THE "SLEEPER" IN THE ENERGY RACE

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There may be a bright future ahead for geothermal power. It is relatively cheap, there are no safety problems, relatively few environmental headaches, and little new technology to develop or prove. The installation at The Geysers in northern California shows what can be done to harness this potential source of useful energy.

Approximately 90 mi (140 km) north of San Francisco—nestled in the rugged terrain of the Mayacmas Mountains—is the site of the world's largest commercial geothermal power complex. In a remarkably short time span—slightly more than 20 yr—the production of electricity at The Geysers has grown from 0 to 522 MW installed capacity; with units projected that will bring the total rating close to 1000 MW by the 1980s. Considering that this was accomplished entirely by private enterprise—without any government funding or support—and in the face of the militant environmentalist movement in California—it is quite an achievement!

Geothermal power derives from the elementary fact that there is considerable heat stored beneath the surface of the earth. If one accepts the premise that the planet Earth was formed as the result of a tremendous explosion/implosion in the solar system, that it was literally a ball of fire at the time of conception, and that it has been gradually cooling down ever since, then it follows that there is a temperature gradient between the outer layer of the earth and its core. Irrespective of theory, however, such observable phenomena as volcanos, geysers, fumaroles, hot springs, etc., prove beyond question that there is a substantial heat source encapsulated within our planet. But the exact nature of the energy—its quantity and quality, where it is located, and how it can be successfully tapped—these are areas of geological investigation that are still in their infancy.

In certain respects we are no better off than the peoples of antiquity. For example, we watch with the same awe and fear as the ancient Romans did the periodic volcanic eruptions of Vesuvius, and we cannot control or even accurately predict the upheavals of this millenium-old crater. And in the realm of superstition, the mythology of Hades has managed to survive the scientific method and lives on in religious folklore as the "fires of hell." It is little wonder, therefore, that when William Bell Elliott, hunting grizzly bears in the Mayacmas hills in the spring of 1847, stumbled on The Geysers and heard the loud noise of steam escaping through narrow fissures, smelled the sulfurous fumes, and saw clouds of water vapor shooting high in the air, his first thought was that he had discovered the "gates to the Inferno"!

Today there is a credible explanation for The Geysers. Volcanic activity within the last 3 million yr has brought magma or molten rock within 5 to 10 mi (8–16 km) from the earth's surface. Water contained in the fractures and formations of the near surface rocks is heated by the cooling magma. Sufficient pressure is generated by the

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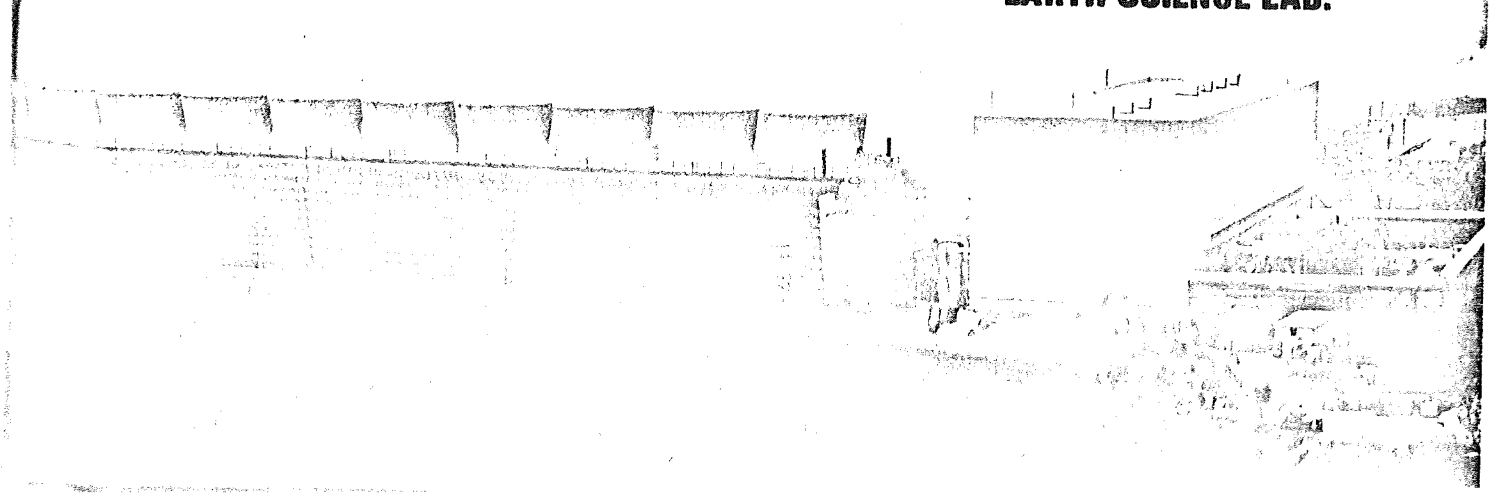
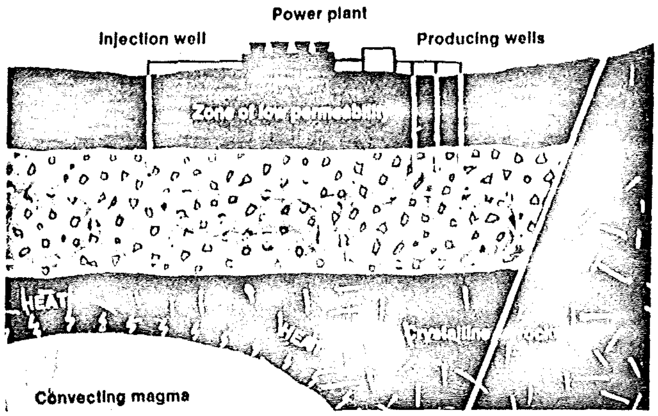
Units 5 and 6, the world's largest geothermal turbine generators, are in operation at Pacific Gas and Electric Co.'s The Geysers Geothermal Power Plant in Sonoma County, Calif. PG&E has installed capacity of 502,000 kW in the 11 units at The Geysers.





Earth tremors more than 60 million yr ago caused fissures to open in the crust and brought magma — a molten mass — 5 to 10 mi (8–16 km) from the earth's surface. Water contained within fractures in the near surface rocks is heated by the cooling magma. When such a reservoir is tapped by drilling, pressure is released. This permits hot water or steam to flow to the surface, which then may be used to generate electricity.

trapped water vapor to cause jets of steam to break through the thin layer of crust and escape in small quantities to the atmosphere. These were the manifestations that caught the attention and fired the imagination of Elliott back in 1847. Of course, when such a reservoir is tapped by drilling, much greater quantities of steam will flow, forced out by the subterranean pressures. Geologists are now attempting to ascertain whether underground waters replace that which is being drawn off as steam. This is one of the more crucial questions, and the answer will obviously help to determine the long-term value of geothermal power.

During the century following Elliott's discovery the therapeutic virtues of The Geysers, rather than its potential as a source of energy, were being touted:

THE GEYSERS is properly called "The Eighth Wonder of the World," "Nature's Gift to California," "The Carlsbad of America," and "The Tourists' Paradise." Here our Creator has provided every thing needed to cure the ills of humanity. Here are the most heavily laden RADIO-ACTIVE Mineral Waters in the World ..... The Hot Magnesia water cures stomach and intestinal disorders, the Liver Spring cures all liver disorders, the Kidney Spring for all kidney troubles, Sulphur and Iron Springs to build up your health in general.

And among the visitors who patronized "The Eighth Wonder of the World," as noted in an old hotel register, were the likes of: ... General Grant, William McKinley, Theodore Roosevelt, Mark Twain, Horace Greeley, Garibaldi, J. Pierpont Morgan, the King of England ...

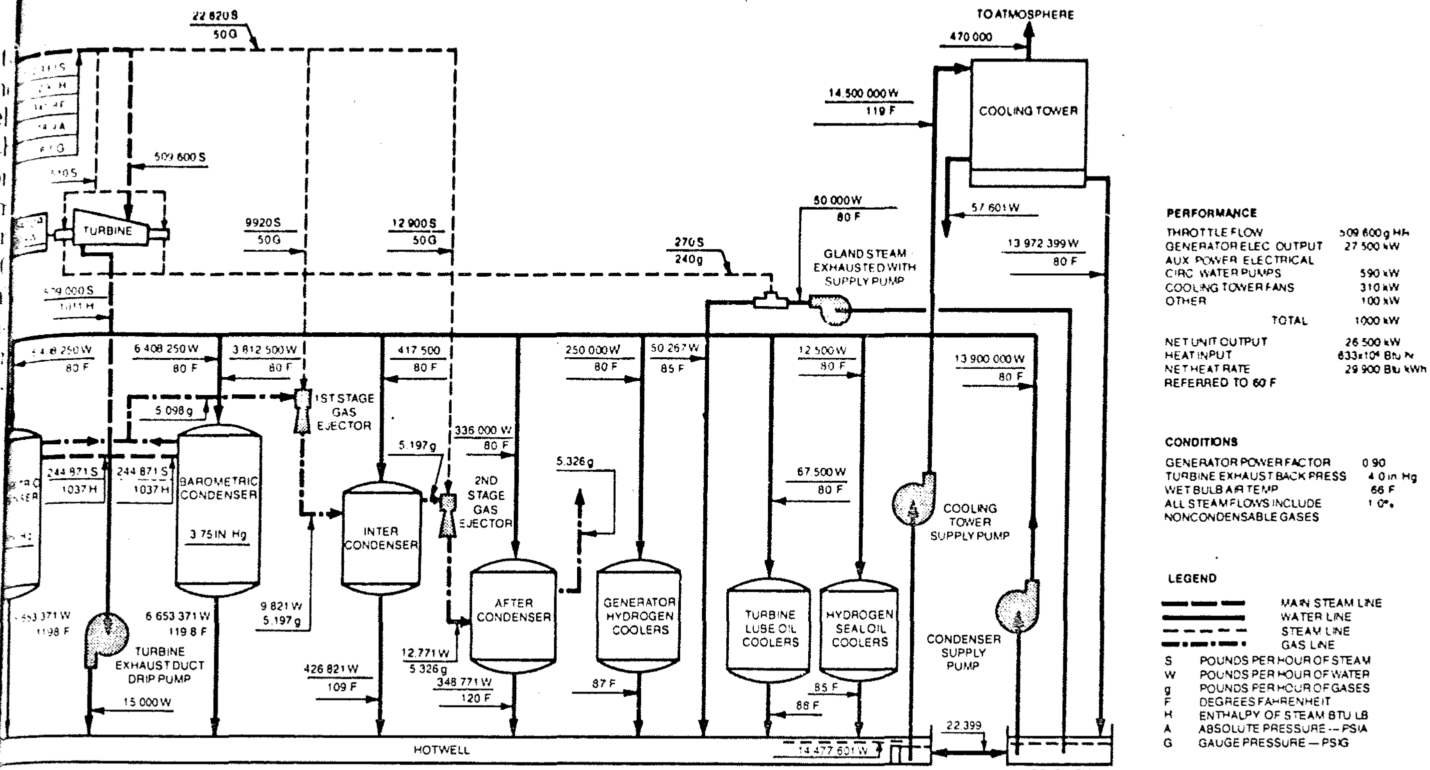
In the meantime, while the "beautiful people" frolicked in California, a pioneer venture in geothermal power was being pursued on the other side of the globe. Appropriately enough in Italy—where the Roman aristocracy also used to luxuriate in their hot thermal baths—it was decided to develop these thermal sites for the practical purpose of generating electricity. The first geothermal power station in the world went on-stream at Larderello (between Rome and Pisa on the western side of the Apennine Range) in 1904. By the late 1930s, capacity had increased to 100 MW; and the present installed capacity of all Italian geothermal power plants is over 400 MW. Dry steam flows from 181 wells in the Larderello region with an average production per well of about 50,000 lb/hr (23 t) at 302°F (150° C) with shut-in pressure of 73 psi (5 atm) and power station pressure of 62 psi (4.2 atm). The upper limits of steam production of the Larderello fields have probably been reached (they've been worked continuously for over 7 yr) but there are at least nine more promising thermal areas lying along a 500-km (300-mi) zone in the Apennines in central Italy. These prospects are now either being extensively explored or in various stages of development.

Exploration, Imagination, Exploitation

When the tourist phase at The Geysers had run its course (apparently the health cures did not live up to their advance billing) a group of enterpreneurs moved in in the early 1920s and drilled eight shallow wells, ranging in depth from 154 ft (47 m) to 636 ft (194 m). Rigs using the cable tool concept (then called churn drills) were employed to bore the holes. The exploration program did prove that large quantities of dry steam were available and that it was feasible to harness this energy to produce electricity. A small 250-kW generator was actually installed, and driven by a noncondensing reciprocating engine, it furnished electric power for a local resort hotel. However, because of the plentiful supply of cheap electricity from conventional hydroelectric and fossil-fuel plants, there was no economic incentive to invest further capital in the development of geothermal power at The Geysers, even though the Italians had already amply demonstrated that geothermal energy could be a commercially competitive factor.

Again The Geysers lay dormant. The resort lapsed into a state of decay. Only an occasional hiker or weekend motorist visited this out-of-the-way spot. Fortunately, it fell to an imaginative and competent lumber merchant from Los Angeles, Mr. B. C. McCabe, to revive interest in The Geysers as a geothermal project. Although "Mac" McCabe has no formal engineering training and no past association with the power business, he was stimulated by the geothermal challenge and he set out to prove that it offered a profitable opportunity for the utilities and a sound investment for himself. Risking his own money, McCabe leased from The Geysers Development Company—a private firm holding title to much of the property—approximately 3620 acres (1460 hectares) of land along Sulphur Creek, a stream that serves as a runoff channel for the area. The initial well drilled by McCabe's operating entity, Magma Power Co., was called Magma No. 1 and was completed in 1955 to a depth of 817 ft (249 m.). The flow rate of dry stream was roughly 150,000 lb/hr (68 t) at a wellhead pressure of 100 psig (7 kg/cm^2).

An old associate of McCabe's, Dan A. McMillan, Jr., was tempted to join the action. He, too, formed his own vehicle—Thermal Power Co.—and Magma and Thermal then agreed to share equally in the leasing and drilling expenses as well as in the anticipated profits of the combined undertaking. By 1957, six wells had been drilled at The Geysers, with depths running from 527 ft (161 m) to 1414 ft (431 m). By December of that year



Plant Flow Diagram. Unit 3.

flow tests had been made on four of the completed wells.

Enter P.G.&E.

At about this time McCabe and McMillan began looking around for a customer to purchase their steam. Representatives of one of the largest utilities on the West Coast, Pacific Gas and Electric Co., were invited to visit the site and to review the results to date. P.G.&E. conducted its own independent studies and tests and became convinced that there was at least enough steam available at The Geysers to justify a substantial capital investment that could be safely amortized within a period of 30 yr. A contract was signed on October 30, 1958 whereby P.G.&E. committed itself to install a 12,500-kW turbine-generator operating on the condensing cycle; and Magma and Thermal obligated themselves to supply steam at the turbine steam strainer inlet at the rate of 235,000 lb/hr (107 t) and at a pressure of 100 psig (7 kg/cm^2). The contract also provided that additional units could be added as: (1) steam became available; (2) there was need for the power generated; and (3) it could be economically produced in comparison with other sources of power.

The first 12,500-kW unit went on-line in April of 1960. This turbine-generator had been functioning for 42 yr for P.G.&E. in a standard fossil-fuel steam generating plant using steam at an inlet pressure of 250 psig (17 kg/cm^2). The turbine was already on the way to the scrap heap when it was decided to salvage it for duty at The Geysers. The blading of the rotor and stator sections was rebuilt for the use of steam at an inlet pressure of 100 psig (7 kg/cm^2). Now the "old war-horse" still performs faithfully, operating at 85 psig (6 kg/cm^2) with a back pressure of 4 Hg absolute, and exhausting to a barometric condenser with cooling water supplied by a mechanical induced draft cooling tower.

Starting with 1960, the following units have been installed at The Geysers:

Unit No.	Start-up	Cap. MW	RPM	Inlet psig.	Exh. Press. Hg abs., in.	Gen. Cool.
1	1960	12	1800	85	4	air
2	1963	14	3600	65	4	air
3	1965	28	3600	65	4	hydrogen
4	1968	28	3600	65	4	air
5	1971	55	3600	100	4	hydrogen
6	1971	55	3600	100	4	hydrogen
7	1972	55	3600	100	4	hydrogen
8	1972	55	3600	100	4	hydrogen
9	1973	55	3600	100	4	hydrogen
10	1973	55	3600	100	4	hydrogen
11	1975	110	3600	100	4	hydrogen
		522 Total Capacity				

The stated capacities are total generator capabilities. The plant auxiliaries consume approximately 4 percent of the generator output, with the remaining 96 percent being delivered into the transmission grid for P.G.&E. customer use. Units 12 through 15 are in the planning stages. Unit 12 will be operating in 1978 with two 55-MW turbine-generators producing a total output of 110 MW. Unit 13 will add another 135 MW; Unit 14, 110 MW; and Unit 15, 60 MW. Therefore, if these projections fully materialize, there will be 937 MW worth of geothermal power flowing from The Geysers within the coming decade.

The principal advantage of the geothermal steam cycle is the elimination of the boilers. With the low quantity of noncondensable gases in the steam at The Geysers, it is economical to condense the steam. About 30 percent of the cost of the plant is in the condensing system and about double the power can be obtained by using a condensing turbine instead of one with atmospheric exhaust.

The plant cycle for Unit 3 is shown in the accompanying diagram. The cycle for Unit 4 is the same except the steam flow to the turbine is 1.2 percent greater because the generator is air-cooled instead of hydrogen-cooled. Also, the cooling water for the generator is to air-coolers instead of hydrogen-coolers. The flows in the plant cycle for Units 1 and 2 are about half those of Unit 3.

The noncondensable gases in the steam require a large-size gas ejector on the condenser compared to the normal air ejector called for with a conventional unit. There is a two-stage steam jet gas ejector utilizing about 4 percent of the total steam flow. The gases were ejected to the atmosphere high above the barometric condenser so that the hydrogen sulfide in the noncondensable gases would be diluted to reduce ground-level concentrations to an acceptable figure. The off-gas is now discharged into the cooling tower structure to mix with chemical solutions for abatement of hydrogen sulfide.

The geothermal steam has entrained in it subsurface rock particles and dust plus noncondensable gases totaling about 0.20–0.50 percent by weight of total mass flow. The table below is a typical example of the steam conditions relative to noncondensable gases, etc.:

Composition, Percentage by Weight of Total Flow

	H_2	CO_2	N_2	CH_4	H_2S	NH_3	Total
Steam	0.005	0.280	0.004	0.020	0.016	—	0.325
Condensate	—	0.090	—	—	0.014	0.025	0.129
Total	0.005	0.370	0.004	0.020	0.030	0.025	0.454

During initial stages of well flows, the noncondensables may represent as much as 1 percent of total mass flow, but will subside to some 0.5 percent or as low as 0.20 percent in just a few months' time.

Environmental Problems

The hydrogen sulfide is probably the main culprit that has exercised the environmentalists—and perhaps with good cause. H_2S has a strong pungent odor—not unlike rotten eggs. Although it is not known to be harmful at the present concentration levels to humans, animals, or vegetation, its obnoxious smell makes its presence highly undesirable. As of last year, The Geysers were pumping close to 25 tons of H_2S daily into the air; and, while the region is sparsely settled, nevertheless there are small communities scattered throughout the area. It seems that when the wind blows from the right direction, some of the neighboring townsfolk get a whiff of hydrogen sulfide gas. The locals have quickly learned that even the slightest complaint of pollution brings the full and immediate wrath of the environmentalists down upon the heads of the offenders. Lawsuits, injunctions, court hearings, and regulatory agencies are all mobilized and there is literally no place left to hide! The best defense generally is prompt compliance. By installing pollution control equipment at The Geysers and by carefully sealing off leakages, the H_2S output to the atmosphere has been brought down to about 20 tpd. Further measures should make it possible to reach a goal of 5 tons—an amount that everyone apparently agrees that they can live with.

The other environmental problems could be coped with more expediently. Take the complaint of Mrs. Faye Dewey, for instance—an elderly lady who is the proprietress of the sole tavern/general store in the vicinity of The Geysers. Mrs. Dewey resented the roaring noise created when the wells are allowed to blow freely to the atmosphere. This noise is often deafening—somewhat like living next to Niagara Falls—especially when the sound echoes off the steep walls of the canyon. Every effort was made to ease Mrs. Dewey's discomfort. Wells were capped when not in use and the operators were instructed to hold down the decibels as much as possible. The good-neighbor policy has helped to keep this problem within bounds.

Dumping wastewater containing ammonia into Sulphur Creek also became a "no-no" when it was learned that even slight amounts of this toxic substance killed off the fish population.

An ongoing program was instituted in 1973 to landscape those sites that were deformed or scarred by drilling and construction activities. Replanting trees and shrubbery, terracing, and the removal of unnecessary structures and eyesores has gone a long way to restore or maintain some of the area's natural beauty.

The corrosive effects of the noncondensable gases have called for certain precautions to be observed in the selection of materials used at The Geysers. Again, the chief villain is H_2S, which has a voracious appetite and affinity for anything containing copper. Aluminum, stainless steel, epoxy-coated asbestos cement, and cast iron have served as substitutes for copper in condensate lines, underground piping, gas and oil cooler tubes, and cooling tower hardware. Exposed copper in the plant is either tinned or protected by coatings to prevent damage by the hydrogen sulfide in the atmosphere. To avoid using copper commutators required by rotating exciters, static excitation systems are employed. Meters and relays pose special problems. Meters with platinum taut-band suspensions have successfully replaced meters using conventional copper-alloy springs. Relays with special proprietary corrosion resistant provisions have proven equally satisfactory.

Geothermal Steam Characteristics

The differences between a geothermal power plant compared with a fossil-fueled thermal installation—apart from the fact that there is no boiler—lie in the characteristics of the geothermal steam. These characteristics can be divided into physical and chemical components. The chemical properties have already been mentioned. The principal physical feature is the huge volume of geothermal steam that must be processed to produce 1 kWh of electricity. This means, for one thing, large steam lines and larger quantities of cooling water that have to be handled for each generated kilowatt-hour. An idea of the comparative statistics is illustrated in the table tabulating side-by-side data from Units 3 and 4 at The Geysers with the equivalent information from a conventional P.G.&E. power plant (Units 6 and 7 at the Moss Landing Power Plant):

Power Plant Comparisons

	Geysers 3 or 4	Moss Landing 6 or 7
Unit Size, MW	28	750
Inlet Stm. Press., psig	65	3675
Inlet Stm. Temp., °F	342	1000
Lb Stm./kWh	18.54	6.68
Ratio of Stm. by Wt.	2.78	1
Inlet Stm. Vol., cu ft/lb	5.8	0.193
Ratio of Stm. by Vol.	30	1
Ratio cu ft of Stm./kWh	83.4	1
Cooling Water, gpm/kW	1.03	0.41
Net Heat Rate, Btu/net kWh	23,900	8300

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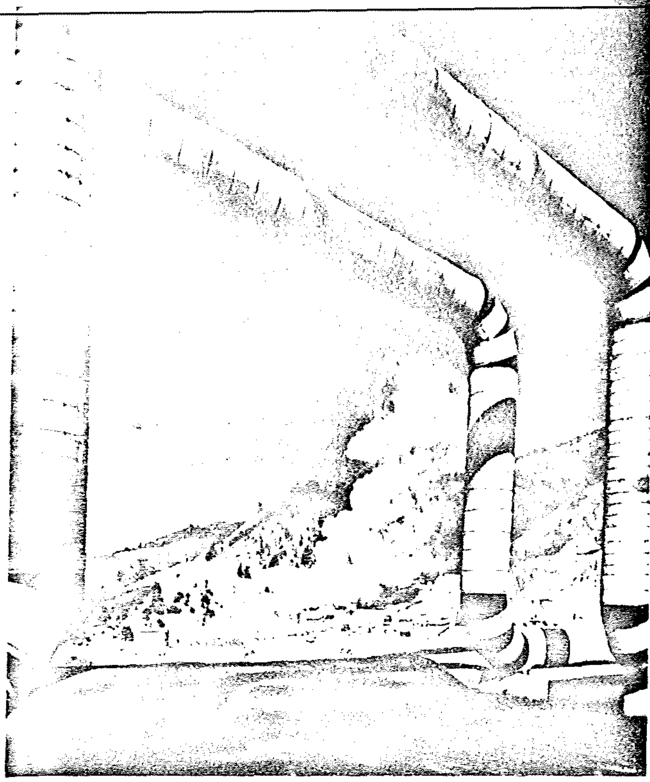


Expansion loops carry geothermal steam from wells drilled to a depth of more than 1½ mi (2.5 km) to Pacific Gas and Electric Co.'s plant at The Geysers in Sonoma County, Calif. The plant is located about 90 mi (140 km) northeast of San Francisco.

Since there is no boiler which needs to be fed with condensate, a less expensive direct contact or barometric condenser is adequate. The cooling water in this type of condenser mixes with the steam exhausted from the turbine and condenses it. The mixture of condensate and cooling water could be dumped if a large river were handy from which to draw a supply of cooling water, but then only if dilution was sufficient to prevent heat and/or toxic pollution. However, this not being the case at The Geysers, cooling towers are required. Part of the condensate—about 75–85 percent of the water being added from the turbine unit—is evaporated, and the remainder overflows to a reinjection disposal system. The amount of evaporation is determined by the atmospheric conditions. No make-up is needed from external water sources and the circulating water becomes essentially condensate. The overflow keeps the buildup of chemicals in the water from the noncondensable gases to a low limit.

Geothermal steam coming from the wells is passed through in-line separators to prevent fine sand and rock particles from reaching the turbine blades and causing damage or serious erosion. Each well, therefore, is equipped with an in-line centrifugal separator. A second separator, installed in the steam line of each turbine near the turbine room, acts as a backup separator and final cleanup of the steam before it enters the turbine. According to the contractual arrangements, the steam suppliers are responsible for providing acceptably clean steam to the power plant.

Economics

It has been commercially practical to generate power from geothermal steam at The Geysers because it can be produced economically in comparison with power from other sources in the P.G.&E. system. The capital cost at The Geysers is $132/kW in Units 9, 10, and 11. Future installations are expected to average in the neighborhood of $250/kW. By comparison, large coal-burning plants run $300–400/kW; and nuclear plants are $500–600/kW. Also, lower operating and maintenance costs are experienced because there is no boiler to operate and the units are designed to function unattended.

Operating personnel are present during each of the three 8-hr shifts per day. Maintenance personnel and office staff are present during the 8 a.m. to 4 p.m. shift. The units have been installed in pairs so that the cost of the second unit tends to be less per kilowatt because most of the cost of the site development work was ab-

Units 3 and 4, shown here, went into commercial operation in 1967 and 1968, respectively. They brought plant capacity to 82,000 kW. In the foreground are steam pipes with expansion loops. The loops allow the pipe to contract when the plant has to be shut down and to expand on startup. The steam condensate rising from the row of five low stacks at left marks the location of blowdown valves. When the plant has to be shut down, the steam escapes through these valves.

sorbed in the overhead for installing the first unit.

The thermal efficiency of a geothermal unit is considerably less than that of a conventional steam boiler unit because it uses natural steam which has low pressure and little superheat. The net thermal efficiency of Unit 3 at 28,000 kW is about 14.3 percent. The plant is still economical, however, because of the lower cost of natural steam.

One of the outstanding features of this project is the resultant conservation of fuel oil. The kilowatt-hours generated in 1975, some 3.37 billion, represents about 5,500,000 bbl of fuel oil. This is based on a heat rate of 10,000 Btu average heat rate in a modern fossil fuel fired steam-electric power station. From April 1960 through June 1976, the total generation represents the conservation of about 24,800,000 bbl of fuel oil. The steam is paid for on the basis of the amount of electrical energy that is actually delivered to the P.G.&E. system. For the first two units, for example, the price paid for the steam was 2.5 mills/kWh. For the additional units, the cost is calculated each year on the basis of the weighted average of (1) 2.5 mills/kWh, adjusted for current fuel costs and the best heat rate for fossil units compared with December 1958 (later agreed to 1968 values) fuel costs and best heat rate; and (2) the average nuclear fuel costs. For 1966, the payment for energy from additional units was 2.55 mills/net kWh; and in 1967 it was 2.27 mills/net kWh. The 1976 rate is 11.35 mills, which includes 1/2 mill for water injection services.

The following table shows the principal costs for the first four units installed at The Geysers:

	Units 1 and 2	Units 3 and 4
Gross Generating Capacity, kW	26,000	56,000
Total Capital Cost of Power Plant	$3,800,000	$6,900,000
Cost per Gross kW	$146	$123
Total Capital Cost of Transmission Line	$215,000	$310,000
1967 Energy Cost, Mills/kWh	2.5	2.27
Total Estimated Cost Delivered to System at 90% Capacity Factor Including Transmission, Mills/kWh	5.65	4.71

Operating Procedures

Inflation has clearly manifested its presence. The estimated costs of additional units are now in the area of $250/kW. Steam wells, gathering system, roads, and other supporting facilities will add about another $175/kW, resulting in a total capital cost of approximately $425/kW. The principal difference in operating procedure for the geothermal units of The Geysers is the practice of shutting down the plant every few months for a few hours as a trip test, so that a functional test of the plant's automatic protection features can be carried out. On conventional units, these tests are performed as part of an on-line testing program during maintenance outages. The shutting down of the geothermal units provides an opportunity to do preventive maintenance on those parts of the electrical switchgear that are subjected to the corrosive attacks of the hydrogen sulfide in the atmosphere, which has been a primary maintenance problem. This type of servicing is the only practical method of preventing an operating failure of the electrical switchgear and its components. This has been upgraded considerably by housing much of the sensitive instrumental control devices in a filtered air environment.

The annual capacity factor of the geothermal units has varied over a range of 70 to 96 percent since 1960. This is approximately the same as the unit availability—because the units are normally operated either at their maximum rating or else they are shut down for maintenance. None of the units is classified as standby.

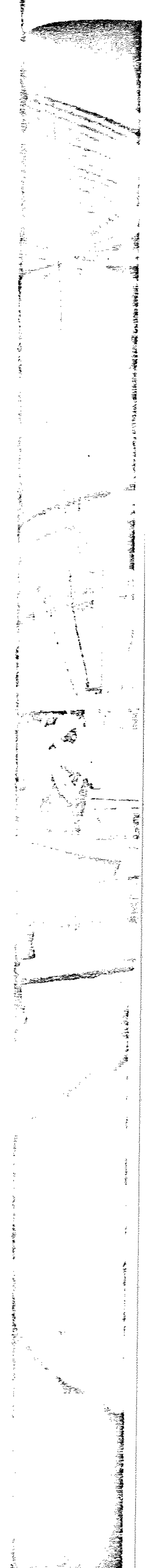
During turbine overhauls, the upper casing is removed and the turbine is dried out to inhibit corrosion. The only corrosive effects that have been noted in the turbine itself have been at the shaft seals—which had to be replaced with corrosion-resistant stainless steel. Experience has confirmed that with the proper selection of materials designed to withstand the corrosive atmospheric conditions—i.e., H_2S—plant maintenance problems are similar to those prevalent in conventional power plant equipment.

The same modern drilling rigs that are common in oil and gas fields are employed to drill holes to the steam-producing zones at The Geysers. Depths presently range from 4000 ft (1200 m) to 10,000 ft (3000 m). Some of the earlier wells of the 1950s were as shallow as 500 ft (150 m). The wellbores are cased to the depths necessary to reach into the graywacke formation, which is a rock type hard enough to support fractures. The fractures then act as conduits for the steam. The wellbore is open hole (uncased) from the bottom of the casing to the final depth. In drawing steam from underground, care must be taken to avoid sudden shocks (like turning a valve on or off too abruptly) in the closed system. Such changes might create a reverberating effect that would cause damage to the subterranean formations.

Completed wells come in at about 75,000 to 350,000 lb/hr (34 to 159 metric tons/h) at a wellhead pressure of roughly 125 psig (8.8 kg/cm^2). Shutoff pressures average 475 psig (33.4 kg/cm^2) with a temperature in the neighborhood of 465°F (240°C) corresponding to an enthalpy of approximately 1204 Btu (669 cal/kg). Design pressures at the turbine strainer inlets are 65, 85, and 100 psig (4.6, 6.0, and 7.0 kg/cm^2) at an enthalpy of about 1200 Btu (667 cal/kg) and with superheats of 59, 52, and 50°F (15, 11, and 10°C) respectively.

Most of the turbine-generators used at The Geysers have come from Toshiba of Tokyo. General Electric Co. has been the successful bidder for Unit 13 (135 MW) and Unit 15 (60 MW), while Units 5 to 11, now in service, are Toshibas. Units 12 and 14 (110 MW), now on order, are also being made by Toshiba.

As the operations at The Geysers have grown in size and scope, they have become more institutionalized. In June 1967, Magma Power Co. and Thermal Power Co.—as joint ventures—entered into an agreement with the Union Oil Co. of California. In effect, Union Oil has taken over the responsibility of operating and managing the geothermal wells that are sending steam to P.G.&E.'s power stations. The greater resources of Union Oil have also enabled the partners to expand the steam production rates to keep pace with P.G.&E.'s planned schedule of adding 100 MW of annual capacity



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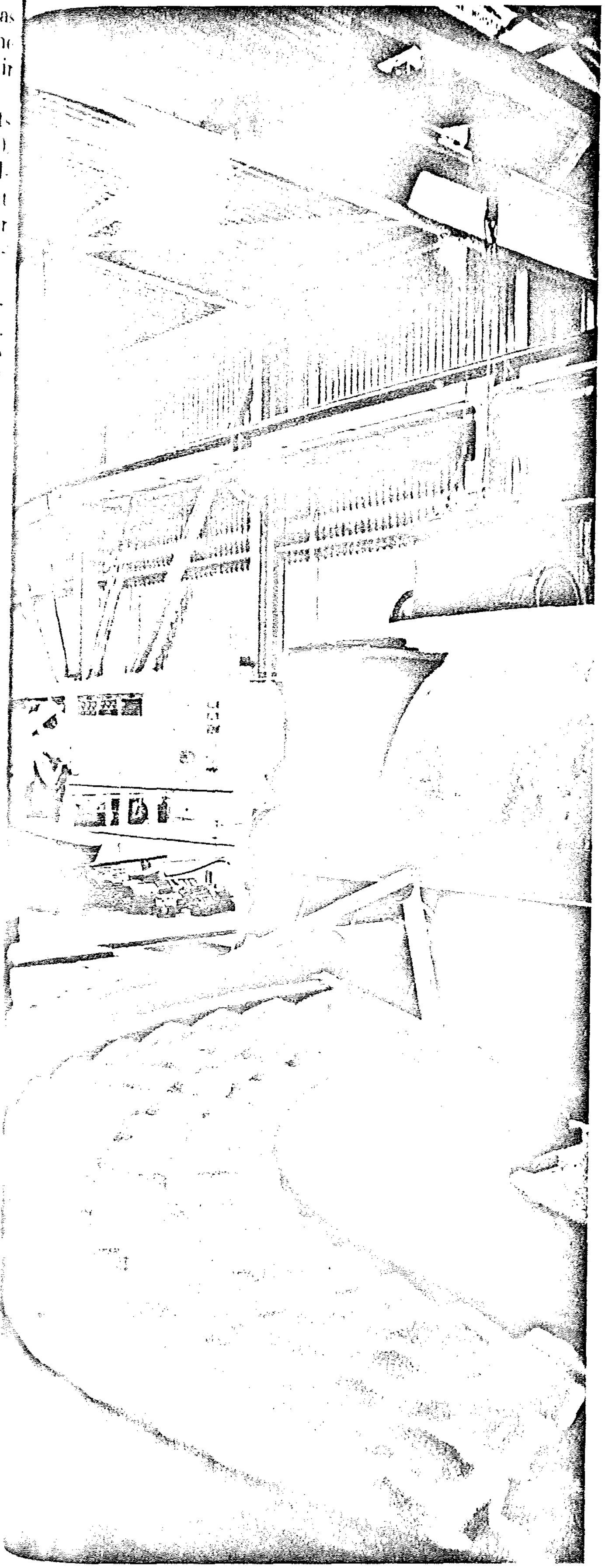

Workman uses a 25-ton bridge crane to move a main geothermal steamline into position at Unit 7 of Pacific Gas and Electric Co.'s Geysers Power Plant. In the foreground near the generator is part of the turbine blading for the unit. Units 7 and 8, housed in this building, both have net generating capacities of 53,000 kW. They went into commercial operation in 1972.

from 1971 onward. During Magma Thermal's period of operation, lease holdings had increased to about 4500 acres (1800 hectares)—and, when combined with Union Oil's 9500 acres (3800 hectares) this made a grand total of approximately 15,000 acres (6000 hectares). The overall holdings have, in the meantime, grown to encompass more than 20,000 acres (8000 hectares). But that has not deterred the competition! On the contrary—the smell of success, as usual, has spurred rivalry!

Coming: Lots of Competition

Since at the moment the developed area in the region of The Geysers is approximately 7 mi long and 2.5 mi wide (11 × 4 km), and it is anticipated that future outstep wells will considerably enlarge the area of proven development, there is lots of room for newcomers. Pacific Energy Corp. has already drilled wells on its lease holdings with a sufficient steam output to support a 60-MW power plant. Aminoil U.S.A. (formerly Burmah Oil & Gas), Shell, Geo-Kinetics, and McCulloch are among those busy exploring and enlarging their respective holdings. Nor is it likely that P.G.&E. will long retain its present exclusive use of the geothermal steam on the power generating side of the business. Other utilities and municipalities are considering the establishment of their own generating facilities at The Geysers while contracting to purchase steam from any or all of the above-mentioned producers.

There have been other changes as well. Mr. McMillan—one of the original entrepreneurs—passed away and the Thermal Power Co. was recently sold to the Natomas Co. in San Francisco. Mr. McCabe—the true visionary—is still active, and his enthusiasm for the development of geothermal energy has helped stimulate corporate enterprises to invest in and develop this relatively new energy industry.

What about the global scene? There are known geothermal areas in countries ranging from Iceland to New Zealand. The Russians, the Japanese, the Mexicans, the Italians, and others are actively engaged in pursuing geothermal energy programs. In the search for low-cost energy, geothermal power offers a quick and attractive solution.

As was stated earlier in this article, the geologic understanding of geothermal energy is in its infancy; and so is the commercialization of geothermal power. Perhaps it is valid to draw an analogy with the discovery of oil in Pennsylvania over 100 yr ago. There, too, it was surface seepage of oil that first attracted attention. As was the case at The Geysers, the early wells that were drilled in the Pennsylvania oil fields were shallow and primitive (by modern standards). Then gradually, as the art of discovering oil fields became more sophisticated and predictable, so did drilling and pumping techniques. It can fairly be said that the mastery of the geology paved the way for the petroleum industry as we know it today. Maybe geothermal energy will evolve along a parallel path. If, once again, the geologists can find the answers to locating steam-bearing subterranean formations, then the rest is a foregone conclusion. The power companies stand ready and waiting to put the geothermal steam to work. In this respect, the experience at The Geysers in California speaks for itself.