Management-By-Objectives

FY 1989

Geothermal Technology Division
U.S. Department of Energy

December 1988

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MANAGEMENT-BY-OBJECTIVES PLAN

FISCAL YEAR 1989

U.S. Department of Energy

**Assistant Secretary for
Conservation and Renewable Energy**

Geothermal Technology Division

December 1988

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I. INTRODUCTION

The Geothermal Technology Division (GTD) of the Department of Energy uses management by objectives to direct its research program. The objectives which govern the content of GTD's program are developed on three levels. Level I objectives provide a target for decreasing the total cost of power for generating electricity from geothermal energy. Level II objectives address incremental improvements in the cost and/or performance of major system components that make up a geothermal power project. And Level III objectives identify improvements in cost, efficiency, and certainty of performance to which our individual research activities are geared. The achievements of research objectives (Level III) ultimately influence the total cost of power (Level I).

The individual research activities and objectives which are the most dynamic part of each year's program, and therefore they require annual updates. The purpose of this document is to present the research objectives and related activities as they apply to Fiscal Year 1989 with a look ahead to Fiscal Year 1990.

OBJECTIVES

At present, the Level I objectives for each resource type are:

- Hydrothermal - The overall objective of the program is to reduce the cost of electric power from liquid-dominated, moderate-temperature hydrothermal resources to 3-10 cents per kilowatt-hour (kWh) by 1992. This compares with a cost range of 4-18 cents/kWh for hydrothermal electric power as of 1986.
- Geopressured-Geothermal - The objective is to improve the technology for producing energy from the geopressured-geothermal resource to a cost equivalent of 6-10 cents/kWh by 1995.
- Hot Dry Rock - The objective of hot dry rock R&D is to provide the technology to enable industrial hot dry rock projects to generate power at the equivalent of 5-8 cents/kWh by 1997.

- Magma - The R&D objective is the creation of a technology by which energy could be produced experimentally from magma at an equivalent cost of 10-20 cents/kWh by the year 2000.

PROGRAM STRATEGY

In order to assure the achievement of these objectives, the Geothermal program must see that the needed technologies are developed, and that they are readily available within the geothermal industry. The overall strategy, therefore, is to determine what technologies are needed, sponsor research and development projects that will produce them, and assure the transfer of the new technology to the appropriate industry.

The assessment of needs and the preparation of plans to meet them involve close DOE liaison with the geothermal industry, and with leading technical experts. The consultative and review process addresses not only completed and ongoing projects, but also the setting of directions for future work, and involves leading technical experts, industry leaders, national laboratory staff members, and management personnel from DOE headquarters and the field offices.

The approved plans for research and development are carried out, within financial and legal constraints, under the overall direction of the Division, with active day-to-day management responsibility delegated to field offices. The program exercises its legal obligation to utilize appropriated funds to sponsor, monitor and manage research and development activities required to reach the program goals. Thus, this program achieves its results by accessing a broad range of scientific talent in industry, DOE labs, universities, and the private sector, rather than attempting to do it all "in house."

An essential element of the strategy is the delivery of the newly developed technology to the end users. Research results that are only filed and forgotten do not contribute to achievement of geothermal program

objectives. Therefore, the effort to assure that the results of research for which the program has paid actual represent usable technology available to industry is a crucial element of the strategy. Documentation of and preservation of the research results is necessary, as is the dissemination of research results directly to the proper technical and industry communities. Workshops and conferences are useful dissemination techniques, as is publication in industry technical and trade journals. But perhaps the most effective technology transfer technique of all, where possible, is the direct participation of target industry entities in the research itself, through contracting with them as performers, or through cost-sharing arrangements that may include the acquisition of proprietary rights in the research.

PROGRAM OVERVIEW

The Geothermal R&D Program contains four categories that parallel the resource types - Hydrothermal, Geopressured-Geothermal, 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 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-Geothermal 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.

Table 1
PROGRAM HIERARCHY
GEOTHERMAL R&D

ACTIVITIES

SUBACTIVITIES

RESOURCES BY MAJOR PROGRAM ELEMENT (\$1000)

	FY 1989
Geopressured-Geothermal Research.....	\$ 6,000*
Hydrothermal Industrialization.....	0
Geothermal Technology Development.....	
Hard Rock Penetration Research.....	2,300
Reservoir Technology.....	2,500
Conversion Technology.....	1,935
Hot Dry Rock Research.....	3,500
Magma Energy.....	1,700
Capital Equipment.....	795
Program Direction.....	826
Total, Geothermal Technology.....	\$19,556

* In addition \$4,450 K was reprogrammed from prior year funds for operations at the geopressured Hulin well in Louisiana.

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. The objectives collectively define the task objectives that will ultimately reflect the overall category objectives of the entire research program.

HYDROTHERMAL RESEARCH

1. Industrialization

State-Coupled Grants

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

Direct-Heat Participation

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

Honey Lake Hybrid Power Plant

- Mutual termination of project in FY 1989

Baca Demonstration Power Plant

- Equipment sales during FY 1989

Heber Binary Demonstration Power Plant

- Plant divestiture during FY 1989

2. Reservoir Technology

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

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

Brine Injection

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

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

Lost Circulation Control

- Reduce costs associated with lost circulation episodes

Rock Penetration Mechanics

- Reduce deep coring costs
- Reduce costs of deep wells and directionally drilled wells

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

Geothermal Drilling Organization

- Develop and transfer other related technology to effect an additional reduction in well costs

4. Conversion Technology

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.

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.

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. Well Operations

Gladys McCall Reservoir

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

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.

Hulin Reservoir

- Prepare well for future tests by workover.

2. Geoscience and Engineering Support

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.

Liquid Hydrocarbons

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

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.

Logging

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

Environmental Effects

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

3. Energy Conversion

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. Management Support

General Administration

- Technical and managerial support to DOE-ID.

Technology Exchange

- Provide transfer of new technologies.

HOT DRY ROCK RESEARCH

1. Fenton Hill Operations

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.

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.

Site Support

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

2. Scientific and Engineering Support

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.

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.

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. Long Valley Operations

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.

Supporting Science

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

2. Laboratory and Engineering Support

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.

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.

Energy Extraction

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

TASKS/PROJECTS	FISCAL YEAR 1989				FISCAL YEAR 1990			
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
HYDROTHERMAL								
Industrialization								
- State-Coupled Grants	Continue throughout year							
- Direct Heat Participation	Continue throughout year							
- Honey Lake Hybrid Power Plant				1				
- Baca Demonstration Power Plant				1				
- Heber Binary Demo Power Plant				1				
Reservoir Technology								
- Reservoir Analysis				1,2	3,4			
- Exploration Technology				1,2				
- Brine Injection		1	2	3				
- Geothermal Technology Org.				1				

TASKS/PROJECTS	FISCAL YEAR 1989				FISCAL YEAR 1990			
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
HYDROTHERMAL (Continued)								
Hard Rock Penetration								
- Lost Circulation Control		1		2,3,4				5
- Rock Penetration	1	2,3	4	5,6				7,8,9
- Instrumentation	1	2	3	4,5,6				7,8,9
- Geothermal Drilling Org.	1	2	3,4	5				6,7,8
Conversion Technology								
- Heat Cycle Research	1,2	3		4,5,6				7,8
- Materials Development	1,2	3	4,5	6				
- Advanced Brine Chemistry	1			2,3,4	5			

MILESTONES FY 1989-1990

HYDROTHERMAL RESEARCH

1. Industrialization

- a. State-Coupled Grants
 - 1. Continue state reservoir studies.
- b. Direct Heat Participation
 - 1. Continue technical assistance for direct heat projects.
- c. Honey Lake Hybrid Power Plant
 - 1. Complete mutual termination of project.
- d. Baca Demonstration Power Plant
 - 1. Complete equipment sales.
- e. Heber Binary Demonstration Power Plant
 - 1. Accomplish final plant divestiture.

2. Reservoir Technology

- a. Reservoir Analysis
 - 1. Complete the development of conceptual models for fluid and heat transfer in fractured two-phase reservoirs.
 - 2. Finish testing advanced geophysical borehole techniques.
 - 3. Demonstrate the application of geophysical techniques for fracture control of permeability.

MILESTONES FY 1989-1990

HYDROTHERMAL RESEARCH (Continued)

4. Formulate and test conceptual methods of fracture control permeability.
- b. Exploration Technology
 1. Complete development of algorithms to model the resistivity and AMT response to fractures and permeable zones.
 2. Complete construction of the field system to measure resistivity and audio magnetotellurics.
- c. Brine Injection
 1. Provide FRACSL code and users manual to industry.
 2. Complete field testing of tracers and demonstration of analytical methods for Dixie Valley reservoir.
 3. Complete models of injection plumes and heat extraction in fractured two-phase reservoirs.
- d. Geothermal Technology Organization
 1. Complete negotiations of additional cost-shared projects through the Geothermal Technology Organization.
3. Hard Rock Penetration
 - a. Lost Circulation Control
 1. Initiate analysis and testing of temperature-setting cements.
 2. Complete screening and material properties tests on candidate high temperature bridging materials.

MILESTONES FY 1989-1990

HYDROTHERMAL RESEARCH (Continued)

3. Complete analysis of transient wellbore hydraulics during loss of circulation and determine potential for characterizing loss zones using measured hydraulic parameters.
4. Complete concepts and supporting analysis for emplacing and containing polymers in severe loss zones.
5. Develop and initiate tests of field procedures for characterizing loss zones and complete analysis and laboratory testing of techniques for plugging severe loss zones.

b. Rock Penetration mechanics

1. Purchase several joints of prototype insulated drill pipe.
2. Complete fabrication and analysis of scale models of drill string transducers.
3. Determine advanced drilling/coring concept that can be developed with industry participation and support.
4. Complete fabrication and analysis of drill collar transducer.
5. Complete laboratory evaluation of prototype pipe.
6. Design and begin construction of full scale transducers.
7. Design iteration of insulated drill pipe and begin design of high temperature drilling system.
8. Design advanced drilling/coring system.
9. Complete full scale design of acoustical data telemetry system.

c. Instrumentation

1. 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.

MILESTONES FY 1989-1990

HYDROTHERMAL RESEARCH (Continued)

2. Complete final report on first prototype radar tool.
 3. Initiate design of overall concept for a versatile downhole modular instrumentation system.
 4. Prepare proposal for second generation prototype tool and determine industry interest in cosponsorship.
 5. Complete detailed design of microprocessor/memory module.
 6. Upgrade electrical design of radar tool sampling circuit and avalanche transistor circuit to reduce electrical noise.
 7. Fabricate new modular downhole electronic tool.
 8. Evaluate downhole flow measurement techniques for application in geothermal wells.
 9. Initiate development of second generation radar fracture mapping tool with industry.
- d. Geothermal Drilling Organization
1. Determine future test plan for urethane foam tool.
 2. Finalize logging arrangements for borehole televiewer.
 3. Fabricate high temperature rotating head seals.
 4. Complete field tests of drill pipe protectors.
 5. Field test rotating head seals.
 6. Complete field testing of air turbine.
 7. Complete testing of rotating head seals.
 8. Initiate project in high temperature elastomers for blow out preventors.

MILESTONES FY 1989-1990

HYDROTHERMAL RESEARCH (Continued)

4. Conversion Technology

a. Heat Cycle Research

1. Complete installation of the two dimensional nozzle and laser droplet illumination system at the HCRF.
2. Complete the installation of the HCRF at the GEO McCabe plant.
3. Complete installation of the fouling test unit at the selected site.
4. Complete the investigation of the condensation behavior of the supersaturated turbine expansions with an isobutane working fluid.
5. Complete the scoping study of the advanced heat rejection systems and select a system for further investigation.
6. Issue an informal report on polymer-concrete lined tubes to fouling.
7. Complete supercritical cycle testing at final condenser attitude.
8. Complete testing of metastable supersaturated vapor expansions.

b. Materials Development

1. Selection of best candidate material for lightweight CO₂-resistant well cement.
2. Selection of field test site for prototype heat exchanger test.
3. Complete field test of prototype heat exchanger.
4. Completion of 1-year downhole exposure testing in low CO₂ containing brine at 300°C.

MILESTONES FY 1989-1990

HYDROTHERMAL RESEARCH (Continued)

5. Complete BNL section for Annual Report on PC-lined heat exchanger tubes. Report to be issued by INEL.
6. Peer-review publication on PC surface modifications to reduce scale accumulation.

c. Advanced Brine Chemistry

1. Report preliminary results of different cultures under scaled-up conditions in the flat and/or fluidized bed type reactors.
2. Set-up laboratory equipment to conduct experiments in support of the theoretical brine modeling efforts.
3. Report on effects of different mixed cultures under scaled-up conditions.
4. Prepare input to draft Brine Chemistry Users Manual.
5. Assess kinetics of scale-up waste detoxification experiments.

TASKS/PROJECTS	FISCAL YEAR 1989				FISCAL YEAR 1990			
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
GEOPRESSURED - GEOTHERMAL								
Well Operations								
- Gladys McCall Reservoir				1				
- Pleasant Bayou Reservoir				1			2,3,4	
- Hulin Reservoir	1							
Geoscience & Engineering Support								
- Rock Mechanics				1-4				
- Liquid Hydrocarbons				1-7				
- Reservoir Engineering				1-8				
- Logging				1-3				
- Environmental Effects				1,2				
Energy Conversion								
- Pleasant Bayou Hybrid Power System				1,2				3
Management Support								
- General Administration		Continue throughout year				- as needed		
- Technology Exchange		Continue throughout year				- as needed		

MILESTONES FY 1989-1990

GEOPRESSURED-GEOTHERMAL RESEARCH

1. Well Operations

a. Gladys McCall Reservoir

1. Complete pressure buildup monitoring at well site.

b. Pleasant Bayou Reservoir

1. Initiate long term flow tests.
2. Complete long term flow tests.
3. Evaluate scale inhibitor treatment
4. Decision to shut down hybrid power system.

c. Hulin Reservoir

1. Complete workover and update test plan.

2. Geoscience and Engineering Support

a. Rock Mechanics

1. Complete strength and mechanical property testing of Pleasant Bayou cores.
2. Complete compaction and creep testing of Gladys McCall cores.
3. Additional creep testing capabilities developed.
4. Test tensile behavior on geopressured-geothermal sandstones.

MILESTONES FY 1989-1990

GEOPRESSURED-GEOTHERMAL RESEARCH (Continued)

b. Liquid Hydrocarbons

1. Measure solubility of certain aromatic hydrocarbons.
2. Sampling of brine and cryocondensates completed as scheduled.
3. Correlation completed of cryocondensates yields with well operations.
4. Operational wells monitored for aliphatic hydrocarbon production.
5. Correlated hydrocarbon production with well operating parameters.
6. Theoretical models of reservoir hydrocarbons developed.
7. pH monitor developed and testing.

c. Reservoir Engineering

1. Preliminary hydrogeologic model developed.
2. Sampling procedure reviewed and modified.
3. Hydrogeologic data evaluated.
4. Hydrogeochemical data evaluated.
5. Hydrogeology and Hydrogeochemistry integrated.
6. Effects of compaction on geopressured reservoirs analyzed petrographically.
7. Improved scale inhibitor treatment developed.
8. Synthesized and integrated geoscience research on geopressured design wells.

MILESTONES FY 1989-1990

GEOPRESSURED-GEOTHERMAL RESEARCH (Continued)

d. Logging

1. Complete well log analysis.
2. Progress made in research on the effect of rock wettability and shale content on rock resistivity.
3. Progress made in research on the effect of boron and trace elements on the neutron log.

e. Environmental Effects

1. Established systems maintained for monitoring subsidence, seismicity, and water quality around test wells in Louisiana and Texas.
2. DOE apprised of any additional environmental concerns and recommendations made for a plan of action.

3. Energy Conversion

a. Pleasant Bayou Hybrid Power System

1. Complete construction of hybrid power system.
2. Begin operation of hybrid power system.
3. Complete operation of hybrid power system.

MILESTONES FY 1989-1990

GEOPRESSURED-GEOTHERMAL RESEARCH (Continued)

4. Management Support

a. General Administration

1. Technical and managerial support to DOE-ID.

b. Technology Exchange

1. Provide transfer of new technologies.

TASKS/PROJECTS	FISCAL YEAR 1989				FISCAL YEAR 1990			
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
HOT DRY ROCK								
Fenton Hill Operations								
- Phase II Energy Extraction System	1				2,3			
- Phase II Ancillary Activities	TBD							
- Site Support			1					
Scientific & Engineering Support								
- Tools & Instrumentation				1	2			
- Reservoir Engineering	TBD							
- Technology Applications	TBD							
MAGMA								
Long Valley Operations								
- Drilling and Engineering				1				2
- Supporting Science			1	2,3,4				5,6
Laboratory & Engineering Support								
- Drilling Techniques					1			
- Geochemistry & Materials			1	2	3			
- Energy Extraction	1		2	3				4

MILESTONES FY 1989-1990

HOT DRY ROCK RESEARCH

1. Fenton Hill Operations

a. Phase II Energy Extraction System

1. Start pressurization tests.
2. Complete surface system installation.
3. Start Long Term Flow Test.

b. Phase II Ancillary Activities

c. Site support

1. Complete EE-1 Storage Pond.

2. Scientific and Engineering Support

1. Complete laboratory experiments on adsorption of chemically-reactive tracers.
2. Complete water loss reservoir experiments.

MILESTONES FY 1989-1990

MAGMA RESEARCH

1. Long Valley Operations

a. Drilling and Engineering

1. Drill and complete 1st phase on Long Valley exploratory well.
2. Complete Phase II of exploratory well to a depth of 7500 feet.

b. Supporting Sciences

1. Complete synthesis of geologic results from existing holes on resurgent dome.
2. Complete schedule for 1st phase of supporting on-site scientific measurements.
3. Collect geologic results from magma well.
4. Complete initial computer model of magma/hydrothermal systems at Long Valley.
5. Conduct seismic and thermal wellbore measurements.
6. Coordinate outside supporting scientific measurements in well.

2. Laboratory and Engineering Support

a. Drilling Techniques

1. Design drill bit for entry into magma.

b. Geochemistry and Materials

1. Document the research of metal compatibilities with rholite magma, glass and fluids.

MILESTONES FY 1989-1990

MAGMA RESEARCH (Continued)

2. Determine the rate and extent of magma degassing (vesiculation) upon decompression or cooling.
3. Characterize feldspar dissolution mechanism in aqueous solutions.

c. Energy Extraction

1. Summarize recent advances in energy extraction research.
2. Complete generalized energy extraction computer code.
3. Design integrated energy extraction experiment.
4. Design and initiate large scale experiment to demonstrate concepts of direct contact heat exchange in magma.