon production with well operating parameters - 9/89.
- Theoretical models of reservoir hydrocarbons developed - 9/89.
- Complete pH monitor development and testing - 9/89.

c. Reservoir Engineering

- Preliminary hydrogeologic model developed - 9/89.
- Sampling procedure reviewed and modified - 9/89.
- Hydrogeologic data evaluated - 9/89.
- Hydrogeochemical data evaluated - 9/89.
- Hydrogeology and Hydrochemistry integrated - 9/89.
- Effects of compaction on geopressured reservoirs analyzed petrographically - 9/89.
- Improved scale inhibitor treatment developed - 9/89.

- Synthesized and integrated geoscience research on geopressured design wells - 9/89.

d. Logging

- Complete well log analysis - 9/89.

- Progress made in research on the effect of rock wettability and shale content on rock resistivity.

- Progress made in research on the effect of boron and other trace elements on the neutron log.

e. Environmental Effects

- Established systems maintained for monitoring subsidence, seismicity, and water quality around test wells in Louisiana and Texas.

- DOE apprised of any additional environmental concerns and recommendations made for a plan of action.

3. Energy Conversion

a. Pleasant Bayou Hybrid Power System

- Complete construction of hybrid power system - 8/89.

- Begin operation of hybrid power system - 9/89.

4. Management Support

- Long Range Research planned.

- AOP prepared.

- Reports prepared as required.

- Overall program budget analyzed.

- Test plans and work scopes prepared.

- On-going review carried out on Quality and Safety of Testing Operations.

- Day-to-day management provided in FY-89.

- Technical monitoring and support of University research efforts provided.

- Assistance provided in the transfer of technical data to the industrial arena.

- Special services and equipment procured as needed.

HOT DRY ROCK RESEARCH

1. <u>Fenton Hill Operations</u>

   a. Phase II Energy Extraction System

      - Start pressurization tests - 12/88.

   b. Phase II Ancillary Activities

      - TBD

   c. Site Support

      - Complete EE-1 Storage Pond - 4/89.

2. <u>Scientific & Engineering Support</u>

   - Complete laboratory experiments on adsorption of chemically-reactive tracers.

MAGMA RESEARCH

1. <u>Long Valley Operations</u>

   a. Drilling and Engineering

      - Drill and complete 1st phase of Long Valley exploratory well - 7/89.

   b. Supporting Sciences

      - Complete initial computer model of magma/hydrothermal system at Long Valley - 9/89.
      - Complete schedule for 1st phase of supporting on-site scientific measurements - 8/89.
      - Complete synthesis of geologic results from existing holes on resurgent dome - 4/89.
      - Collect geologic results from magma well - 8/89.

2. <u>Laboratory and Engineering Support</u>

a. Drilling Techniques

- None this FY.

b. Geochemistry & Materials

- Document the research of metal compatibilities with rholite magma, glass and fluids - 6/89.
- Determine the rate and extent of magma degassing (vesiculation) upon decompression or cooling - 8/89.

c. Energy Extraction

- Summarize recent advances in energy extraction research - 11/88.
- Complete generalized energy extraction computer code - 6/89.
- Design integrated energy extraction experiment - 9/89.

TABLE 2. FY 1989 FUNDING REQUIREMENT SUMMARY
(thousands of dollars)

Tasks	Management	In-House Research	Sub-Contract	Capital Equipment	Total
Industrialization	--	--	--	--	$ 0
Reservoir Technology					$ 2,500
Hard Rock Penetration					$ 2,300
Conversion Technology					$ 1,935
Geopressured-Geothermal					$ 6,000
Hot Dry Rock					$ 3,500
Magma					$ 1,700
Other					$ 1,621
Totals					$ 19,556

IV. OUTYEAR PLAN OF THE GEOTHERMAL PROGRAM

HYDROTHERMAL RESEARCH

1. Industrialization - Outyear activities are undefined beyond continuation of technical assistance for direct-use projects and state reservoir studies from previous year funding.

2. Reservoir Technology

   a. Reservoir Analysis

      - Outyear activities will include development of integrated, comprehensive geologic models of geothermal fields to improve the effectiveness of energy recovery and the development of sophisticated well test, heat recovery, geochemical and material/energy balance models for geothermal systems.

   b. Brine Injection Technology

      - During this period, field testing and data analyses will be completed to verify the use of tracer techniques to track the migration of injected fluids. Rock-water interaction studies will be completed and validated. Analytical techniques will be developed to interpret integrated heat transfer, fluid transport and chemical interaction data sets from active geothermal systems. Methods will be published for use in predicting the impacts of injection.

   c. Exploration Technology

      - Development of surface and borehole techniques to locate fracture zones and permeable formations in geothermal reservoirs and refinement of geophysical equipment and methods of interpretation will continue.

   d. Geothermal Technology Organization

      - The Geothermal Technology Organization, comprised of the geothermal industry and DOE, will continue to cooperatively fund research related to geothermal reservoirs and reservoir development.

3. Hard Rock Penetration

a. Lost Circulation Control

- FY 90 - Develop and initiate tests of field procedures for characterizing loss zones and complete analysis and lab testing of techniques for plugging severe loss zones.

- FY 91 - Complete tests of field procedures for characterizing loss zones and initiate testing of techniques for plugging severe loss zones.

- FY 92 - Initiate development of expert system for characterizing loss zones and identifying appropriate treatments.

- FY 93 - Complete development of expert system.

b. Rock Penetration Mechanics

- FY 90 - Design iteration of insulated drill pipe and begin design of high temperature drilling system; Design advanced drilling/coring system; Complete full scale design of acoustical data telemetry system.

- FY 91 - Complete design and begin fabrication of high temperature drilling system; build and test advanced drilling/coring system; field test acoustical data telemetry system.

- FY 92 - Field test high temperature drilling system; field test advanced drilling/coring system; complete data-transmission-while-drilling field tests.

- FY 93 - Initiate commercial development of acoustical data telemetry system.

c. Instrumentation

- FY 90 - Fabricate new modular downhole electronic tool; Evaluate downhole flow measurement techniques for application in geothermal wells; initiate development of second generation radar fracture mapping tool with industry.

- FY 91 - Field test modular electronic tools in geothermal wells; field test second generation radar fracture mapping tool.

- FY 92 - Develop instrumentation modules for magma energy exploratory well; Transfer radar fracture mapping technology to industry.

- FY 93 - Test electronic tools in magma well.

d. Geothermal Drilling Organization

- FY 90 - Complete test of rotating head seals; initiate project in high temperature elastomers for blow out preventors.

- FY 91 - FY 93 - Identify and develop new projects.

4. Conversion Technology

a. Heat Cycle Research

- The Heat Cycle Research Project will complete the super critical cycle investigations and transfer the information gained to the industry through the publication and presentation of the results in reports, technical journals, and the proceedings of technical meetings.

- Demonstrate that the net geothermal fluid effectiveness of the binary power cycles can be improved by 20% by incorporating the advanced concepts investigated in the project, by 1992.

- Show that an additional 8% improvement can be achieved in the advanced binary plant performance by allowing supersaturated turbine expansions by 1992.

- Define a heat rejection system which will achieve a performance similar to that of a convention "wet" cooling system with a 20% lower make-up water requirement.

b. Materials Development

- During the period FY 1990-1993 ensure that the ability of GTD to meet its Level I objective for hydrothermal research will not be constrained by the availability of economically and technologically viable materials for well drilling and completion, and for the containment and handling of geothermal and associated fluids during production, energy conversion, and disposal.

- Work to develop lightweight CO_2-resistant cements for well completions will be continued. The most promising high-alumina cement formulations identified in FY 1989 will be exposed downhole for one year to brine containing CO_2 concentration sufficient to cause deterioration of conventional calcium-silicate-hydrate-based cements within a short time.

- A small prototype shell-and-tube heat exchanger containing thermally conductive polymer-concrete-lined tubes will be tested at appropriate field sites. Contingent upon the successful operation of the unit in FY 1989 with brine as the tube-side fluid and water on the shell side, the latter will be replaced with a binary fluid. Measurements to determine scaling factors, heat-transfer coefficients, and corrosion rates will be repeated. Tubing with enhanced heat-transfer surfaces (fins, etc.) and/or lined with alkali scale-resistant formulations will also be evaluated. Based upon these data, designs and potential costs for full-sized units will be determined.

- The FY 1989-initiated effort to develop and test advanced high-temperature elastomers for use as a stator in a downhole drill motor will be continued as a subcontracted effort and with a cost-sharing industrial partner. Contingent upon FY 1989 results, a full-scale Moineau stator will be fabricated and tested in a well.

- The cooperative effort to develop advanced high-temperature chemical systems for lost-circulation control will be completed. The work will culminate with the performance of a field demonstration.

c. Advanced Brine Chemistry

- Carry out biochemical experiments to evaluate promising techniques to dispose of geothermal wastes containing toxics that exceed regulatory limits.

- Continue both laboratory and theoretical research to develop a unique mathematical brine chemistry model capable of predicting potential scale formation in reservoirs and power plant equipment.

- Continue to work with industry on cooperative process chemistry activities.

GEOPRESSURED - GEOTHERMAL RESEARCH

- The scientific support work on the Gladys McCall well will be completed in FY-89 or FY-90. The well will be logged, zones adjacent to the production zone will be opened for a check of pressure, a pill of scale inhibitor will be injected, and side cores will be taken to check for the effects of the extensive testing and the injection of the pill of scale inhibitor. Following the coring, the well will be plugged and abandoned.

- The Pleasant Bayou Well will be flowed at a maximum rate during the year the HPS system tested until it has accumulated a full year of operational history. The Hybrid Power System will be disassembled and surplused after the year of operation.

- Detailed planning will initiate for recompletion of the Hulin Well. Supporting research will continue in the general areas of reservoir analysis, logging, rock mechanics, associated hydrocarbons, geology and geochemistry. Distribution of funds and detailed tasks will be based on research results in FY-89. Work based on decisions regarding utilization of the Hulin Well will proceed as planned.

- An industry forum will be scheduled to transfer technical results. The Industrial Consortium initiated in 1989 for industrial participation in the utilization of geopressure-geothermal energy will be continued.

- Hulin planning will be completed.

- As a result of studies at The Pleasant Bayou site a determination will be made on the future use of the well.

- Operation of the Pleasant Bayou Well will be terminated after the reservoir pressure decline is established and a scientific program of variable flow rate testing, diagnostic logging, geochemistry analysis, cryocondensate analysis, downhole pressure measurements, and sidehole coring is completed. Following the scientific experiments, the well will be plugged and abandoned.

- Rework of the Hulin Well will be completed in FY-90 and operation of the well will be initiated in FY-91. A test program will be conducted to establish the reservoir characteristics. In FY-92 one consideration will be to test and compare three electrical power generation system modules in conjunction with flowing the well. Following the scientific program the well will be sold to industry if it is profitable, or if it is not profitable, it will be plugged and abandoned in FY-93. Environmental monitoring around the well will continue until 1995.

- The supporting research program will be concluded and final reports written on all tasks. A complete final report summarizing the Geopressured-Geothermal program will be written and final industry coordination meetings will be held.

HOT DRY ROCK RESEARCH

- The primary objective of the Hot Dry Rock Fenton Hill Project Phase II effort is to demonstrate creation and control of a multiply-fractured reservoir with extended longevity by creating a larger system (20 to 35 MW_t) with a projected life in excess of 10 years. To this end the following are outyear milestones:
- FY 90 - Complete Surface System Installation
- FY 90 - Complete water loss Reservoir experiments
- FY 90 - Start the Long Term Flow Test
- FY 91 - Complete the Long Term Flow Test
- FY 92 - Complete the Long Term Flow Test analysis

MAGMA RESEARCH

a. <u>Long Valley Operations</u>

- FY 90 - Complete Phase II of exploratory well to a depth of 7500 feet. Conduct seismic and thermal wellbore measurements. Coordinate outside supporting scientific measurements in well.
- FY 91 - Complete Phase III of exploratory well to a depth of 14,000 feet. Conduct seismic and thermal wellbore measurements. Coordinate outside supporting scientific measurements in well.
- FY 92 - Complete Phase IV of exploratory well to a depth of 20,000 feet. Conduct seismic and thermal wellbore measurements. Coordinate outside supporting scientific measurements in well.
- FY 93 - Complete wellbore scientific measurements. Refine model of Long Valley magmatic system.

b. <u>Laboratory and Engineering Support</u>

- FY 90 - Design drill bit for entry into magma. Design and initiate large scale experiment to demonstrate concepts of direct contact heat exchange in magma. Characterize feldspar dissolution mechanism in aqueous solutions.
- FY 91 - Test magma drill bit and design pressure control system for entry into magma. Complete large scale direct contact heat exchanger experiment. Measure and characterize feldspar dissolution at hydrothermal temperature and pressure.

- FY 92 - Select materials for cementing casing at temperatures to 500^{o}C and high density drilling muds for pressure control. Initiate planning and designing of magma field energy extraction experiment. Evaluate effects of solution composition upon mass transport of aluminosilicates.

- FY 93 - Test cementing materials and drilling mud. Complete design of magma field energy extraction experiment. Estimate temperature-pressure-composition conditions of magma from wellbore samples.

V. FISCAL YEAR 1989 MANAGEMENT PLAN

MANAGEMENT OF THE GEOTHERMAL PROGRAM

The management responsibilities of DOE Headquarters, Operations Offices, and national laboratories that will be followed in managing the program are highlighted in the following paragraphs.

1. Headquarters

The Geothermal Technology Division has overall management responsibility including policy setting, program planning, budgeting, allocating funds, providing guidance to the field, and serving as the focal point for intra- and interagency coordination, required interaction with upper DOE management, and technology transfer.

2. Operations Offices

The Albuquerque (ALO), and Idaho (IDO) Operations Offices are the principal field offices for the Geothermal Program and are responsible for the technical and operational management of specific program tasks.

3. Technical Centers

The following laboratories are responsible for technical coordination of research in specific subject areas as well as conducting research as described in their Field Task Proposal/Agreements (FTP/A's):

- Idaho National Engineering Laboratory
- Lawrence Berkeley Laboratory
- Los Alamos National Laboratory
- Sandia National Laboratories
- Brookhaven National Laboratory

The preparation and implementation of the FTP/A's by each laboratory is critical to program management, implementation, and evaluation. Each laboratory, with guidance from Headquarters, is responsible for preparing and submitting an FTP/A to Headquarters, via the Field Office, for approval. Revisions to the FTP/A are also prepared and submitted to Headquarters for approval. Laboratories undertake the research tasks and technology transfer activities for which they are responsible, coordinate those tasks with the Field Offices and related efforts of other laboratories and contractors, and inform Headquarters of research progress.

ORGANIZATIONS

The Geothermal Program is managed by the Director of the Geothermal Technology Division (GTD) at DOE Headquarters, Washington, D.C. GTD is responsible to the DOE Assistant Secretary for Conservation and Renewable Energy, the Deputy Assistant Secretary for Renewable Energy through the Director, Office of Renewable Energy Technologies.

The Director of GTD provides the centralized leadership necessary to ensure that Geothermal Program activities are consistent with national energy policy, priorities, laws, and directives. Day to day management of technical activities is delegated to the various DOE Field Offices, and through them to the National Laboratories.

REVIEW AND ASSESSMENTS

Overall, the program's progress is measured against broadly stated, long-term objectives that do not easily lend themselves to a quantitative assessment process. Therefore, a formal set of criteria and a procedure for evaluation against these criteria have been established. These correspond closely with the criteria used in the planning process. The evaluation process may be viewed in three parts:

(1) Establishment of program milestones and periodic internal review of progress against these milestones.

(2) Periodic peer group review of current research.

(3) Periodic external review of current research by representatives from industry to provide guidance on how the Federal government can best respond to industry needs.

The evaluation required in item (1) involves periodic program management reviews at different levels within the DOE organization. The primary purpose of this evaluation is to identify management, technical, or policy problems as they arise in the conduct of work.

The evaluation required in item (2) is based on critical reviews of specific project accomplishments by researchers. All projects associated with a specific research plan are subject to ongoing review and assessment.

The evaluation required in item (3) is designed to ensure that the program remains on track with respect to meeting industry needs. Reviews conducted by industry groups and university researchers help the program maintain broad based feedback. They serve as an efficient mechanism for obtaining information on industry viewpoints, on new private sector developments, and other factors that should properly be a part of future year programming decisions.

TECHNOLOGY TRANSFER

Technology transfer is an integral program activity. The Geothermal Program's investment in research activities is of little value unless the results are promptly transferred to the private and public sectors. Systematic means are in place to assure that geothermal developers, utilities, materials and components manufacturers, and other members of the geothermal industry readily acquire and implement the output of the Geothermal Program research effort.