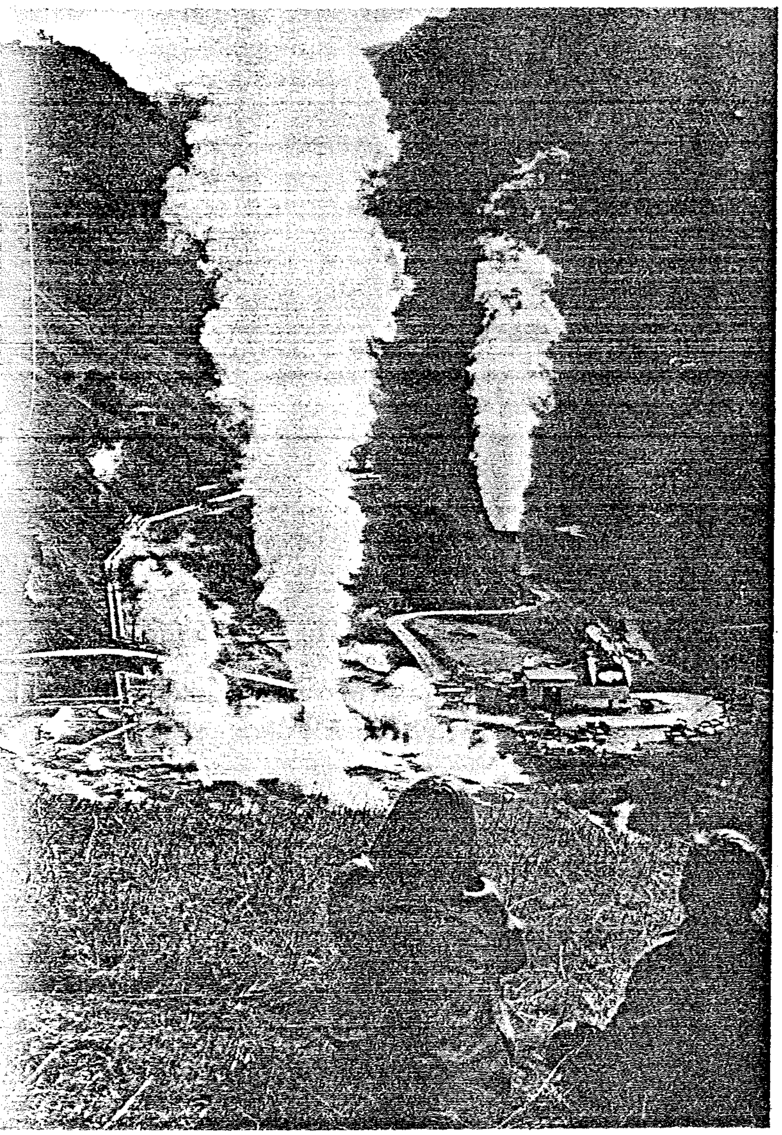
Geothermal resources: potential energy giant

Much exploration and technological development lie ahead, but underground steam, hot rocks, and other resources are abundant enough to play a major role in power generation by the end of the century.

By MICHAEL A. VERESPEJ

These two units launched California's Geysers operation in 1960 and 1963. Their combined capacity is 24 megawatts. Subsequent units have boosted capacity to 396 megawatts, with the total to hit 908 megawatts in 1977.



ENERGY FROM geothermal resources could save the U. S. in a given year anywhere from 560 million barrels to 5.6 billion barrels of oil by the year 2000.

Just what that energy savings will be depends a great deal on research work now going on in the industry and in government.

Estimates of geothermal power potential in the U. S. by 2000 have ranged from 40,000 megawatts daily to 400,000 megawatts daily. The wide range stems from the lack of past research to verify how much geothermal energy exists in the 13 western states and Alaska, how much of it can be harnessed, and how long fields will keep producing.

Generally, geothermal companies use a 30-year lifespan in selling power to utilities. But the first dry-steam field in the world—at Lardello, Italy—is still in operation today producing more power than it did in 1904.

Geothermal energy, officials admit, is limited in that powerplants must be built near where the energy is found. But they are quick to add that the energy generated can be transmitted to nearby cities, that industry has a history of moving to power sources, and that the fuel it replaces can be transported to another area of the country.

In the past, the argument against geothermal energy has been economic unfeasibility. But now, with the usual fuels no longer readily available and costs rising, that argument has faded.

The U. S. Dept. of Interior estimates that geothermal dry-steam costs are lower than any other fuel and that the cost of hot water (wet steam and hot brine) power generation—which represents 90% of all geothermal resources—is lower than oil costs and just slightly higher than coal and natural gas.

The only commercial production field in the U. S. today is the Geysers dry-steam field, about 80 miles north of San Francisco. Although it has enough capacity to provide two-thirds of the electric power needs of a city the size of San Francisco (and is expected to triple in size in three years), its 396-megawatt capacity still represents just one-tenth of 1% of U. S. generating capacity.

And, points out Dr. Alfred J. Eggers Jr., assistant director, research applications, National Science Foundation (NSF), such "superheated or dry

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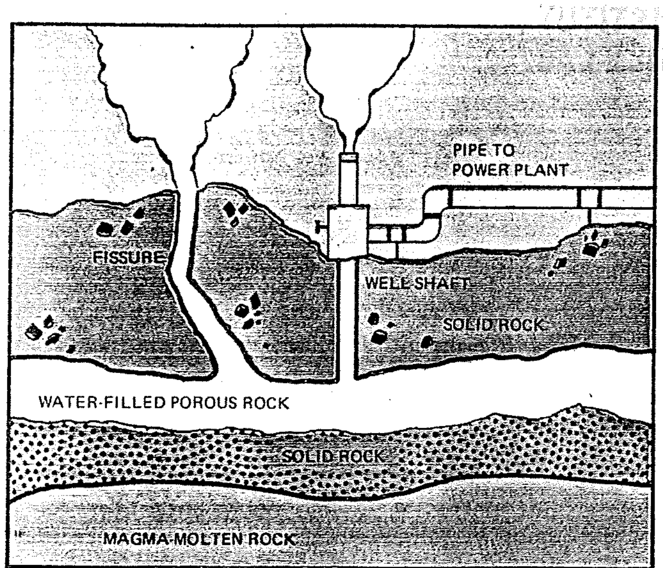

Geothermal is . . .

The energy in a geothermal reservoir, explains the U. S. Geological Survey, consists of heat that is stored largely in rocks and to a lesser extent in liquid water or steam filling pores and fractures. The water and steam provide the means by which heat from deep sources is transferred by convection to depths shallow enough to be tapped by drilling.

The fluid in most geothermal reservoirs is liquid water that is held at temperatures above surface boiling by the confining pressure. A decrease in pressure upon withdrawal of the liquid water causes steam to form by boiling, and a mixture of steam and water is produced at the surface more than 90% of the time. A few reservoirs contain primarily steam, and the wells produce dry or superheated steam with no water.

For a geothermal reservoir to have an appreciable potential for exploration, it must meet the following requirements: a relatively high temperature (at least 300 F), a depth shallow enough (10,000 ft or less) to permit drilling, sufficient rock permeability to allow the water or steam to flow continuously at a high rate, and sufficient water recharge to maintain production over many years.

For the geopressured zones and hot, dry-rock geothermal resources, drilling techniques must be perfected for depths of 15,000 ft to 20,000 ft.

There are four types of geothermal resources in this country:

- **Dry steam,** which contains little or no liquid water and comes out at 350 F.
- **Hot water,** at temperatures ranging from 300 F to more than 600 F. This is divided into wet steam and hot brine fields. Wet steam fields have low salinities and temperatures of more than 500 F, which permits flashing to steam. Hot brine fields (300 to 500 F) require cleaning up the brine and a heat exchange method.
- **Geopressured zones,** which occur where mud, silt, and organic material have sunk to great depths and have been trapped within permeable sands below a sealed, insulating layer of rock. Water trapped in the sands is extremely hot and is under tremendous pressure. The water contains vast quantities of natural gas.
- **Hot, dry rock** formations which exist in large volumes relatively near the surface of the earth. These require drilling and fracturing of formations and injection of water to get the steam to the surface.

steam has few technological problems as it is introduced directly from the ground into turbines of a design similar to other types of generators.

"To obtain more power from geothermal resources," says Dr. Eggers, "we need to work with the more abundant resources that are not as easy to utilize."

These include hot water areas, geopressured zones, and hot dry rock, all of which have problems that must be overcome and technologies that must be developed before they can be utilized most efficiently to their fullest extent.

Using wet steam from hot water fields, for example, requires flashing and better steam separating units. With hot brine, points out Dr. Eggers, there is a need for better separators and scrubbers, plus additional components such as downhole pumps, impulse or bladeless turbines, or closed binary fluid systems.

Devices for including porosity and permeability in rock formations will be needed for hot dry rock power generation, he says, along with systems for fluid circulation to transport the energy to the surface.

Money flow is increasing

But research and money can solve the problems, and both are increasing.

Federal government spending for geothermal energy rose from $11 million in fiscal 1974 to $47 million this fiscal year. And a bill introduced by Rep. Mike McCormack (D, Wash.) would create a single agency to direct geothermal research projects and to provide the NSF with $60 million annually and individual companies with up to $150 million in guaranteed loans over the next ten years.

The bill's goal: develop six to ten demonstration plants by the end of the decade producing electricity from the various types of geothermal energy.

The Interior Dept. is developing a better data base and better sensing and drilling devices.

The NSF hopes to increase the efficiency of geothermal powerplants by developing individual process components such as heat exchangers which can withstand the corrosive nature of geothermal brines while operating at maximum efficiency for extended periods of time.

Such hardware, believes Dr. Eggers, would allow "large-scale hot brine plants to be designed and constructed in this decade."

The Atomic Energy Commission (AEC) has test projects to develop powerplants representative of each type of hot water field by 1979. These are combinations of high and low temperatures and high and low salinities.

"The technology is available for the technique where the fluid is allowed to flash to steam and the residual brine is discarded," says Dr. Louis Werner, chief, geothermal branch, Applied Technology Div., AEC.

But, he says, temperatures of more than 500C are required, and a very small number of hot water projects appear to be that high in temperature. In addition, he points out that "if it could be perfected, the method where [the fluid] is not flashed would be more efficient."

He says the AEC is working on a project in California's Imperial Valley (where most of the highly concentrated brines occur) that would use "a total flow concept capable of extracting a larger percentage of energy out of the geothermal brine than you could if you flashed to steam."

What they hope to do, he says, "is pass the brine and steam mixture through a converging-diverging nozzle and use an impulse turbine."

But the larger part of the research is being done by private industry, which is concentrating more on the use of heat exchangers to mix the brine with a low boiling point fluid, the steam vapors from which would be used to run the turbine.

"Heat exchange technology is effective in the range of 500C, down to just about 300C [low temperature brine prospects]," says Dave Butler, manager, geothermal exploration program, Chevron Oil Co.'s Mineral & Oil staff. "And that is where the bulk of the potential resources lie."

Water is pumped out of the well while under pressure, Mr. Butler explains, and into a heat exchanger with tubes containing low boiling point fluids such as isobutane or freon. The vapor drives the turbine, the working fluid returns to the tubes, and the cooler water that comes out of the heat exchanger is then reinjected into the ground in a closed double loop system.

The system's problem: deposition of solids. Because of that, only a small-scale plant in Kandalaksha, Russia, is in operation today.

Possible solutions include treating the hot brine with chemical inhibitors or setting up parallel circuits and using one while you clean up the other.

Chevron's current project is at Heber, south of the Salton Sea in California's Imperial Valley, where the brines are just above the level of sea water salinity. It is a joint project with Magma Power Co. and San Diego Gas & Electric Co.'s subsidiary, New Albion Resources Corp. (NARCO).

"No one yet has enough operating experience to decide exactly what these problems are, and what to do about it," Mr. Butler says.

"Unless the problems are more severe than we think," says Mr. Butler. "It is just a matter of someone taking their guts in their hands to see what the problems are so we can design around them. And once the technology is proved and available, it will open up many areas where the waters aren't anywhere near as saline as even the good [low salinity] parts of the Imperial Valley."

Equally as optimistic is Martin R. Engler Jr., senior vice president, San Diego Gas & Electric. Mr. Engler says original tests by its NARCO subsidiary showed heat exchangers had a useful life of just 80 to 110 hours before cleaning (at $5,000 per cleaning) was needed.

But now, after trying various combinations of steam separators and scrubbers before passing the fluids to heat exchangers and turbines, "performance is significantly improved and the steam is relatively clean," he says.

What must be done now, says Mr. Engler, is fur-

Where are the resources?

Geothermal areas exist throughout the world, primarily along the belts of young volcanos that ring the Pacific Ocean and that follow midoceanic ridges.

And while there are several belts of this energy across the world, there exist today only four major commercial power production fields.

The largest is the Geysers field north of San Francisco. The joint project of Union Oil Co. of California, Thermal Power Co., and Magma Power Co. currently produces 396 megawatts of power for use by Pacific Gas & Electric Co. Its projected output by the end of 1976 is 608 megawatts, with 300 more megawatts scheduled to come on line in 1977 at the dry steam field.

The next largest field, also of the dry steam nature, is at Lardello, Italy. It produces slightly more than 350 megawatts of power.

Two wet steam fields are also in existence: a 192 megawatt field in Wairakei, New Zealand, and a 75 megawatt plant south of Mexicali at Cierro Pietro, Mexico.

The USSR, Japan, El Salvador, and Iceland all have small plants of less than 50 megawatts. Drilling and exploratory work are going on around the world, primarily under the direction of the United Nations.

ther work to "get the steam to its cleanest point, put it through heat exchangers, see what their life performance will be," and then decide whether that is "adequate enough to go forward.

"Research is one failure after another," says Mr. Engler. "But once you break through the learning curve, others can benefit from your experience. I think that we will indeed be able to whip some of these problems and that, within the next five years, the technology can be developed.

Nontechnological barriers

In addition to conquering technological barriers, geothermal companies must also overcome several legal, regulatory, and tax obstructions.

Before byproducts of geothermal resources can be used, a change will be necessary in various state laws which prohibit power companies from dealing in areas such as "water desalination, mineral extraction, and providing hot water for air conditioning, home and industrial heating, and agricultural refrigeration," says Dr. Joseph Barnea, former United Nations geothermal specialist.

And, he points out, there is the reverse problem that the "sale of electricity is restricted to power companies." The only way out, he says, "appears to be to grant to multipurpose geothermal companies the right to produce and market all of their products, including electricity.

L. Kirk Hall of the House Science & Astronautics Committee points out that an ownership question may crop up in relation to geopressured zones, because "many were found in conjunction with oil and gas drilling, and underlie lands that somebody has the oil and gas rights to.

"So, if all of a sudden, it becomes feasible to use this high-temperature, high-pressure water, who owns it? Is it the guy that has the original rights, or the explorer who develops it and is ready to deliver the energy right now?"

Another problem that might slow geothermal development, even if technology is perfected, are federal leasing laws, which require that half the bid be deposited in cash when applying for a known resource land.

"That is fine for large companies," says Donald F. X. Finn, managing director, Geothermal Energy Institute, "but if you only have $4.5 million, you want to use it to drill. Such procedures will not develop the resource and it will not give the country the energy it needs."

Malcolm H. Mossman, geophysicist, Anschutz Corp., Denver, adds that the combination of those leasing procedures and tax laws (which prohibit deduction of geothermal exploration expenses except at the Geysers) is serving only "to delay the development of new areas and postpone the time when electricity, working interest, income, royalties, and taxes are generated."

And many geothermal experts, including Dr. Joseph Barnea, former United Nations geothermal specialist, believe development of such wet steam fields is the key to obtaining energy from geothermal areas.

"The total heat flow of a hot water field is much higher than that of a dry steam well," says Dr. Barnea. After the power generation, he says, nearly "80% of the hot brine, by weight, remains, and can be used for such applications as home and industrial heating, water desalination, agricultural refrigeration, and mineral and gas extraction."

Although little work has been done in that area, "no one has abandoned it, either," says Mr. Butler.

"Power is in demand at the moment," he points out. "And we have to get it off the ground first. The other will come as a shakeout of that program. There is a tremendous amount of leftover heat and products that will be usable."

And after technologies for wet steam and hot brine fields are perfected, research can move into the areas of hot dry rock and geopressured zones.

One geopressured zone, along the Gulf Coast waters of Texas and Louisiana, for example, contains trapped in its hot waters 2,700 trillion cu ft of natural gas, estimated the resource appraisal panel of the NSF Conference on Geothermal Energy two years ago. The panel said the natural gas there could be recovered over a period of 20 to 30 years and fill U. S. needs for half a century.

But to utilize that dissolved gas, geothermal wells must be dug to a depth of 15,000 ft as opposed to today's depths of 5,000 to 8,000 ft, says Robert W. Rex, president, Republic Geothermal Inc., Whittier, Calif.

Development has also been restricted, he says, by a lack of knowledge of the amount of subsidence that would occur, plus the inability to use —at this time—the thermal energy from the waters because it involves the still undeveloped technology of underwater transmission of electricity.

To obtain energy from hot dry rock, energy extraction methods, deep drilling technology, and water injection systems must be developed, claims Dr. Morton L. Smith, project manager, geothermal energy, for an AEC experiment at the University of California's Los Alamos Scientific Laboratory in New Mexico.

Dr. Smith sees hot dry rock use at least five years away. One method being tested now for use in granite with low permeability to water, he says, involves drilling two holes, connecting them by means of a large crack (made by hydraulic fracturing) and then pumping in pressurized water to extract the heat from underground up toward a heat exchanger.

The initial development of hot dry rock, Dr. Smith is certain, will be in the western U. S. because the rock temperatures at depth "are high and the hot rock is usually granite."

Dr. Smith says that if just 40 cubic miles of granite could be cooled from 500F to 140F, enough energy could be extracted as was used for all purposes in the U. S. in 1970 (the approximate energy content of all the oil in Alaska's North Slope).

And Dr. Smith estimates that 250,000 square miles of land in the western third of the U. S. is underlain by rocks at least as hot at 500F at depths less than 20,000 ft.

More than technology

But conquering the technology does not mean that geothermal energy can be immediately put to use.

Leadtimes for geothermal powerplant construction often run as long as five years.

"We have to drill a well, find a temperature and flow rate, then drill maybe five more wells to determine if we have a potential commercial field and to find out how big it is," says Mr. Butler.

The peculiarities of the brine must then be unraveled and a system developed to minimize the corrosion and deposition problems. Because about 15 wells are needed (at a cost of $300,000 each) just to produce 100 megawatts of power, Mr. Butler says that often you are talking of "a range of five to seven years from the first time you drill a well until you can be producing."

And that first production, he adds, often is just a 50 megawatt test facility, and rapid and multiplying growth from a geothermal resource area seldom occurs until after a field reaches the 200 megawatt stage.

Another drawback is that 60% of potential geothermal resources are on federal lands, and they were not opened up for leasing until this year. But the response was overwhelming: 57 applications for 50,000 acres of known geothermal lands, and 2,456 applications for 5.3 million acres of potential geothermal land. And there are still nearly 50 million acres of federal lands which could be leased later.

But the importance of developing the technology for using geothermal resources cannot be underestimated, says L. Kirk Hall, technical specialist, House Science & Astronautics Committee.

"If we don't go out now and get the technology ready, 15 years from now when we run out of oil or someone decides to charge high prices for it again, we would be in the same situation that we are in today: having a five-to-15 year lag time for its development."

It is imperative in the next five years that "we have to work up to some level where we have narrowed the transition time to use geothermal energy to two to three years," he believes.

"Then," says Mr. Hall, "we can use geothermal energy when it is economic or becomes necessary. We will have the research done in advance."

Dr. Carel Otte, vice president and manager, Union Oil Co. of California's Geothermal Div. (which operates the Geysers field), adds that "with improvements in utilization techniques and the removal of certain institutional barriers [legal, regulatory, federal, and local], geothermal energy could become a major element of central station power generation, and, in the process, make up for delays in the growth of other sources of supply, reduce the need for additional importation of petroleum products and release petroleum and natural gas for more appropriate uses.

"The nation's geothermal energy resource is potentially vast," adds Dr. Otte, "particularly that portion that may be tapped by deeper drilling technology. The successful development of stimulation techniques permitting the development of the deep, hot dry rock masses would enormously expand the geothermal energy reserves."

Although Dr. Otte believes that the major thrust of geothermal energy will be directed toward power generation (and that byproduct use of minerals, gases, and heating will be limited), he sees the geothermal future as bright and "possibly exceeding" even the most optimistic forecasts.

R. W. Maxwell, manager, geothermal exploration, Gulf Mineral Resources Co., Denver, comments:

"Geothermal power will have a minimal influence by 1980 because the known sources which can be developed by that time are limited in number and size. But with geothermal energy, we know we are on the threshold of something—which though limited in scope—will come to play an increasingly important role in these energy-short times." □