ANNUAL OPERATING PLAN
FY 1991

GEOHERMAL DIVISION
U.S. DEPARTMENT OF ENERGY

June 5, 1991

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I. INTRODUCTION

I. INTRODUCTION

PURPOSE

This Annual Operating Plan describes the technical operational plan of the Geothermal Division (GD) of the U.S. Department of Energy (DOE) for fiscal year 1991. Descriptions of approaches, objectives and priorities, control measures and milestones, and review and evaluation procedures are included.

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 developing a logical, balanced strategy for the geothermal research program. The strategy emphasizes research directed toward achieving a significant role for geothermal energy in the U.S. electric power industry.

In accordance with legislative mandates and policy guidance, the Geothermal Program sponsors high-risk, potentially high payoff research and development in geothermal energy technology. This technology forms a 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 geothermal resource types - Hydrothermal, Geopressured, Hot Dry Rock, and Magma. These categories, as shown in Table 1, are further subdivided into tasks, projects and 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 task also provides cooperative research with industry to develop geothermal binary cycle technology. 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 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.

Figure 1
PROGRAM HIERARCHY
GEOTHERMAL R&D

ACTIVITIES

SUBACTIVITIES

Geopressured research includes four tasks. The Well Operations task verifies the reliability of geopressured-geothermal reservoirs through long-term well testing. The Geoscience and Engineering Support task involves the development of predictive models for reservoir performance. The Energy Conversion task supports the decommissioning of the Pleasant Bayou Hybrid Power System in Texas, which used 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 three 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. The Nutriso task supports the State of Arizona in demonstrating the viability of using hot dry rock technology to generate electricity.

Magma is divided into two tasks - The Long Valley Operations task and the Laboratory and Engineering Support task.

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.

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 willingness 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 1990 MAJOR ACCOMPLISHMENTS OF THE GEOTHERMAL PROGRAM

The following are major accomplishments of the 4 research categories completed during FY 1990.

HYDROTHERMAL RESEARCH

1. Industrialization

- Technical studies and field work were completed for seven of the SCP grants, and neared completion for the remaining four grants.
- Dr. Donald Thomas (University of Hawaii state team) reported successful results in acid treatment of high silica brines from the Hawaiian East Rift Zone.
- Mr. Thomas Flynn (University of Nevada-Division of Earth Sciences) and his team members completed a significant study which casts new light on the origin of geothermal fluids in the Great Basin.
- In New Mexico, Mr. Jim Witcher has discovered a previously unknown low-to moderate-temperature geothermal system in the Rincon area using oil-gas radon techniques followed up with shallow thermal gradient drilling.
- Mr. Robert Blackett and his team at the Utah Geological and Mineral Survey have identified the controlling features and properties of the hidden Newcastle geothermal system.

- The State of Washington, Department of Natural Resources, completed drilling eight 152 meter temperature gradient holes to better define the Southern Washington Cascade Range heat flow anomaly.

2. Reservoir Technology

- Prepared a major release of the MULKOM reservoir simulator under the name TOUGH2 and held a user workshop.
- Developed a flow model for the Coso geothermal system based on geochemical interpretations.
- Published a paper on advances in practical well testing.
- Released simulator code utilizing initial efforts to incorporate combined flow and transport in and between porous matrix and fractures.
- Compiled thermodynamic data on candidate high-temperature tracers, particularly tracers for use in vapor-dominated systems.
- Continued development of geophysical equipment for use in exploration and in determination of reservoir characteristics with in-hole and between-hole measurements.
- Extended the agreement with the Geothermal Division (GD) which provides for cost-shared research.
- Reviewed potential research projects and initiated a study of tracer stability and injection at The Geysers.

3. Hard Rock Penetration

- Published a journal article on lost circulation material (LCM) testing for severe environments. Article included mathematical modeling of the particle bridging process and development of laboratory test equipment and procedures.
- Generalized earlier mathematical models of the particle bridging process to allow two particles with different sizes, shapes, and mechanical properties in the same bridge. Solved system of equations using the properties of ground rubber tires and walnut shells to determine the optimal blend and particle-size distribution of the mixture.
- Developed a fabric test facility for evaluating potential fabrics for the porous packer. Facility measures permeability and burst strength of fabric as a function of fluid viscosity and temperature.

- Developed a concept and filed a patent application for a drillable straddle packer for isolating loss zones and directing the flow of cementitious materials into the zone. Designed and fabricated a drillstring coupler that allows remote decoupling from the packer assembly at the bottom of the wellbore. Initiated testing of full-scale packer assemblies to evaluate potential fabrics.
- Designed and constructed a full-scale packer test facility for evaluating drillable straddle packer and porous packer concepts. Facility includes: a vertical 14 foot section of 16 inch diameter casing with simulated production and loss zones; an elevated work platform with ladder access; and a hoist for lifting for lifting and emplacing full-scale packer assemblies.
- Completed the first-phase contract with the University of Arizona to develop flow models for cementitious muds in the drillstring, wellbore, and fracture environments.
- Developed a concept and filed a patent application for a flow transducer to measure the outflow of drilling fluid from the wellbore during drilling. Concept utilizes a rolling float that combines velocity and flow level line information to provide a measure of flow rate in the mud return flow line. Designed and initiated construction of a fluid flow loop for evaluating this and other rig instrumentation needed to identify and characterize lost circulation zones.
- Completed the first phase of a borehole televiewer study on the measurement of fracture apertures at the borehole wall. Developed two techniques for properly adjusting the televiewer gain to provide quantitative information on fracture size and orientation.
- Completed a re-design of the antenna system for the radar tool to enable a better coupling of electromagnetic energy to ground material. This effort was cost-shared with Nuclear Treaty Verification projects.
- Demonstrated value of borehole televiewer for casing inspection by logging problem wells in The Geysers.
- Issued a Request for Proposals to the logging industry to assess its interest in providing a high-temperature televiewer logging service to geothermal operators. After extensive discussion, it was ascertained that the market for such devices is too small to warrant establishment at the present time.
- Initiated development of a 64 Mbyte, 33 Mhz computer system for use in "memory" logging systems deployed in hot holes. This system is generic in that it will support one or more sensors.

- Designed, assembled, and successfully tested a circuit for effective noise and echo cancellation during acoustic data telemetry.
- As a result of GDO testing of rotary head seals, a new elastomer configuration was developed and introduced in the Drillex product line.

3. Heat Cycle

- The heat exchanger tubes in the HCRF preheater and vaporizer were replaced. The existing tubes had reached the anticipated service life cycle and the facility operation was periodically interrupted by tube failures.
- The supercritical cycle testing at the near vertical condenser orientation was completed with the isobutane working fluid.
- The two-dimensional expansion nozzle and the laser droplet illumination system were received at the HCRF, and installation initiated. This equipment will be used in the investigations to examine the condensation behavior of an isobutane working fluid during a simulated supersaturated turbine expansion.
- The specification was completed for a reaction turbine to be tested at the HCRF; a competitive solicitation was initiated.
- The evaluation of the data collected at the near horizontal condenser orientation was completed and a report on the results of the analysis issued.
- The applicability of the Kalina cycles for geopressure applications was considered and a topical report issued.
- The Puna Research Center on the island of Hawaii was unavailable for conducting the fouling investigations with the polymer-concrete lined (PCL) heat exchanger tubes, and an alternate site was solicited. During the solicitation period, the fouling test unit was installed at the HCRF and a series of baseline thermal and hydraulic performance test conducted with the relatively benign East Mesa brines.
- A subcontract was awarded to Red Hill Geothermal for conducting the PCL fouling investigations at the Salton Sea Del Ranch power plant. Equipment was moved from the HCRF to the Del Ranch facility and installed.

4. Materials Development

- The pumpability of well cements was improved by using inorganic acid retarders.
- Polymer concrete lined heat exchanger tubes were tested at the Heat Cycle Research Facility.
- Wax-coating of MgO was evaluated as a technique for managing the consistency of lost-circulation control materials.
- Sections of polymer-concrete lined well casing were tested by geothermal operators at The Geysers.

5. Advanced Brine Chemistry

- Comparative analyses were carried out using previously scaled-up bioreactor designs. These include: (a) configuration, (b) reactor site, (c) agitation, (d) single vs. mixed cultures, (e) pH and dissolved oxygen, (f) cell growth, (g) concentration of sludge, (h) addition of biomass, and (i) temperature.
- In addition to FBBR, MFBBR, AGBR, and FBABR, a model of rotating blade counter-current flow system (RBCCFS) was constructed and tested.
- Arrangements were made for visiting scientists, high school teachers and students, particularly those in the chemical engineering area, to participate in the kinetic, analytical and bioreactor design work.
- Used the data generated and initiated a second technical and economic feasibility study of the scaled-up process. This was done in collaboration with Dr. R. Sproull, OSU, and summer students at BNL in a manner analogous to the first such study which used students from the Massachusetts Institute of Technology (MIT) graduate school.
- Continued kinetic studies using mixed cultures of different strains of acidophilic and thermophilic microorganisms from the BNL collection have been aimed at the outstanding of parameters which influence the detoxification process(es).
- As in the past, further collaboration with industry, particularly UNOCAL, and others (e.g. EPRI) were pursued. Also continued to interact with industry and secured additional sludge samples.
- Incorporated work on fugacities and phase behavior in the CO₂-CH₄-H₂O system as a function of pressure.

- Modeled the solubility of mixtures of CO₂ and CH₄ in geothermal brines to high temperature and pressure.

GEOPRESSURED-GEOTHERMAL RESEARCH

Pleasant Bayou Reservoir

- Operated production facilities, produced 4.5 million barrels of brine, and acquired reservoir drawdown data.
- Scaling and corrosion successfully monitored and controlled in the production facilities.
- Successfully tested The Hybrid Power System at Pleasant Bayou for eight months, producing 3,445 MWh of power to the local utility.

Gladys McCall Reservoir

- The pressure buildup test was continued at the Gladys McCall site through FY-90 to within 700 psia of original pressure.
- Developed final scientific test plan to measure reservoir transmissivity and determine if crossflow is a valid drive mechanism.

Hulin Reservoir

- All environmental and safety documentation was developed for workover and short-term flow test at the Hulin site.
- Well was flow tested for 35 days. Samples were taken and the highest flow rate tested was about 5000 bpd.

HOT DRY ROCK RESEARCH

- Completed basic design of surface facilities for the Long-Term Flow Test at Fenton Hill.
- Completed evaluation of the failure of the GT-2 casing, and reevaluated the completion design while modifying the Phase II wells to prevent damage should a GT-2 types failure occur at these wells again.
- Completed the design, procurement, and installation of the EE-1 pond and liners. The Fenton Hill experimental area was also regraded to upgrade the storage ponds.

- Secured extension of existing water rights, made progress toward securing additional water for the Long-Term Flow Test, and obtained approval of discharge plan from the New Mexico Environmental Improvement Division.
- Developed engineering model to explain data and predict water loss performance of the reservoir at various operating conditions.
- Verified aseismicity of the reservoir under steady state pressure condition below 2700 psi through comprehensive seismic monitoring.
- Lowered the detection threshold of the reactive tracer designed for use during the Long-Term Flow Test to less than 1 part per billion in the presence of reservoir fluids.

MAGMA RESEARCH

- Developed, submitted, and successfully defended grant application to the California Energy Commission.
- Received grant of \$1.5 million - \$1.2 million for Phase II drilling and \$300 thousand for Phase III.
- Completed preparation of RFP for Phase II drilling contract.
- Published SAND report documenting Phase I drilling.
- Completed summary SAND report documenting all energy extraction work.
- Provided all the articles for a special Magma Energy issue of the GRC Bulletin.

II. GEOTHERMAL PROJECT OBJECTIVES AS OF FISCAL YEAR 1991

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The following section details the project objectives for FY 1991 research activities. These objectives set the standards toward individual activity milestones (see Sections III) are directed.

The annual project objectives collectively define task objectives that will ultimately reflect overall programmatic objectives of the Geothermal Technology Program. Each project objective is linked to the broader programmatic objectives (see Programmatic Objectives of the Geothermal Division, May, 1989) which direct the entire research program.

HYDROTHERMAL RESEARCH

1. Industrialization

a. State Coupled Grants

- Increase knowledge of low- and moderate-temperature (less than 150°C) geothermal resources by funding cost-shared, state-oriented research and development of geothermal energy.

b. Direct Heat Participation

- Encourage the direct use of geothermal resources by providing technical assistance to business and individuals for geothermal resource development using low- to moderate-temperature brines.
- Encourage use of geothermal heat pumps as part of electric utilities' integrated resource planning.

c. Heber Binary Demonstration Power Plant

- Facilitate negotiations between the resource owners, plant owners, and prospective buyers with the expectation that the plant will be sold.

d. Geothermal Test Facility

- Dispose of barrels of possibly hazardous materials at the Geothermal Test Facility.
- Characterize the pond sludge at the Geothermal Test Facility and initiate corrective action.
- Transfer the Geothermal Test Facility to industry.

e. **Boise, Idaho Project**

- Analyze reservoir and improve Boise district heating system.

2. **Reservoir Technology**

a. **Reservoir Analysis**

- Improve production well citing accuracy for both reservoir identification and confirmation wells.
- Decrease the uncertainty associated with long-term decline predictions of reservoir temperature, pressure, and flow rate.

b. **Exploration Technology**

- Improve methods of locating and determining the geometry, structure, and physical properties of geothermal reservoirs.

c. **Brine Injection**

- Reduce the adverse thermal and chemical effects of injection on geothermal reservoirs.

d. **Geothermal Technology Organization**

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

3. **Hard Rock Penetration**

a. **Lost Circulation Control**

- Improve technology to identify the location and extent of loss zones and methods for plugging them.

b. **Rock Penetration Mechanics**

- Explore advanced concepts for drilling and coring in hard rock.
- Improve high speed applications of the PDC bit.
- Develop high temperature drilling systems for operation above 300 degrees C.

- Improve methods for collecting drilling performance data at the bit face in real time during drilling.

c. Instrumentation

- Improve downhole electronic memory tools for use in even harsher geothermal environments.
- Improve well siting accuracy through better identification of well fractures.

d. Geothermal Drilling Organization

- Develop and transfer to industry cost-shared technology which will reduce overall well costs.

4. Conversion Technology

a. Heat Cycle Research

- Increase net geothermal fluid effectiveness of binary plants.
- Reduce the consumptive cooling water requirements for geothermal power plants and still maintain heat rejection performance comparable to that of a conventional wet cooling system.

b. Materials Development

- Develop high-temperature chemical systems for repair of lost circulation zones.
- Develop materials, which will extend the operating range of equipment in terms of temperature limits and tolerance to chemically aggressive fluids.
- Develop materials which extend equipment life and reduce maintenance and replacement costs.
- Develop lower cost materials.

c. Advanced Brine Chemistry

- Reduce the costs for well maintenance, fluid surface equipment, and power plant maintenance and equipment replacement related to scale deposition and corrosion.
- Reduce costs of surface disposal of sludge from geothermal brines.

GEOPRESSURED-GEOTHERMAL RESEARCH

1. Well Operations

a. Gladys McCall Reservoir

- Determine the drive mechanism(s) in the geopressured-geothermal reservoir and the reservoir's long-term production capacity.

b. Pleasant Bayou Reservoir

- Determine reservoir's long-term production capacity.
- Reduce the cost of production of geopressured-geothermal energy through process automation, control of scale and corrosion, and increase experience in surface handling facilities.

c. Hulin Reservoir

- Determine reservoir's energy content and production capacity.
- Determine if the high salinity brine reservoir is acceptable for geopressured geothermal energy production.

2. Geoscience and Engineering Support

a. Rock Mechanics

- Compile previous rock mechanics test data.

b. Liquid Hydrocarbons

- Determine source and flow mechanisms for the liquid hydrocarbons and methane being produced from geopressured reservoirs.
- Construct and field test a pH probe for use in geopressured-geothermal surface facilities.

c. Reservoir Engineering

- Develop techniques to increase confidence in the ability to locate and evaluate geopressured resources.
- Analyze well test data and improve existing reservoir simulation for geopressured geothermal reservoirs.

- d. **Logging**
 - Evaluate logs as required for programmatic activities.
 - Complete final report on the effect of trace elements on neutron logs with emphasis on boron in geopressured-geothermal formations.
- e. **Environmental Effects**
 - Determine environmental effects of developing geopressured-geothermal reservoirs.
- 3. **Energy Conversion**
 - a. **Pleasant Bayou Hybrid Power System**
 - Complete final report and dismantle Hybrid Power System.
- 4. **Management Support**
 - a. **General Administration**
 - Provide technical and managerial support to DOE-ID.
 - b. **Technology Exchange**
 - Transfer new technology to the industrial arena.

HOT DRY ROCK RESEARCH

- 1. **Fenton Hill Operations**
 - a. **Phase II Energy Extraction System**
 - Based on pressurized tests estimate water loss for the Long Term Flow Test (LTFT).
 - Conduct high backpressure flow test to verify theoretical calculations of reservoir performance and condition reservoir for LTFT.
 - b. **Phase II Ancillary Activities**
 - Comply with environmental safety and health regulations applicable to operations at Fenton Hill during the LTFT.
 - Acquire water rights for LTFT and complete study of LTFT water handling systems.

c. **Site Support**

- Maintain the site, equipment and facilities in satisfactory condition to perform the planned experimental operations.

2. **Scientific and Engineering Support**

a. **Reservoir Engineering**

- Determine water losses as function of pressure.
- Complete modeling of 2D and 3D thermal/fluid dynamic and mass transfer.
- Complete automation of fracture mapping techniques, reanalysis of seismic data from massive hydraulic fracturing experiment, and fault plane spectra analysis.
- Develop techniques for analyzing tracers at expected low concentrations and complete laboratory absorption tests.
- Continue study of fracture healing in laboratory under simulated HDR reservoir conditions of temperature and pressure.

b. **Technology Applications**

- Continue transfer of tool and equipment information; interface with industry on LTFT participation.

3. **Nutriso**

- Support the State of Arizona for the purpose of demonstrating the viability of using hot dry rock to generate electricity.

MAGMA RESEARCH

1. **Long Valley Operations**

a. **Drilling and Engineering**

- Drill Phase II leg (to 7500 feet depth) of Long Valley Experimental Well.
- Direct investigation of the geophysical anomalies interpreted to be magma.

- Conduct investigation of the patterns and conditions of deep fluid circulation and heat transport below the caldera floor.
- Determine the amount of collapse and subsequent resurgence of the central portion of Long Valley caldera.
- Determine the intrusion history of the central plutonic complex beneath the caldera, and determine the relationship of intrusive to eruptive events.

III. ACTIVITY MILESTONES FISCAL YEAR 1991

III. OPERATING PLAN ACTIVITY MILESTONES FY 1991

HYDROTHERMAL RESEARCH

1. Industrialization

a. State Couple Grants

- Each grant requires delivery of draft final reports to DOE and UURI 45 days prior to the project completion date.

b. Direct Heat Participation

- Continue to provide technical assistance to utilities, businesses, communities, and individuals seeking to develop space or district heating systems, greenhouses, aquaculture applications, and geothermal heat pumps.

c. Heber Binary Demonstration Power Plant

- Continue facilitating negotiations between the resource owners, plant owners, and prospective buyers of the plant.

d. Geothermal Test Facility

- Remove barrels of possibly hazardous materials. (2/91)
- Characterize pond sludge and initiate corrective action. (5/91)

2. Reservoir Technology

a. Reservoir Analysis

- LLNL to report on The Geysers attenuation image. (11/90)
- LBL to document and release additional geothermal modules for MULKOM/TOUGH2 reservoir simulator. (6/91)
- LBL to report on study of multi-phase flow in fractured media. (1/91)
- ORNL to report on laboratory measurements of hydrogen chloride solubility in geothermal fluids. (8/91)

b. Brine Injection

- LLNL to initiate seismic monitoring studies at The Geysers. (1/91)
- LBL to perform simulation studies to design new injection experiments and large-scale operations with the purpose of optimizing heat extraction from geothermal reservoirs. (1/91)
- Stanford to evaluate tracer test data from industry experiments at The Geysers. (2/91)
- UURI to conduct tracer recovery analysis at The Geysers. (3/91)
- INEL to initiate evaluation of effects of current and past injection on reservoir performance at The Geysers, and to predict the impact of larger injection operations. (10/90)

c. Exploration Technology

- UURI continue development of cross-borehole and borehole-to surface electrical geophysical methods and complete field deployment. (8/91)

d. Geothermal Technology Organization

- INEL complete negotiations of additional cost-shared projects through the Geothermal Technology Organization. (10/90 and continuing)

3. Hard Rock Penetration

a. Lost Circulation Control

- Complete testing of encapsulated-accelerator cementitious muds in the high differential-pressure cement tester at Brookhaven. (6/91)
- Complete testing of candidate porous packer fabrics. (2/91)
- Complete feasibility study of downhole injector. (2/91)
- Complete second-phase study of BHTV use in characterizing loss zones. (2/91)

- Identify candidate porous packer setting fluids and initiate testing in the fabric test facility. (3/91)
- Complete laboratory and analytical evaluations of ground rubber tire/walnut shell LCM mixtures. (6/91)
- Complete construction of flow loop and initiate testing of drilling hydraulics transducers. (10/90)
- Initiate design of porous packer service module. (4/91)
- Complete laboratory testing of drillable straddle packer. (5/91)
- Complete flow-loop testing of velocity-level transducer and selected commercial flow transducers. (4/91)
- Complete feasibility study of SEA-MIST concept for emplacing downhole hardware. (9/91)

b. Rock Penetration Mechanics

- Complete overall systems analysis of geothermal drilling. (4/91)
- Complete analysis of reservoir testing in small diameter wellbores. (4/91)
- Define data requirements for corehole field tests. (6/91)
- Field test site selection and test definition. (8/91)
- Complete survey of PDC bit research applicable to core drilling. (9/91)
- Complete systems analysis of core drilling. (9/91)

c. Instrumentation

- Evaluate logging services applicable to The Geysers and choose a logging service company. Place a logging contract. (1/91)
- Arrange for access to wells in The Geysers. (1/91)
- Conduct logging exercises. (3-9/91)

- Complete the prototype downhole computer. (1/91)
- Complete the design and construction of a power supply. (3/91)
- Complete the design of the dewar/pressure unit and arrange for its construction. (3/91)
- Complete the dewar and conduct a field test. (9/91)

d. Geothermal Drilling Organization

- Finalize legal agreement with Unocal. (11/90)
- Complete televiewer documentation and train Unocal personnel. (12/90)
- Complete joint field testing and transfer all equipment to Unocal. (4/91)
- Complete field test of drill pipe protectors. (3/91)
- Field test rotating head seals. (6/91)

4. Conversion Technology

a. Heat Cycle Research

- Complete the 100 day fouling investigation test with the polymer-concrete lined heat exchanger tube at the Salton Sea site. (5/91)
- Report the results of the investigation of the fouling resistance of the polymer-concrete lined heat exchanger tube; include recommendations relative to future testing. (7/91)
- Heat Cycle Research Program Review at DOE-HQ. (12/91)
- Initiate investigation of condensation behavior of supersaturated expansions with the isobutane working fluid using the two dimensional expansion nozzle. (5/91)
- Complete procurement of reaction turbine to be utilized at the HCRF in the investigation of the condensation behavior of the supersaturated turbine expansions. (9/91)

- Complete the installation of the reaction turbine and begin investigations of impact of supersaturated turbine expansions on turbine performance using the isobutane working fluid. (12/91)
- Complete preliminary evaluation of utilizing a supercritical binary cycle with working fluid mixtures in a standardized, modular binary power plant. (9/91)
- Prepare final report on counter-current flow, in-tube condensation testing at the HCRF. (8/91)

b. Materials Development

1. **Advanced High Temperature Lightweight Cements**
 - Complete downhole testing of best candidate lightweight CO₂-resistant cement. (9/91)
 - Peer-review publication on FY 1991 work. (12/91)
2. **Thermally Conductive Polymer Concrete Liners**
 - Complete field test of HX-1. (5/91)
 - Issue interim report. (7/91)
 - Initiate field test of HX-2. (7/91)
 - Complete field test of HX-2. (11/91)
 - Initiate field test of HX-3. (1/92)
 - Complete field test of HX-3. (5/92)
3. **Chemical Systems for Lost Circulation Control**
 - Selection of material. (9/90)
 - Complete mud displacement test with industry. (4/91)
 - Cost-shared field test. (9/91)
 - Peer-review publication. (12/91)
4. **Corrosion Mitigation at The Geysers**
 - Completion of preliminary testing of lined casing selection. (10/90)

- Complete development of method for joining lined casing selections. (3/91)
 - Install lined casing string for downhole evaluation. (8/91)
5. High Temperature Chemical Coupling Systems
- Identification of metallic surface modification process. (12/90)
 - Selection of organic bonding system. (3/91)
 - Complete characterization of metal/bonding agent/elastomer interfaces. Initiate long-term autoclave exposures. (8/91)
 - Peer-review publication. (10/91)
6. Advanced Elastomers for Downhole Drill Motors
- Select industrial partner. (12/90)
 - Complete stator design and fabrication. (6/91)
 - Complete laboratory evaluation. (8/91)
 - Issue interim report. (9/91)
- c. Advanced Brine Chemistry
- Initiate preparation of a peer-review paper dealing with high temperature/pH bioprocess conditions. (2/91)
 - Annual Operating Plan. (4/91)
 - Complete analysis and recommendations based on the first generation of modified bioreactors. (7/91)
 - Subject to information gained above, consider options for the construction of a model process system. (9/91)
 - Annual Report. (12/91)
 - Issue user manual for Brine Chemistry Model. (11/90)
 - Begin development of Al and HSO₄ preliminary model. (7/91)

GEOPRESSURED GEOTHERMAL RESEARCH

1. Well Operations

a. Gladys McCall Reservoir

- Complete long-term pressure buildup monitoring. (6/91)
- Complete short-term flow test and short-term pressure buildup. (9/91)
- P & A or turn over to industry. (9/91)

b. Pleasant Bayou Reservoir

- Evaluate surface facilities operation and begin pressure buildup test. (9/91)

c. Hulin Reservoir

- Initiate development of ES and H and quality assurance. (2/91)
- Initiate facility designs. (10/91)

2. Geoscience and Engineering Support

a. Rock Mechanics

- Complete report on rock mechanics testing. (9/91)

b. Liquid Hydrocarbons

- Complete annual report on aromatic hydrocarbon sampling and analysis and pH probe testing. (9/91)
- Complete testing of pH probe in geopressured surface facilities. (9/91)
- Complete investigation of adaptation of pH probe to harsher (downhole) conditions. (9/93)

c. Reservoir Engineering

- Develop methods to analyze single well transient pressure test data. (9/91)
- Establish sensitivity of well and reservoir response to drive mechanisms. (9/91)

- Develop reservoir simulation model representing total test history of Gladys McCall reservoir. (9/91)
- Develop maps of co-located geopressured-geothermal brine with medium-heavy oil for Louisiana and Texas. (9/91)
- Complete data analysis and model development of the Pleasant Bayou reservoir. (9/92)
- Modify or develop simulation model incorporating geology, geochemistry, rock mechanics and reservoir data, as a result of a conceptual model. (9/93)

d. Logging

- Follow test program results at the three design wells and provide logging data as appropriate. (9/91)
- Complete final report on boron in geopressured formations and its effect on neutron logs. (9/91)

e. Environmental Effects

- Conduct microseismic and subsidence monitoring at the three well sites and complete annual report. (9/91)
- Conduct water quality monitoring at all sites and complete annual report. (9/91)
- Update geology of McCall and Hulin well sites. (9/91)

3. Management Support

- Prepare a well-written Annual Operating Plan. (6/91)
- Prepare test plans and work scopes. Carry out ongoing review on Quality and Safety of Testing Operations.
- Prepare INEL Geopressured-Geothermal monthly report. (monthly)
- Provide coordination, integration, and technical support to the Reservoir Engineering project. (9/91)

HOT DRY ROCK RESEARCH

1. Fenton Hill Operations

a. Phase II Energy Extraction System

- Receive delivery of high-pressure pumps for LTFT. (12/90)
- Complete installation of LTFT system. (9/91)
- Complete high backpressure flow test. (6/91)

b. Phase II Ancillary Activities

- Log wells during reservoir tests. (9/91)
- Acquire water rights for LTFT.
- Continue environmental monitoring of hydrologic and seismic data. (9/91)

2. Scientific and Engineering Support

- Develop reservoir analyses and modeling of hydraulic and thermal performance. (6/91)
- Conduct geochemistry analysis of water-mineral interactions and effects on an energy extraction-utilization system and the environment. (9/91)
- Continue microseismic studies to provide data for long term well operations, reservoir analysis, and environmental monitoring. (9/91)
- Continue study of geology and rock data acquired during drilling and coring with rock mechanics (laboratory) tests and theories to compare reservoir analyses, behavior and modeling is necessary for application of the total technology. (9/91)

3. Nutrioso

- Provide grant to Arizona Department of Commerce. (6/91)

MAGMA RESEARCH

1. Long Valley Operations

a. Phase II Energy Extraction System

- Execute Phase II drilling contract. (6/91)
- Purchase casing. (6/91)
- Mobilize rig. (6/91)
- Begin Phase II drilling. (7/91)
- Complete Phase II drilling, run casing, and take core. (9/91)
- Prepare site for standdown. (10/91)

TABLE 1
ESTIMATED
FY 1991 GEOTHERMAL PROGRAM BUDGET
(Thousands of Dollars)

<u>Program Area</u>	<u>Management</u>	<u>In-House Research</u>	<u>Sub-Contract</u>	<u>Capital Equipment</u>	<u>Total</u>
Hydrothermal Systems	735	5,081	11,407	405	17,628
Hard Rock Penetration	150	1,735	500	0	2,385
Reservoir Technology	210	2,083	2,907	300	5,500
Conversion Technology	175	1,263	400	105	1,943
Other	200	0	7,600	0	7,800
Geopressured Research	1,286	285	4,429	0	6,000
Advanced Systems	340	2,001	2,626	0	4,967
Hot Dry Rock	190	2,001	1,776	0	3,967
Long Valley	150	0	850	0	1,000

IV. OUTYEAR PLAN OF THE GEOTHERMAL PROGRAM

IV. OUTYEAR PLAN OF THE GEOTHERMAL PROGRAM

HYDROTHERMAL RESEARCH

1. Industrialization

a. All Projects

- No defined plan has been made as of FY 1991.

2. Reservoir Technology

a. Reservoir Analysis

- Future year 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

- FY92 - Field test drillable straddle packer, velocity-level flow transducer, and high-temperature LCM. Complete development of porous packer. Initiate development of downhole injector and SEA-MIST hardware.
- FY93 - Field test porous packer and BHTV loss-zone characterization techniques. Complete development of downhole injector, small-scale laboratory studies of cementitious muds, and wellbore hydraulic models.
- FY94 - Field test downhole injector and wellbore hydraulics models. Complete large-scale laboratory tests of cementitious muds. Initiate development of expert systems for lost circulation control. Complete development of SEA-MIST hardware.
- FY95 - Field test cementitious muds. Field test expert system for lost circulation control. Field test SEA-MIST hardware.

b. Rock Penetration Mechanics

- FY92 - Field test to compare production in large and small wellbores. Build and test PDC coring bits. Define needs for high temperature, slim-hole drilling fluids. Collect cost data for conventional exploration. Design drilling hardware for cost effective emplacement of vertical heat exchangers for geothermal-based heat pumps.
- FY93 - Define needs and begin development of surface technology for coring rigs. Develop high temperature core barrels. Begin development of high temperature drilling fluids. Continue collection of cost data. Fabricate drilling hardware for heat pump installation. Design advance coring system for geothermal exploration.
- FY94 - Hardware prototypes for coring rig's surface equipment. Define needs and begin development for measure-while-coring (MWC) system. Development of high temperature, slim-hole drilling fluids and lost circulation materials (LCM). Continue collection of cost data. Test heat pump drilling hardware at several installations. Build and test advanced coring system.

- FY95 - Acquire coring rig and modify it with developed technology. Build prototype MWC system. Field test drilling fluids and LCM. Continue collection of cost data. Initiate advanced drilling concepts for geothermal application.

c. Instrumentation

- FY92 - Field test modular electronic tools in geothermal wells and field test commercial downhole radar system.
- FY93 - Develop fiber optic cables for high temperature logging above 300 degrees C.
- FY94 - Develop fiber optic sensors for temperature, pressure and stress measurement.

d. Geothermal Drilling Organization

- FY92 - Fuel test high temperature positive displacement motor.
- FY93 - Identify and develop new projects.
- FY94 - Identify and develop new projects.
- FY95 - Identify and develop new projects.

4. Conversion Technology

a. Heat Cycle Research

- Improve the brine utilization of binary geothermal power cycles.
- Expand the resource base that can be economically developed through the use of innovative technology.
- Demonstrate by 1992, that the net geothermal fluid effectiveness of the binary power cycles can be improved by 20% by incorporating the advanced concepts investigated in the projects.
- Show that an additional 8% improvement can be achieved by 1992 in the advanced binary plant performance by allowing supersaturated turbine expansions.
- Define a heat rejection system which will achieve a performance similar to that of conventional "wet" cooling systems with a 20% lower make-up water requirement.

b. Materials Development

- FY92 - Complete development of lightweight CO₂-resistant cements for well completions. Continue R&D efforts on advanced high temperature elastomers for use in downhole drill motors, high temperature chemical coupling systems, and the mitigation of corrosion at The Geysers. Work will commence on the in-situ conversion of drilling muds into well cements, and metallic liners for well casing.
- The cooperative effort with Sandia National Laboratory to develop cements and ceramic like materials that can be used for well completions at temperatures up to 600 degrees C will be continued.
- Commence work to optimize elastomers specifically for use as a stator in downhole drill motors.
- During fiscal year 1991, BNL will initiate a subcontract with L'Garde, Inc. or equivalent to identify and participate with a drilling equipment company on a cost shared basis, to construct and laboratory test a prototype Moineau stator. Concurrent with this effort, Laboratory tests to develop a chemical system for bonding the elastomer to steel reinforcement will also be conducted. Contingent upon the results, plans will be made to fabricate and lab test a full scale Morineau stator in FY92. A field test will be planned for FY93.
- Identify the most promising high temperature chemical coupling systems for bonding advanced elastomers to metals for applications in many geothermal tools.
- Continue cost-shared work to reduce corrosion of well casing, cements, and above ground components.

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.

GEOPRESSURED-GEOTHERMAL RESEARCH

- FY92 - Shut-in Pleasant Bayou well for pressure buildup test and after reservoir recovery is established, complete final scientific tests and plug and abandon well. Construct production facilities at Hulin well site and flow test reservoir. Continue associated research activities at universities and national laboratories.
- FY93 - Complete flow testing of Hulin well and plug and abandon well or transfer to industry. Continue associated research activities.
- FY94 - Complete all research reports excluding environmental monitoring.
- FY95 - Complete final report on environmental monitoring.

HOT DRY ROCK RESEARCH

- FY92 - Start LTFT operation.
- FY93 - Conduct LTFT using various operating modes.
- FY93 - Begin LTFT analysis.
- FY94 - Conduct post LTFT tests.
- FY95 - Complete LTFT analysis.
- FY95 - Decommission Fenton Hill site.
- FY95 - Begin advanced technology projects.

MAGMA RESEARCH

Note: Pending a decision on the FY92 and Outyear budgets, no plans will be made for magma energy research.

V. FISCAL YEAR 1991 MANAGEMENT PLAN

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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 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 (INEL)
- Sandia National Laboratories (SNL)

Three additional laboratories, Lawrence Berkeley Laboratory, Los Alamos National Laboratory, and Brookhaven National Laboratory also perform geothermal energy R&D activities for DOE under subcontract to the two main technical centers.

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 Division (GD) at DOE Headquarters, Washington, D.C. GD is responsible to the DOE Assistant Secretary for Conservation and Renewable Energy, the Deputy Assistant Secretary for Utility Technologies through the Director, Office of Renewable Energy and Conservation.

The Director of GD 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.