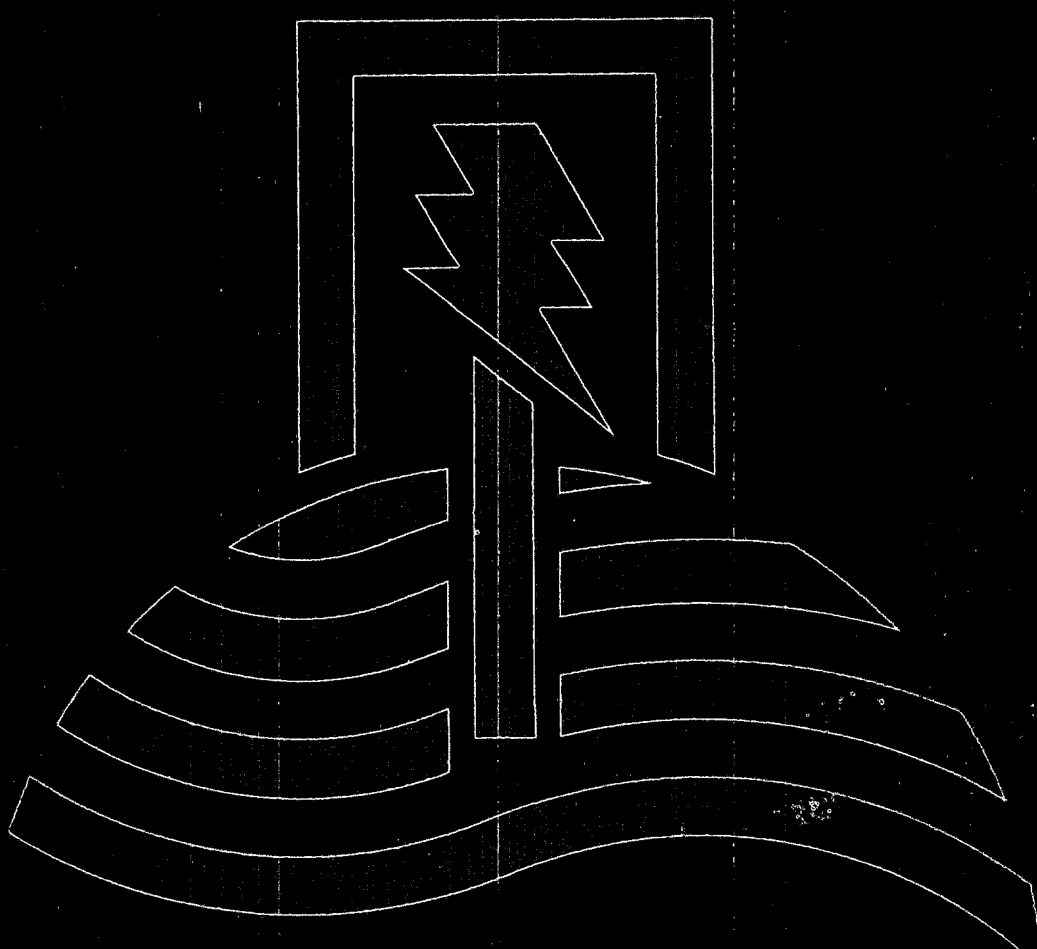
U.S. Department of Energy

Programs in Utility Technologies

Fiscal Year 1991

GEOTHERMAL ENERGY PROGRAM OVERVIEW



DISCLAIMER

Introduction

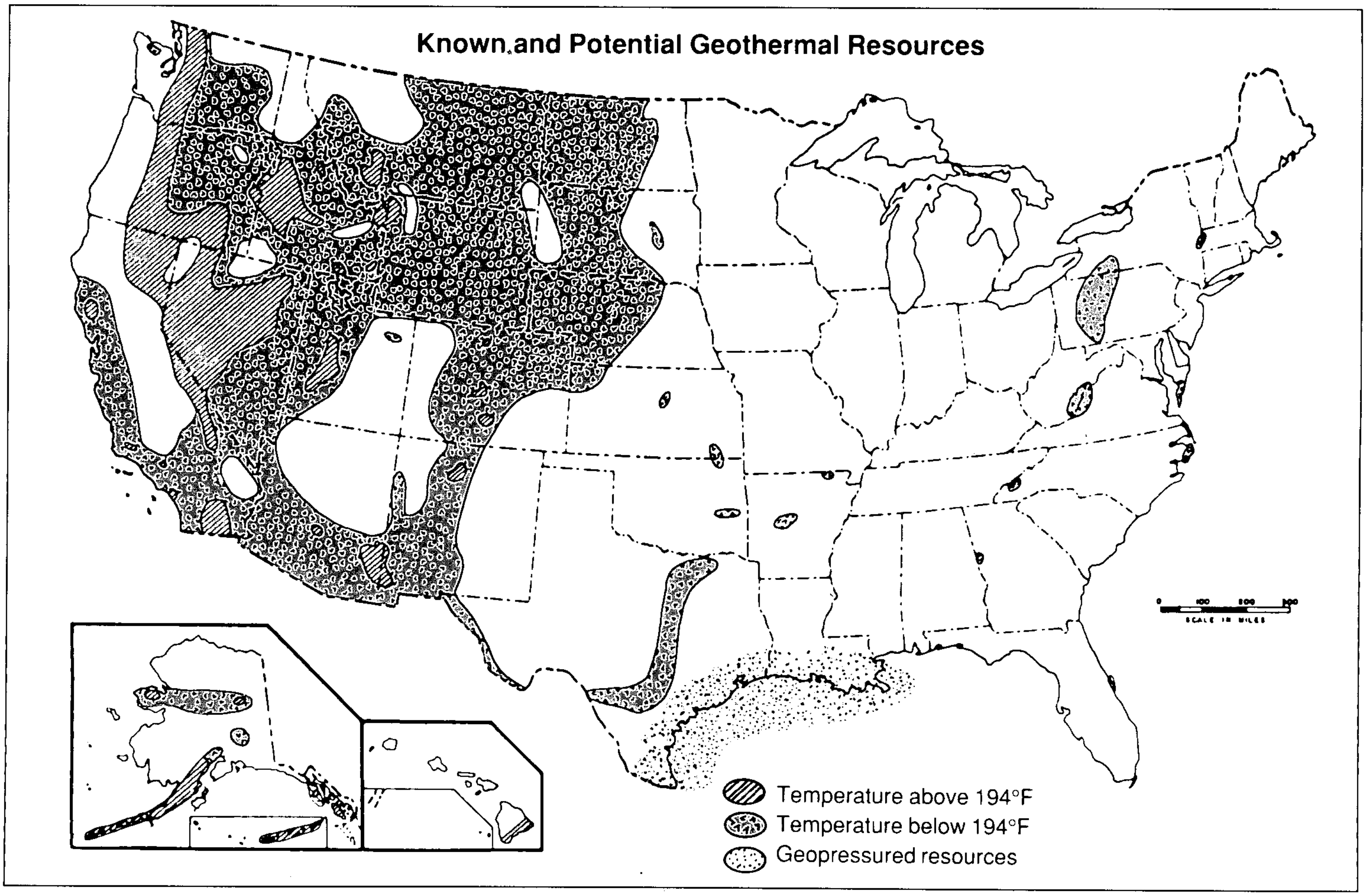
Geothermal energy is a domestic energy source that can produce clean, reliable, cost-effective heat and electricity for our nation's energy needs.

Geothermal energy—the heat of the Earth—is one of our nation's most abundant energy resources. In fact, geothermal energy represents nearly 40% of the total U.S. energy resource base and already provides an important contribution to our nation's energy needs. Geothermal energy systems can provide clean, reliable, cost-effective energy for our nation's industries, businesses, and homes in the form of heat and electricity. The U.S. Department of Energy's (DOE) Geothermal Energy Program sponsors research aimed at developing the science and technology necessary for tapping this resource more fully.

Geothermal energy originates from the Earth's interior. The hottest fluids and rocks at accessible depths are associated with recent volcanic activity in the western states. In some places, heat comes to the surface as natural hot water or steam, which have been used since prehistoric times for cooking and bathing. Today, wells convey the heat from deep in the Earth to electric generators, factories, farms, and homes.

Geothermal Program Mission

The mission of the Geothermal Energy Program is to develop the science and technology necessary for tapping our nation's tremendous heat energy sources contained within the Earth.



Geothermal resources in the United States.

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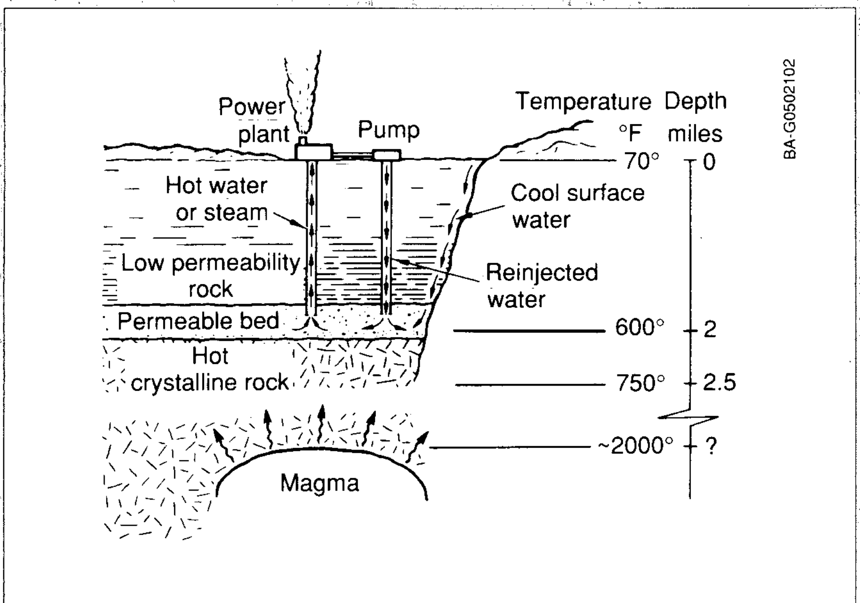


A typical hydrothermal system.

The Four Types of Geothermal Energy

Geothermal energy occurs in four different forms. **Hydrothermal fluids**—hot water or steam—are the easiest to access and therefore are the only forms being used commercially. Hydrothermal resources are found from several hundred feet to several miles below the Earth's surface. The temperature of these fluids varies from about 90°–680°F (32°–360°C).

Geothermal energy is also found in the form of **geopressured brines.** These brines are hot pressurized waters that contain dissolved methane and lie at depths of 10,000 to more than 20,000 feet. The best known geopressured reservoirs lie along the Texas and Louisiana Gulf Coast.

Hot dry rock energy consists of relatively water-free, impermeable rocks at high temperatures. Heat is extracted from the rocks by fracturing to connect two wells. Cool water is injected down one well, absorbs heat as it circulates through the fractures, and is recovered through the second well. At the surface, heat is extracted from the water before it is injected back into the first well in a closed-loop recirculating system.

Magma is molten or partially molten rock that reaches temperatures of nearly 1800°F (982°C). Some magma bodies are believed to exist at drillable depths within the Earth's crust, although practical technologies for harnessing magma energy have yet to be developed.

Putting the Resource to Work

The first steps in using a geothermal resource are locating a reservoir, determining its size and quality, and designing a strategy for developing and managing the field. The geosciences and drilling are used in each of these steps and in every stage of field development.

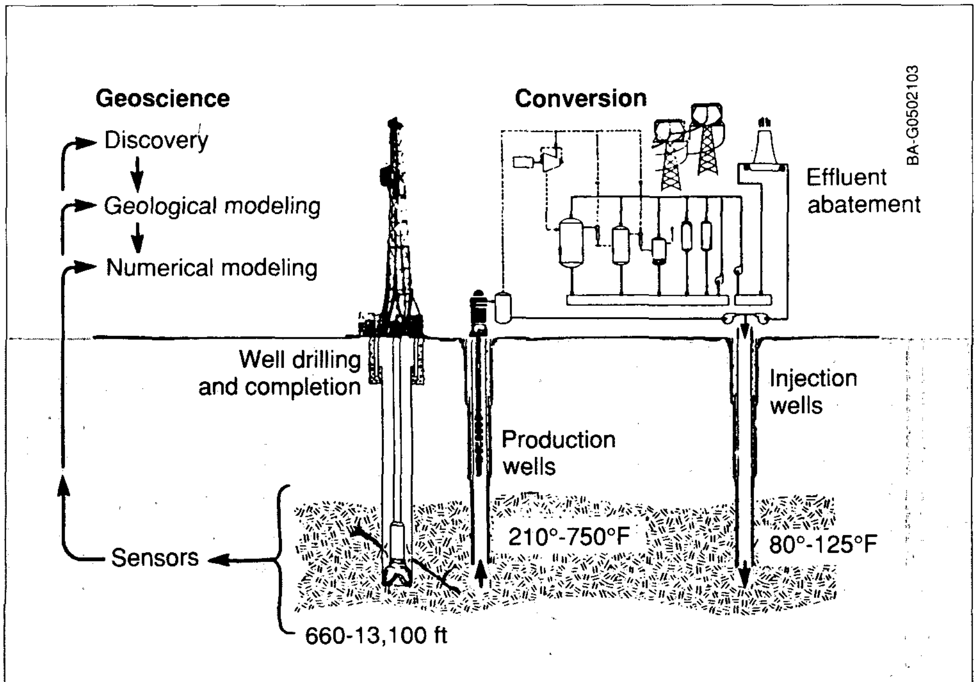
The geosciences—geology, geophysics, geochemistry, and hydrology—help to characterize subsurface properties and optimize well placement. For example, in hydrothermal applications, geologic models define the geometry and physical properties of the reservoir, geochemical models analyze changes in reservoir fluids and rocks, and numerical simulations predict long-term reservoir behavior. Other types of geothermal resources have their own special geoscience requirements.

Initial subsurface assessments are followed by exploratory drilling, production testing, and actual production. The drilling equipment is similar to that used in oil and gas fields but with unique features to accommodate the need to drill through hard, hot rock and chemically hostile fluids.

Power Generation

Today, a total of about 2800 megawatts of electric power (MW_e) generating capacity has been installed at a number of hydrothermal resource sites in the western states. Depending on the state of the resource (liquid or vapor), its temperature, and its chemistry, one of three different energy conversion technologies can be used to convert the thermal energy to electric power:

- **Dry Steam**—Conventional turbine-generators are used with dry-steam resources. The steam is used directly, eliminating the need for boilers and boiler fuel that characterizes other steam-power-generating technologies.



Geothermal power production components.

- **High-Temperature Liquid**—For hydrothermal liquids above 400°F (204°C), flash-steam technology is usually employed. In these systems, the liquid is allowed to flash to steam, which is used to drive a turbine.
- **Moderate-Temperature Liquid**—For liquids with temperatures less than 400°F (204°C), binary cycle technology is most effective. In these systems, the hot geothermal liquid vaporizes a secondary working fluid, which then drives a turbine.

Geothermal energy has the potential to supply a significant fraction of the nation's energy use, which was approximately 80 quadrillion Btu (quads) in 1990. In the production of electricity, renewable energy as a whole produced 6.4 quads in 1990 (8% of the nation's energy consumption), and it has the potential to supply as much as 36.6 quads by 2030. Geothermal power is predicted, by the National Energy Strategy, to be the largest short-term supplier of renewable electric power, with more than a tenfold increase by 2010. By that time, geothermal power could provide more than 3.3 quads or more than 35% of the potential contribution by renewable energy.

Direct Use

Geothermal resources at virtually all temperatures are suitable for direct-heating applications, although it is more common to use the relatively abundant lower temperature fluids that are not economical for power generation. The technology for direct use is drawn mainly from conventional hot-water and steam-handling equipment. For example, several communities use geothermal energy in district heating systems that provide heat to groups of homes or public buildings. In these systems, the geothermal production field (consisting of wells, pumps, and collection lines) replaces the boiler. Geothermal energy also provides direct heat for commercial greenhouses, fish hatcheries, food-processing plants, and a variety of other applications.

Another direct-use application is the geothermal heat pump (GHP) or ground-source heat pump. GHPs use the same principles as the familiar air-source heat pump, but take advantage of the Earth's relatively constant ground temperature as a heat source in winter and a heat sink in summer. GHPs save 30% more energy than conventional heat pumps, which are dependent on widely fluctuating outside air temperatures.

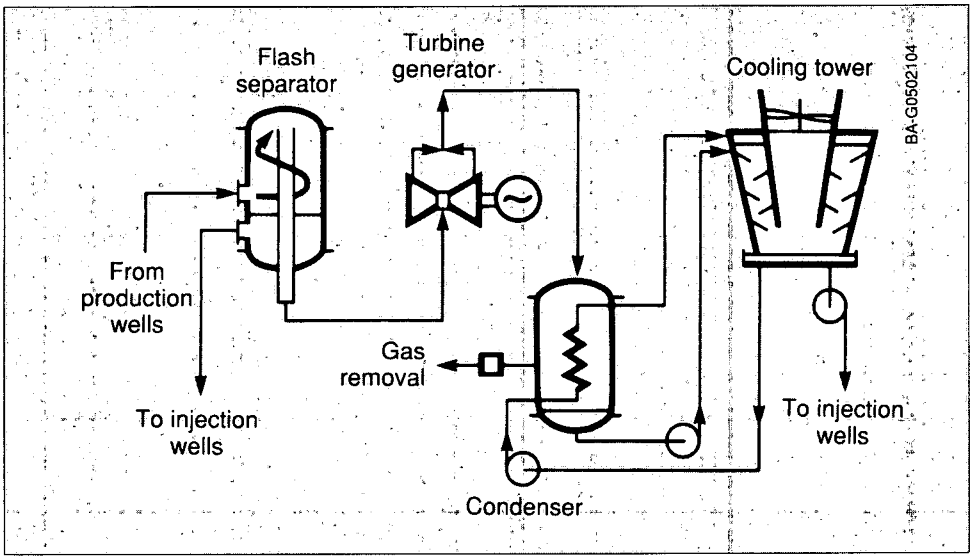
Geothermal heat pumps are applicable throughout the United States and have proven to be an ideal demand-side management technology for utilities.

In supporting documentation for the National Energy Strategy, the Energy Information Administration ranked the potential of GHPs second only to wood/biomass in dispersed applications. GHPs have the potential to supply 2.7 quads by 2030, up from less than 0.1 quad in 1990.

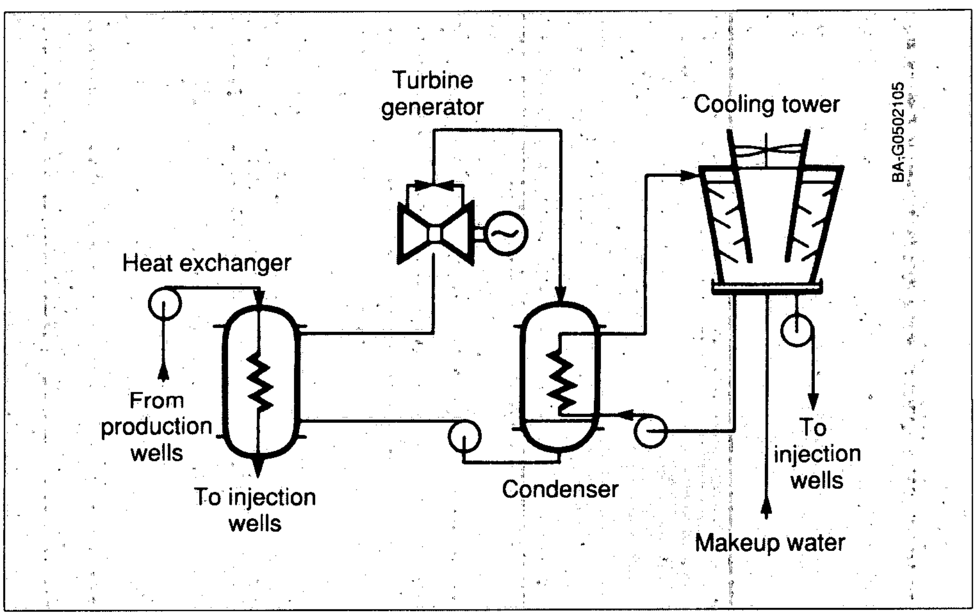
Geothermal Technology Today

When the federal Geothermal Energy Program was established in 1971, the U.S. had less than 200 MW_e of generating capacity in operation—all at The Geysers dry-steam field in northern California—and industry's first hot-water demonstration plant was 9 years in the future. Geothermal drilling costs were up to 4 or 5 times those of oil and gas drilling, yet drilling was necessary to identify and characterize reservoirs in the absence of reliable geoscientific techniques. The chemically aggressive brines of some major reservoirs would corrode and erode turbine blades, plug injection wells, and deposit scale in production wells, shutting them down.

Fiscal year (FY) 1991 marks the 20th anniversary of the program, and in retrospect, considerable strides have been made in the technologies used with hydrothermal resources and the other geothermal energy forms. Drilling, operating, and maintenance costs for hydrothermal fields have improved, and reliability has greatly improved. Increased understanding of the character and performance of geopressured and hot dry rock reservoirs has brought



Flash-steam technology for high-temperature liquids.



Binary cycle technology for moderate-temperature liquids.

these energy sources closer to commercial reality, and the scientific evidence is available to show that the intense heat of magma may one day be commercially extracted. The technologies will continue to advance through program-sponsored research and cooperation with industry.

Hydrothermal Technology

The technology for using the hydrothermal resource has a history of research and commercial development. Many direct-use applications have matured to the point where small projects for space heating, greenhouses, and industrial process heat are common throughout the West. The program supports the transfer of these technologies to the private and public sectors through the Geo-Heat Center at the Oregon Institute of Technology.

Electricity production from hydrothermal resources has also seen significant development. The Geysers has become the world's largest geothermal complex, producing nearly 1500 MW_e from 25 operating units; another 40 plants, operating in three states, are generating an additional 820 MW_e from hot water. DOE-sponsored research has contributed significantly to this development. For example, the results of cooperative research between government and industry at the Geothermal Loop Experimental Facility in the Imperial Valley of California have allowed the use of a unique reservoir where the fluids are 8 times saltier than seawater. A 34-MW_e plant now stands on the site of the experimental facility in an area estimated to have a 2000-MW_e capacity. The economics of five other plants in the area also depend on the crystalizer/clarifier technology developed at the experimental facility.

Despite the progress made since the early 1970s, however, several obstacles remain to the widespread use of the hot water hydrothermal resource. Areas that need more research include reservoir engineering, drilling technology, binary cycle energy-conversion technology, materials compatibility and lifetime, techniques for locating and characterizing resources, and techniques for disposing of spent geothermal fluids. These areas are the focus of continuing DOE research.

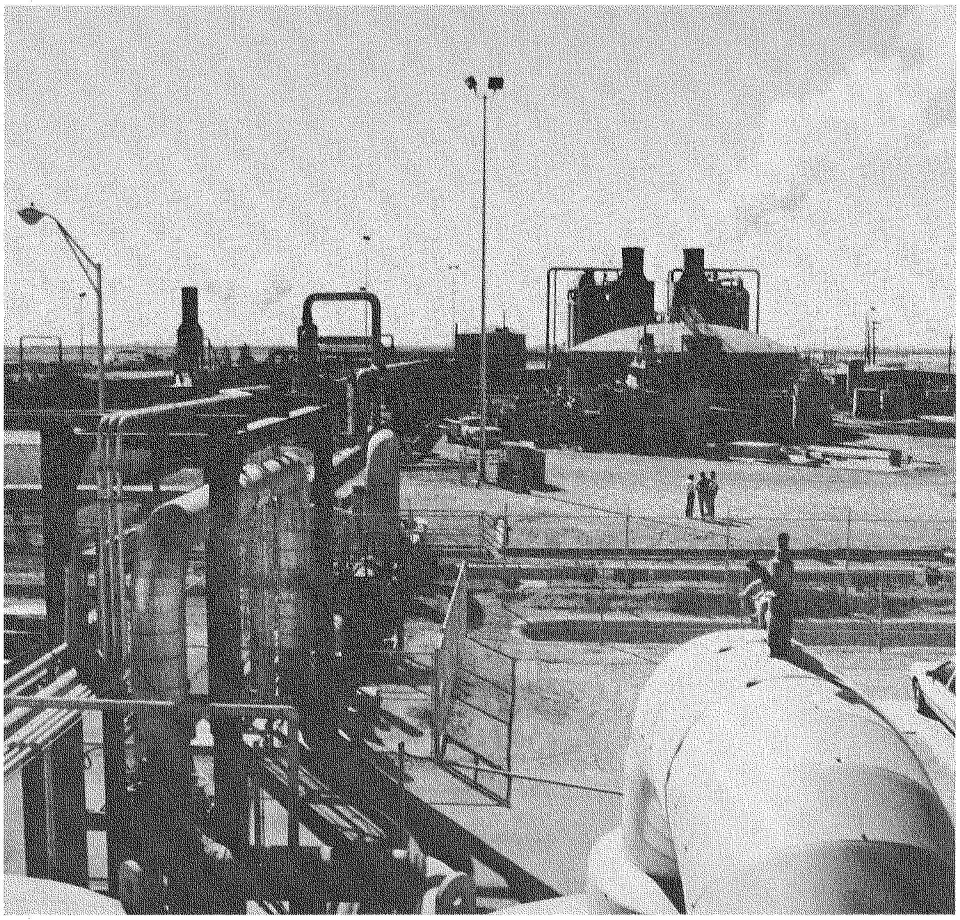
As a whole, progress in hydrothermal technology has been truly *revolutionary;* the U.S. hot water industry did not exist when the DOE research and development program began. Its progress toward competitiveness with conventional fuels has been dependent on an *evolutionary* process, consisting of incremental improvements in methods, equipment, and materials and marked intermittently by significant "firsts." Over the years, the improvements have combined to lower costs and increase utilization of the resource. The industry's continued growth will depend on such improvements in technology and costs.

Advanced Technologies

The technologies for using the energy found in geopressured brines, hot dry rock, and magma, although less developed than those for hydrothermal energy, have advanced significantly in the past two decades. Data obtained from geopressured test wells in Louisiana and Texas indicate the energy source is large and saturated with methane and can be developed with minimal operational or environmental problems. Research has eliminated the problems of scaling, bringing the technology nearer to commercial application. An industrial consortium has been formed to promote the commercialization of the direct use of geopressured energy sources.

The operation of a 1-MW_e demonstration hybrid power system for 8 months at the Pleasant Bayou site in Texas proved the technical feasibility of power generation from geopressured brines, but the process is not yet economical. Research is continuing on reservoir characterization and process optimization.

Hot dry rock technology was proven on a small scale in the late 1970s by fracturing of granitic rock at a site in New Mexico. The reservoir was created by hydraulically fracturing the rock mass between two wells at a depth of about 9000 feet and circulating water in one well and out the other. The test produced enough heat—up to 5 megawatts of thermal energy—to satisfy the electricity needs of several hundred people. A much larger, deeper, and hotter reservoir has since been completed, and a long-term test will increase our knowledge of the characteristics of hot dry rock reservoirs. To make this technology competitive, cost-effective methods must be developed to create and map fractures in underground rocks and to drill wells under high-temperature conditions.

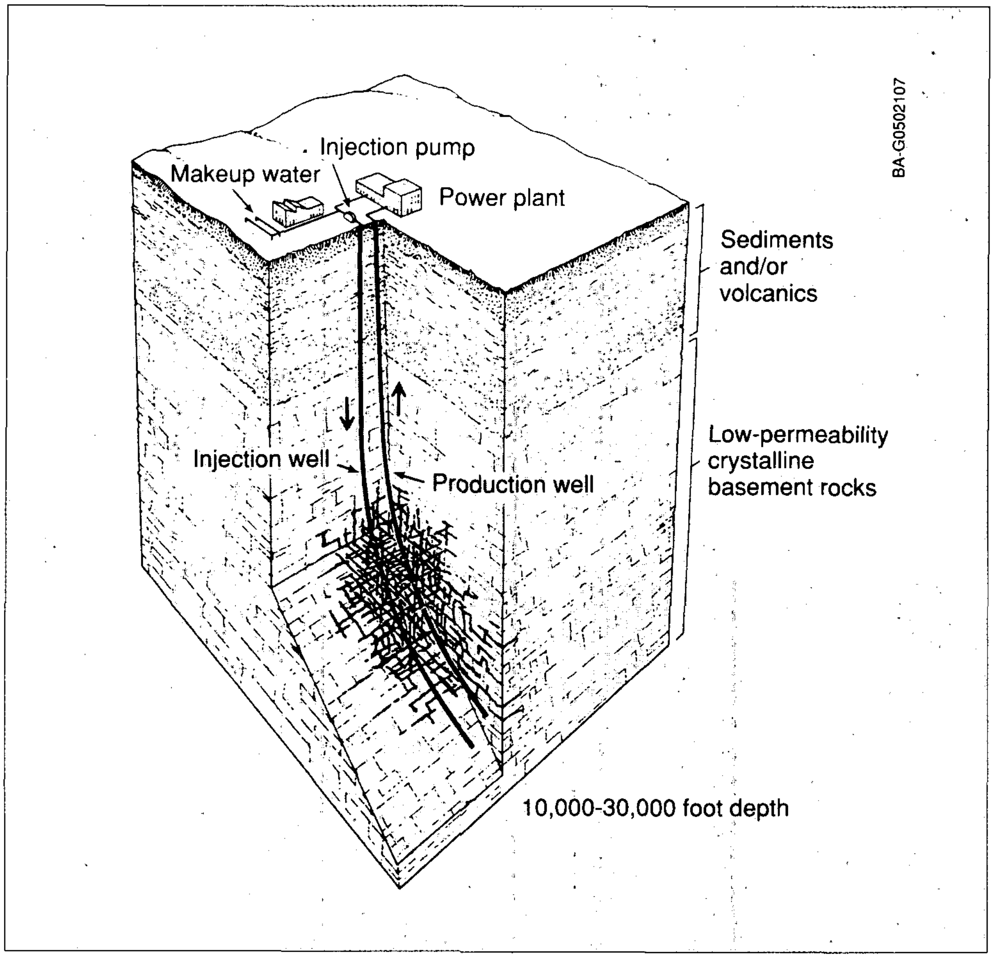


DOE research helped develop the technology to produce power from the concentrated brines in California's Imperial Valley. This 34-megawatt plant stands at the site of the experimental facility that proved the technology.

The scientific feasibility of extracting energy from magma was proven by DOE experiments at a shallow, encrusted lava lake in Hawaii. However, the technology to locate subsurface magma chambers and extract energy from them economically has yet to be developed. The economic feasibility of magma energy will depend on the accessibility, the costs and lifetimes of wells, and the effectiveness of various energy-extraction techniques.

As with the progress made in hydrothermal systems, technological advancement in extracting energy from geopressured brines, hot dry rock, and magma is generally evolutionary. Research in these technologies is justified by the tremendous potential they offer:

- An economic analysis of hot dry rock technology, performed by the Massachusetts Institute of Technology during FY 1990, indicates that with lower drilling and completion costs, U.S. hot dry rock energy sources with temperature gradients greater than 30°C per kilometer could provide more than 23,000 gigawatts of electric power for 20 years with a weighted average cost of 5.7¢ per kilowatt-hour
- The potential power production from domestic geopressured energy sources has been estimated by the U.S. Geological Survey to be 23,000 to 240,000 MW_e for 30 years
- Crustal magma bodies in the United States are believed to contain up to 500,000 quads of thermal energy at temperatures in excess of 600°C and at depths less than 10 kilometers
- Energy production from even a small fraction of these resources would greatly enhance the nation's domestic energy supplies.



The hot dry rock process circulates water down an injection well and through man-made fissures in the hot rock, returning hot water for power production through the production well.

Program Approach

The Geothermal Energy Program supports research and development of technology that will allow geothermal energy to contribute more fully to our nation's energy supply. Specific projects are carefully selected based on their expected impact, chance of technical success, and pertinence to industry needs. The program interacts regularly with the geothermal industry to focus program priorities and often involves industry members in cooperative research and technology transfer. For example, a major thrust of a cooperative effort with industry is to test and prove the usefulness of advanced exploration technology, which will pave the way for industrial drilling in new, undeveloped regions. Progress within the program is measured against cost objectives for electricity generated from hydrothermal energy along with technology improvement objectives for the other forms of geothermal energy.♦

FY 1990/1991 Research Accomplishments

In FY 1990/1991, the Geothermal Energy Program made significant strides in hydrothermal, geopressured brine, hot dry rock, and magma research, continuing a 20-year tradition of advances in geothermal technology.

Hydrothermal Research

A significant portion of program research is dedicated to developing technologies applicable to hydrothermal resources. Research within this category is organized into three tasks:

- Reservoir technology
- Hard rock penetration
- Energy-conversion technology.

Reservoir Technology

Reservoir technology research supports the U.S. geothermal industry by developing new technologies to improve the exploration, development, and long-term operation of commercial geothermal fields. During FY 1990, the Reservoir Technology Research Task initiated a broad program of studies related to understanding The Geysers steam field in California. In cooperation with the geothermal industry, DOE-funded research projects focused on optimizing water injection to recharge the reservoir and on understanding reservoir conditions, which control the flow of steam to production wells.

Reservoir Analysis. Reservoir analysis research emphasizes development of new analytical and interpretive methods for predicting reservoir performance. Accomplishments include better characterization of fractures using surface roughness and effective aperture in calculating effects on fluid flow, and determination of the energy needed to release adsorbed water from fracture surfaces. These accomplishments will allow industry to calculate the productive lifetime of a reservoir and to assess the volume of reservoir needed to provide the production of a well. Researchers solved several test problems prepared by the California Energy Commission as part of a test of reservoir simulators that could be used to predict production at The Geysers.

Brine Injection. Commercial geothermal operations require the majority of produced fluids to be injected to maintain reservoir pressures and to support production. Research is needed to optimize injection and to avoid cold water breakthrough to nearby production wells. A major accomplishment was achieved when easily detected organic chemical tracers were used successfully to monitor fluid flow from one injection well to 36 production wells at The Geysers. This joint DOE/ industry experiment defined the flow paths in the reservoir and verified that injected water feeds production wells.

Exploration Technology. Exploration technology research provides new methodologies for industry to discover and evaluate new geothermal fields. A recent accomplishment is the application of seismic attenuation analysis to the evaluation of a potential geothermal site. Experiments conducted at Medicine Lake Caldera, Calif., and Newberry Caldera, Ore., have shown that steam-filled fractures can be identified by the high attenuation of seismic waves as the waves move through the fractured rock.

Geothermal Technology Organization. The Geothermal Technology Organization (GTO) is a cooperative DOE/industry group formed to encourage technology development related to reservoir performance and energy conversion.

The organization supports projects that lead to products or services that can be commercialized immediately. Projects are jointly funded by DOE and participating industry partners, with industry providing at least 50% of the total cost. The organization and its sister group, the Geothermal Drilling Organization (GDO), frequently provide the test sites for investigating new technology and methods.

In FY 1990/1991, researchers initiated an agreement with several operators to help interpret tracer tests at The Geysers. The tests are designed to help optimize strategies for brine injection by allowing operators to avoid fractures where injection would adversely affect production. Optimum injection techniques and strategies are critical to the continued success of The Geysers.

Hard Rock Penetration

The Hard Rock Penetration Task pursues development of drilling and well completion technologies that considerably reduce the cost of geothermal wells. Geothermal drilling costs are high because of the hard rock, high temperatures, highly corrosive fluids, and problems with lost circulation—the loss of fluids circulated to cool and lubricate drill bits. Because the cost of well field development represents approximately one-third the cost of a geothermal project, reductions in drilling costs are important for the expansion of the industry.

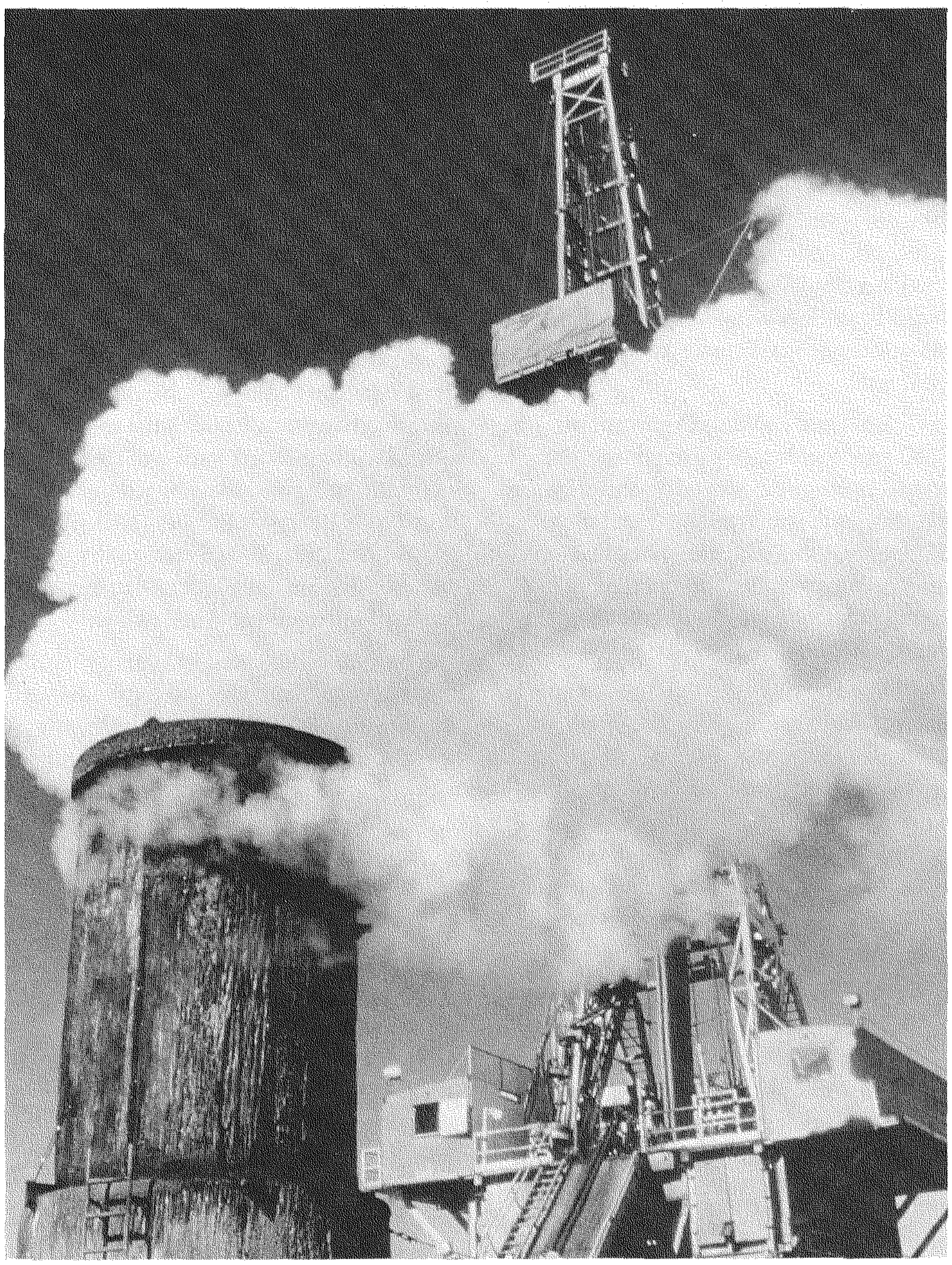
Lost Circulation Control. The most costly aspect of geothermal drilling is the loss of circulation in the drilling fluid system. Loss of circulation occurs when the drilling fluids flow into fractures or voids in the rock, rather than returning up through the borehole. Lost circulation episodes result in downtime and expensive corrective measures and can constitute 20% to 30% of the cost of a well. They also can result in more severe problems, such as borehole instability or stuck drill strings, that could lead to the loss of the well. To help solve these problems, scientists are developing new techniques for identifying the location and magnitude of loss zones and are developing new materials and techniques for plugging those zones.

One effort involves developing advanced, high-temperature, cementitious muds or cements that can be introduced through the drill pipe into the loss zones to plug them without removing the drill string. Eliminating the need to remove the drill string will greatly reduce downtime and aid in the location of the fractured zones, resulting in considerable cost savings. During FY 1990/1991 several cementitious mud formulations were developed for plugging lost-circulation zones in this manner, and several potential encapsulation materials were identified to prevent the cement from prematurely setting up in the drill string. A patent disclosure was filed on a downhole injector system for downhole emplacement of cements through the drill string.

To help monitor circulation fluid loss, a prototype velocity-level flow meter for measuring the rate of outflow of drilling fluid from a well during drilling was designed, fabricated, and tested. Researchers also designed and constructed a laboratory prototype of the drillable straddle packer, completed conceptual design for a system that delivers a sealing material to fluid-loss zones, completed construction of a well-bore hydraulics flow facility to evaluate rig instrumentation needed to measure flow rates during drilling, and completed analysis software to determine loss-zone characteristics.

Rock Penetration Mechanics. Research in rock penetration mechanics is directed at improving drilling and coring systems to reduce costs. Efforts include the development of advanced data transmission methods for measurement-while-drilling (MWD) systems and incremental advancements in drilling and coring systems.

Previous studies indicated that telemetry by acoustical carrier waves within the drill string can improve data collection rates 50-fold over the mud-pulse telemetry that industry uses today for MWD. During FY 1990/1991, researchers completed tests of scale-model transducers that can send and receive a continuous acoustical signal through the drill string and perform active echo suppression. Four patent applications have been filed for this technology.



DOE research at The Geysers is helping to optimize the reinjection of water, which replenishes production wells.

Researchers also completed preliminary analysis of a technique for reservoir evaluation that uses small-diameter coreholes. Exploratory core drilling has the potential to reduce exploration drilling costs by 50%.

Instrumentation. Better downhole instrumentation for gathering data is needed to improve the reliability of data used in exploration and reservoir analysis. Efforts include modifications to existing instruments to improve their performance in harsh geothermal environments. Other efforts include evaluating the feasibility of the downhole radar fracture-mapping tool being developed cooperatively with the Nuclear Treaty Verification Project. In geothermal applications, the tool will help locate rock fractures that do not intersect the well bore. The importance of this tool for the geothermal industry is twofold: fractures account for the greatest number of lost circulation episodes but can also provide a conduit for the hydrothermal fluids. In nuclear weapons testing, the tool can determine the distance and direction of a test site.

Geothermal Drilling Organization. The GDO supports industry's application of new technology developed by the program. It is similar in structure and intent to the GTO, except that it concentrates on the transfer of new drilling technology to industry. Industry provides at least 50% of all project costs.

During FY 1990/1991, a decision was reached to commercialize the borehole televiewer for geothermal operation by allowing Unocal Geothermal to take possession of all GDO equipment and assume responsibility for maintenance. Unocal will then fund a commercial televiewer service to support worldwide geothermal operations.

Another significant FY 1990/1991 accomplishment was the development of a new design for stripper rubbers in rotary head seals. The new design was able to survive up to 1000 cycles in testing. Models for oil and gas wells as well as geothermal wells will soon be available commercially.

Energy Conversion Technology

Conversion technology research aims to increase the effectiveness of geothermal power conversion systems by maximizing the amount of electricity generated for each unit of geothermal fluid produced; developing cost-effective, durable materials of construction for handling hot brine, steam, cooling water, and binary fluids; and designing innovative brine disposal methods to further reduce operating costs. When combined with other new technologies, these improvements will contribute to developing geothermal reservoirs that are economically unattractive with today's technology.

Heat-Cycle Research. The current principal emphasis of heat-cycle research is to improve the performance of binary cycle technology. These improvements should lower costs of generating electricity with binary processes and increase the utilization of the more abundant, lower-temperature reservoirs not suitable for flash-steam technology. Achievement of such improvements requires the use of advanced engineering tools and methods, which are being validated by tests at the Heat Cycle Research Facility (HCRF). In FY 1990/1991, HCRF researchers gathered data on the performance of condensers in nonvertical orientations.

The data will be used to quantify the accuracy of computer codes for modeling the performance of condensers at these orientations.

Materials Development. Because the performance, cost, and lifetime of materials are critical to the economics of hydrothermal systems, researchers continue to work on increasing the temperature and chemical tolerance of metallic and nonmetallic construction materials. In FY 1990/1991, two test sections of steel casing lined with polymer cement were installed at The Geysers in a well where failure of 0.5-inch-thick steel casings generally occurs within 5 weeks. Neither test section failed within 5 weeks, but some chemical attack was apparent, indicating a need for optimizing the formulation to resist the fluid temperature and acidity.

Advanced Brine Chemistry. When the pressure and temperature of geothermal fluids is reduced during the production and extraction phases of the operation, chemical equilibrium of the fluid is disturbed, causing dissolved minerals to precipitate. These precipitates form scale, which builds up and restricts flow through the rock, as well as through the production tubing, distribution system, and plant equipment. Advanced brine chemistry research addresses this problem, as well as methods for remediation of hazardous materials produced at plants utilizing flash technology. During FY 1990/1991, extensive testing of the nonideal behavior of certain ternary gases associated with scaling in geopressured-geothermal systems led to the development of a new equation of state. In addition, refinements were made on the model of calcite scale formation, improving its reliability when applied to brines of unusual composition.

Also in FY 1990/1991, research on biochemical processes for remediating geothermal hazardous waste indicated that at 55°C, fast rates of heavy metal removal (greater than 80% in less than 25 hours) can be achieved. A new generation of bench-scale glass bioreactors was constructed and tested. These bioreactors will be used to generate data for designing and building a complete working prototype system, capable of operating under highly acidic conditions and high temperatures.

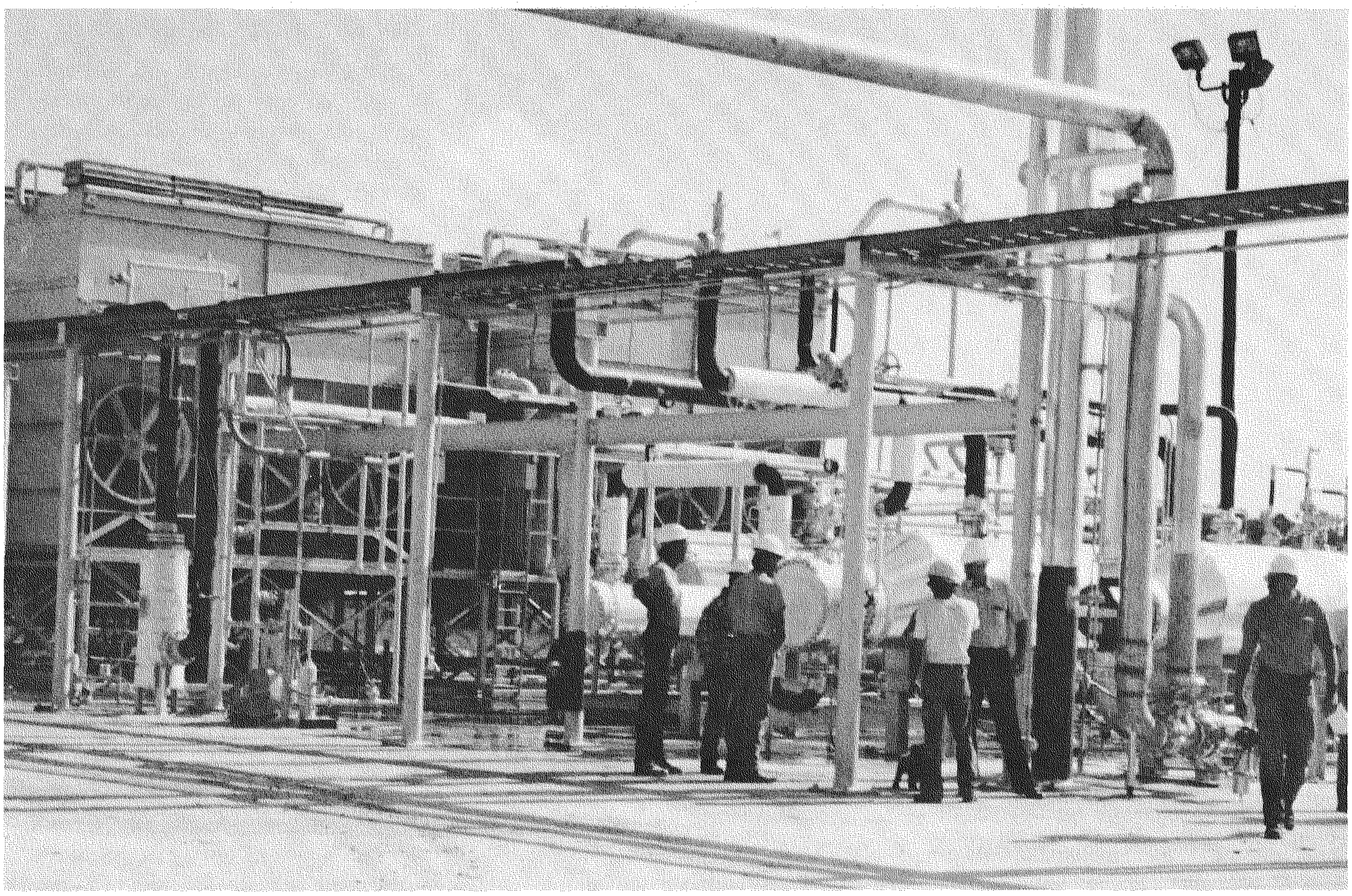
Geopressured Brine Research

Research with the goal of developing our nation's geopressured-geothermal energy sources is organized into three main tasks:

- Well operations
- Geoscience and engineering support
- Energy conversion.

Well Operations

The Well Operations Task consists of high-flow-rate well tests and pressure buildup tests designed to expand our knowledge of reservoir production performance, surface handling systems, well-injection procedures, brine chemistry and scale inhibition, and automation of production systems. The field tests are conducted at Pleasant Bayou and Gladys McCall design wells and at the Willis Hulin "well of opportunity." Design wells are those drilled specifically for scientific study;



The 1-megawatt Pleasant Bayou plant completed 8 months of power production in fiscal year 1991, proving the ability to generate power from a geopressured reservoir using a hybrid system.

wells of opportunity are unproductive oil or gas wells donated by industry.

During FY 1990/1991, flow tests at the Pleasant Bayou well in Brazoria County, near Houston, Tex., provided data for understanding and predicting the performance of the reservoir, surface facilities, and injection system. This well is about 14,700 feet deep, and the brine temperature is about 300°F. The well successfully supplied brine to the 1-MW_e hybrid power demonstration project (see "Energy Conversion" on page 12).

Long-term pressure buildup tests continued at the Gladys McCall well in Cameron Parish, La. This well extends into a geopressured aquifer 15,160–15,470 feet deep, and the brine temperature is 295°F. Testing and data acquisition at this well are nearing completion.

The Willis Hulin well, in Vermilion Parish, La., intersects a geopressured zone at a depth of about 20,000 feet. Due to the great depth, many of the physical parameters of the Hulin well differ from those of the design wells, offering researchers the opportunity to study reservoir drive mechanisms under a different set of downhole conditions. During FY 1990/1991, temporary production facilities were installed at the site, and a short-term flow test was conducted to clean out the well.

Geoscience and Engineering Support

Geoscience and engineering support is focused on analyzing geopressured well data (obtained from well operations testing) to understand the performance of geopressured reservoirs under long-term, high-volume production. The mechanisms driving the production of geopressured fluids are not well understood. Reservoir analysis and the continuing refinement of the DOE geopressured reservoir model are designed to gain a better understanding of these mechanisms and provide the means to predict long-term production based on short-term tests.

FY 1990/1991 accomplishments included (1) integration of new data into the

Construction of the Fenton Hill demonstration project was completed in fiscal year 1991 in preparation for a long-term flow test. This test will help demonstrate the feasibility of hot dry rock technology.

models of the Pleasant Bayou and Gladys McCall reservoirs, (2) development of a model for the Hulin reservoir, (3) completion of analyses of moduli strengths of Gladys McCall and Pleasant Bayou rock samples, and (4) completion of a state-of-the-art Elan log analysis on the Hulin well, resulting in an increase in the estimate of gas production from the well. Also, continued environmental monitoring at the test wells offered no indication of any significant environmental impacts related to any well activities.

Energy Conversion

Geopressured reservoirs offer three primary forms of energy—heat, pressure, and dissolved methane gas. These energy sources can be used together or separately in a variety of ways: the heat can be used directly or converted to electricity; the gas can be sold or converted to electricity; and in some system designs, the high pressure of the brine may be converted to electricity using a hydraulic turbine.

A hybrid cycle uses several of these technologies in the same system and can be more efficient than cycles generating electricity from the methane and brine separately. For example, the exhaust heat from the combustion of the methane can be added to that of the brine or working fluid and converted to electricity in a binary cycle, producing even more power.

During FY 1990/1991, a 1-MW_e hybrid power system of this design was successfully operated for 8 months, supplying 3445 megawatt-hours to Houston Power & Light Company's grid. The project was cosponsored by DOE and the Electric Power Research Institute. Data from the test were analyzed, and a final report was written and issued.

Hot Dry Rock Research

Hot dry rock research seeks to develop practical, economic technology for recovering thermal energy from naturally heated, impermeable rock at accessible depths. Research is conducted within two projects:

- Fenton Hill operations
- Scientific and engineering support.

Fenton Hill Operations

A small, experimental hot dry rock reservoir was created at Fenton Hill, N. Mex., and successfully tested in 1979–1980. The system was essentially trouble free, and some of the heat produced was used to operate a small binary-cycle generating unit. Subsequently, a larger, hotter reservoir was created. During a 30-day flow test, that reservoir produced fluid with a surface temperature of 380°F, well within the range necessary for power generation. Recently, work has focused on preparations for a long-term flow test scheduled to begin in FY 1992. Completing this test will be a significant milestone in hot dry rock research because it will provide information on reservoir impedance, thermal drawdown, energy output, and water consumption at the scale of a commercial hot dry rock modular plant.

In FY 1990/1991, work progressed on schedule to prepare the site for the critical long-term flow test. Design, procurement, and installation of the surface components were completed. A major upgrade of the 1-million-gallon storage pond at the site was completed, and water rights were maintained to ensure an adequate supply of water for the long-term test. Reservoir pressurization studies are continuing.

Scientific and Engineering Support

This project provides the support necessary to meet research objectives during the long-term flow test at Fenton Hill. It includes refining the reservoir model, directing downhole experiments, analyzing test data, and verifying reservoir performance. A major element of this project is providing downhole instruments and equipment by modifying existing downhole tools or developing new tools when necessary. The project also includes developing techniques for evaluating reservoir size and potential productivity. During FY 1990/1991, extensive modeling was employed to better understand fluid flow in the reservoir, and a dual-porosity model was developed to simulate flow through the rock matrix as well as the fractures. Also, an estimate of the pressure-affected volume of the reservoir was calculated.

Magma Research

DOE-sponsored research on extracting energy from magma is experimental in nature and is organized around two projects:

- Long Valley operations
- Laboratory and engineering support.

Long Valley Operations

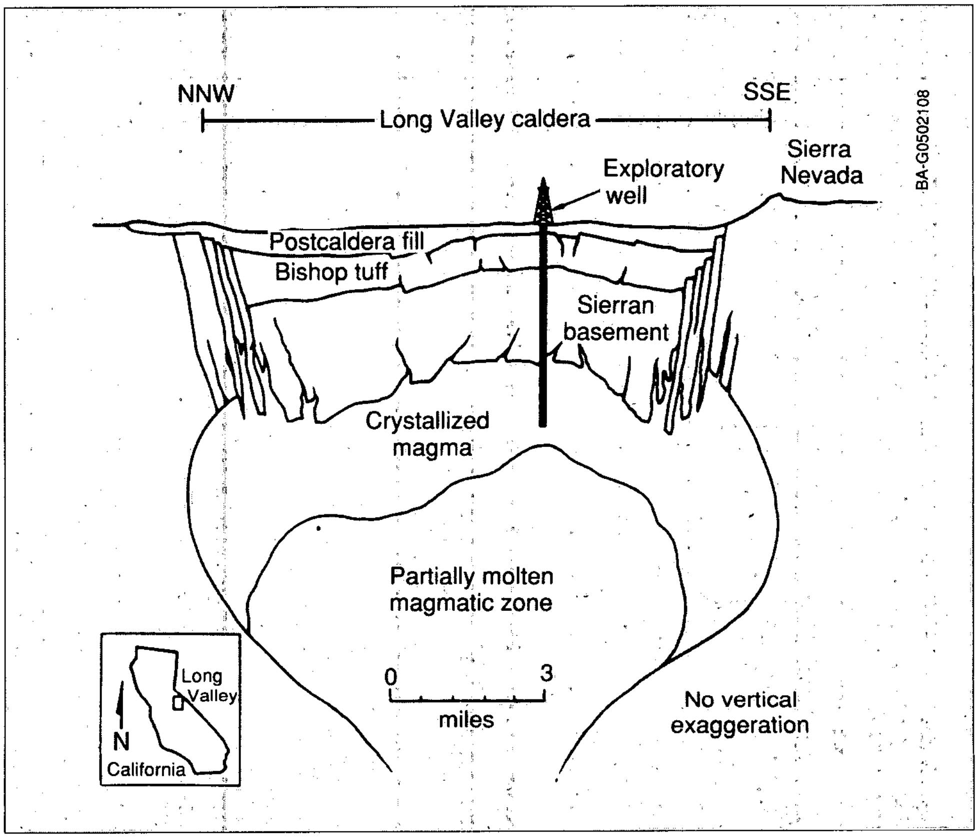
Magma (volcanic, molten rock) makes up a large portion of the total geothermal resource base. After 12 years of investigating the scientific feasibility of obtaining heat from magma, an exploratory well is being drilled as the first step in determining the economic and engineering feasibility of tapping this large resource. Located in Long Valley, Calif., an area of recent volcanic activity, the well is the first in the world to be sited directly over a suspected magma body.

Phase I drilling was completed to a depth of 2568 feet in 1989. A 4-inch core hole was then drilled an additional 187 feet by the Continental Scientific Drilling Program (CSDP), a consortium of the U.S. Geological Survey, the National Science Foundation, and DOE's Office of Basic Energy Sciences. In FY 1990/1991, Phase II drilling extended the well to a total depth of approximately 7000 feet. An additional 4-inch core will be taken in FY 1992 by the CSDP to provide new geoscientific data. Information from this work will contribute to understanding the Long Valley caldera and its associated hydrothermal system.

Laboratory and Engineering Support

This project conducts investigations of various drilling techniques, geochemistry, materials compatibility, and energy extraction processes. In FY 1990/1991, temperature logs of the core hole in the Long Valley well were obtained, and the core and cuttings were analyzed. Also, several evaluations of the chemical compatibility of commercial alloys for construction of a downhole heat exchanger were completed.

In FY 1991, the decision was made to defer further research on magma energy to focus on priority needs for hydrothermal energy. However, work will continue on the Long Valley well to learn more about the hydrothermal system at the site.♦



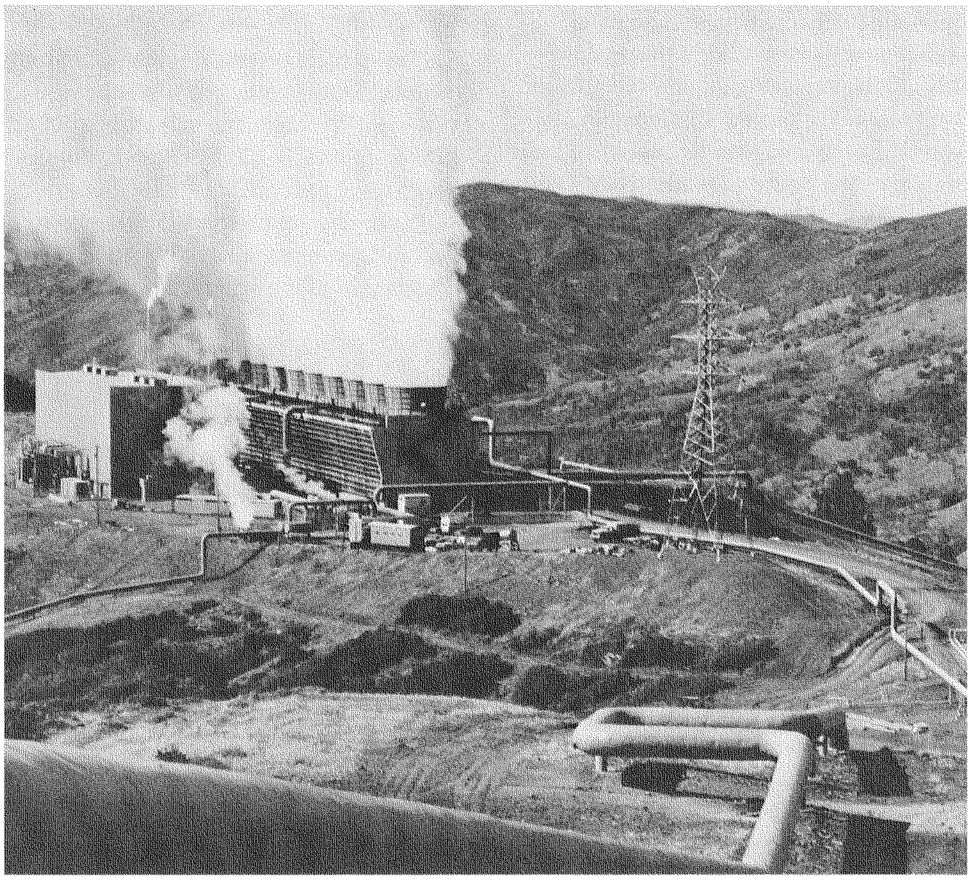
Subsurface view of the Long Valley caldera as depicted by geoscientific studies.

Program Management

DOE's Geothermal Division provides the central leadership to ensure that program activities are consistent with national energy policy and priorities.

The Geothermal Energy Program is managed by the director of the Geothermal Division at DOE Headquarters in Washington, D.C. The division provides the central leadership necessary to ensure Geothermal Energy Program activities are consistent with national energy policy and priorities. The management of technical activities is decentralized among DOE field offices and national laboratories to ensure that technical expertise is available to supervise the research.

To ensure the continuing exchange of technical progress and programmatic concerns, the Geothermal Division sponsors an annual program review during which the field offices, national laboratories, universities, and industry contractors discuss their activities. This review is open, and the public is encouraged to attend. In addition, the participants in each research category gather twice a year for a program review to discuss research progress in more detail. ◆



The world's largest producer of geothermal power is The Geysers, a dry-steam field in northern California.

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The Outcome

Geothermal energy is a large domestic energy source; geothermal power plants can be brought on line quickly in case of a national energy emergency.

Geothermal energy makes a significant contribution to the nation's energy mix, supplying heat and electricity from dry steam and high-quality hydrothermal liquids. These resources together supply about 6% of all electricity used in California, and the growth of the industry in many areas is constrained only by the lack of demand for new power capacity. However, the competitiveness of power generation with lower quality hydrothermal fluids, geopressured brines, hot dry rock, and magma still depends on the technical advancements sought by DOE's Geothermal Energy Program.

The successful outcome of research initiatives will benefit our nation in several ways. First, geothermal energy offers a large source of secure, domestic energy to add to our energy supply portfolio. Moreover, geothermal plants can be brought on line quickly in case of a national energy emergency.

Second, geothermal energy is a highly reliable resource, resulting in very high plant availability. For example, new dry-steam plants at The Geysers are operable more than 99% of the time. In other words, geothermal plants offer an attractive alternative to fossil-fired or nuclear power plants for baseload power: they can operate 24 hours a day and are unaffected by daily or seasonal variations.

Third, geothermal energy offers a source of electricity that is relatively benign environmentally. Today's hydrothermal power plants with modern emission controls have proven to have minimal environmental effects. In fact, carbon dioxide emissions, a major culprit in the global warming phenomenon, are only a fraction of those of fossil-fired power plants. And the results so far with geopressured and hot dry rock resources suggest that they, too, can be operated with minimal environmental impacts. Preliminary studies on magma-derived energy are also encouraging.

The progress made by DOE's Geothermal Energy Program, working in cooperation with the U.S. geothermal industry, gives confidence that the geothermal resource continues on track toward fulfilling its tremendous promise. The program focuses on the technologies that have the best chance of success and that can make the biggest difference in developing cost-competitive geothermal systems. Success during the 1990s will allow industry to expand today's applications and develop new ones to meet our nation's energy needs. ♦

This publication is one of a series of documents on programs in utility technologies sponsored by the U.S. Department of Energy. Individual overviews are available for each of the following programs:

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